NUTRIENT MANAGEMENT COOPERATIVES IN CALIFORNIA'S LOWER SALINAS AND MONTEREY BAY

Modeling Partnerships for Improving Water Quality in Irrigated Lands

Final Report
NRCS Conservation Innovation Grant

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CONTEXT

The Central Coast of California produces over 200 crops worth more than $6 billion and provides the majority of the nation's leafy green and cool season vegetables from April to October. The region is one of the most productive in the country, with extraordinary crop diversity and multiple crop rotations per year. However, the complexity of this intensively cultivated, irrigated and tile-drained agricultural system has made managing water quality challenging for the agricultural sector, as well as for the state agencies responsible for ensuring clean water for the public and the environment. Recent research has shown that drainage from this abundant agricultural system impacts not only the fresh water and groundwater resources in the basin, but survival and growth of important commercial marine fish and other marine species in the Elkhorn Slough and Monterey Bay.[1] Despite these challenges, farmers are motivated to find more effective means to address water quality improvement, making the region a prime candidate for incubating design and testing of a cooperative approach among the region's farmers, conservation groups and public agencies.

Excess nutrients in agricultural runoff are best addressed through a combination of on-farm (operational scale) and off-farm (landscape scale) practices.[2] Growers in the Salinas Valley have typically used on-farm irrigation and nutrient best management practices (BMPs) to reduce nutrient runoff and to attempt to comply with regulatory requirements for individual operators. However, the application of on-farm conservation practices alone has not resolved water quality problems in the region. Off-farm interventions, such as vegetated drainages, constructed treatment wetlands, large-scale wood chip bioreactors, wetland restoration, and two-stage bench wetlands have demonstrated success in the region and beyond for reducing agricultural pollutant loading, particularly nitrate, in freshwater,[3,4] while improving habitat, connectivity, and carbon sequestration. However, these off-farm practices have been underutilized in the region because of the high value of land and the lack of regulatory mechanisms that incentivize pooling of resources for collective compliance. Even where watershed-scale interventions are attempted, they may not be as efficient as they could be because they have not been sited based on a watershed-wide assessment of nutrient loading. Similarly, on-farm interventions may not be as effective as they could be because their placement is driven by the physical/geographic and financial constraints of an individual grower.

THE PROJECT

The CIG project team developed this project in order to explore, test and demonstrate the challenges and benefits of cooperative farm water quality treatment efforts in sub-watersheds of the Lower Salinas Valley where producers and project team members had initiated promising relationships and opportunities. The project team consisted of the Resource Conservation District of Monterey County (RCDMC), the Central Coast Wetlands Group (CCWG), The Nature Conservancy (TNC), the Central California Grower-Shipper Association (GSA), the California Marine Sanctuary Foundation (CMSF), Central Coast Water Quality Preservation Inc.

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[4] O'Geen, A. T., Budd, R., Gan, J., Maynard, J. J., Parikh, S. J., & Dahlgren, R. A. (2010). Mitigating nonpoint source pollution in agriculture with constructed and restored wetlands. *Advances in agronomy*, *108*, 1-76.

(Preservation Inc), and the Monterey Bay National Marine Sanctuary (MBNMS). The nutrient management pilot watershed groups include growers within common drainage basins in the Lower Salinas Watershed and adjacent Moro Cojo Slough Watershed. RCDMC administered the grant and assisted with grower engagement, project outreach and tracking of on-farm practices in the pilot sub-watersheds. CCWG led grower engagement and establishment and monitoring of off-farm treatment areas in the pilot sub-watersheds and served as liaison with the Regional and State Water Quality Control Boards. TNC led the initial formation of the nutrient management cooperatives and provided support for expanding cooperative opportunities in the region. GSA and Preservation Inc led grower engagement throughout the project area and advised the team on the framework for the cooperatives, as well as engagement with the produce industry and Regional and State Water Quality Control Boards. CMSF, MBNMS and Moss Landing Marine Laboratories also contributed technical support for monitoring the off-farm treatment areas and coordinating management plans and monitoring protocols with existing monitoring programs for complying with water quality regulations.

GEOGRAPHIC LOCATION

The project partners initially focused pilot CIG-funded cooperative efforts in the Blanco Drain and Moro Cojo Slough sub-watersheds and ultimately expanded efforts to include the Tembladero Slough/Santa Rita Creek (within the larger Gabilan Creek drainage), Alisal Creek and Old Salinas River Channel sub-watersheds. The Moro Cojo Slough Watershed (10-digit HUC 1806001102) flows into Elkhorn Slough, an estuary that has been part of research and restoration efforts for several decades. The Blanco Drain, Alisal Creek and Tembladero Slough/Santa Rita Creek (via Old Salinas River Channel) sub-watersheds are located in the Lower Salinas River Watershed (10-digit HUC 1806000515). All of these drainages ultimately discharge into Monterey Bay, a marine system of national and international importance. The Salinas River is the largest river draining into Monterey Bay and has experienced excessive

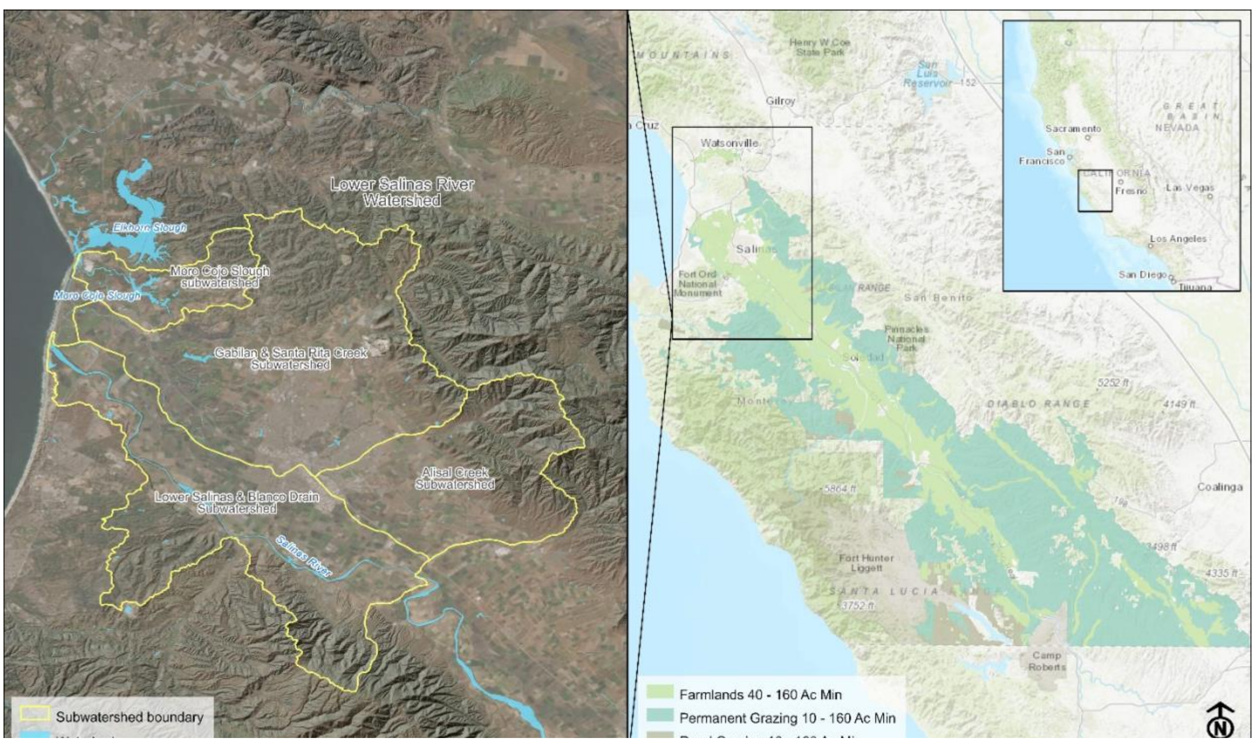

Figure 1. Map of pilot sub-watersheds within the Moro Cojo Slough Watershed and Lower Salinas River Watershed, which includes the Blanco Drain, Tembladero/Santa Rita Creek, and Alisal Creek sub-watersheds.

nutrient concentrations in surface waters in recent years due to intensive agriculture in the watershed.

Similar conditions characterize the majority of California's Central Coast farmed lowlands. Tile drained soils in the region have been associated with changes in watershed hydrology and increased nutrient loading to surface waters. To date, no management strategies have been successful at meeting regulatory water quality targets in the impaired watersheds of this region. Our project included water monitoring and watershed fate and transport modeling in order to inform potential cooperative nutrient management efforts towards achieving water quality targets.

The average farm size in the region is 250 acres. The farms in these areas grow a variety of cool season vegetables and fruits, including broccoli, artichokes, strawberries, lettuce, spinach, brussels sprouts, and celery.

PROJECT ACTIONS AND OUTCOMES

Task 1: Formalize the structure of pilot nutrient management cooperatives

Cooperative concept and regulatory context:

The original objective of the grant was to form farmer cooperatives to improve water quality using a watershed approach. Such cooperatives could opt to collect additional water quality data from members of their sub-watershed areas to inform where and how to target shared water quality improvement projects, to minimize individual costs and maximize treatment effectiveness while providing privacy to individual farmers. Early in the project timeline, project partners the Nature Conservancy (TNC), the Grower-Shipper Association of Central California (GSA) and the California Marine Sanctuary Foundation (CMSF) prepared for 5 stakeholder-farmer engagement meetings for the Moro Cojo Slough and Blanco Drain watersheds. However, due to the serially-delayed finalization and approval of the Central Coast Regional Water Quality Control Board's (CCRWQCB) General Waste Discharge Requirements for Discharges from Irrigated Lands ('Ag Order 4.0'), TNC, GSA and CMSF acknowledged participant farmers' concerns and delayed outreach to stakeholders in order to pull in relevant lessons learned from Ag Order 4.0 proceedings. As the direction of the Ag Order 4.0 became clear in the latter half of the project term, the team shifted the project concept toward a cooperative effort that could provide foundational research needed to inform the evolving regulation and associated reporting of water quality for growers in the lower Salinas, with the goal of supporting development of a more efficient and effective approach to regulation. In short, we shifted our cooperative formation purpose to that of informing pending regulation to ensure structural support or incentives for proliferation of the cooperative approach.

TNC summarized these learnings in two reports on the feasibility of a cooperative approach and requirements for launching a cooperative effort. The memos highlight important administrative and legal considerations for participating landowners that derive from lessons learned from another local cooperative effort initially led by TNC and GSA (in partnership with RCDMC) starting in 2011, the successfully-growing Salinas River Stream Maintenance Program. There was an opportunity to build on this and other previous TNC cooperative work to inform how the CCRWQCB could structure its regulation to encourage small watershed programs, collaborations, or cooperatives achieve and verify water quality improvements while addressing key concerns from the agricultural community. To advance this approach, the partners met with CCRWQCB staff about the initial and revised CIG project concept. The team was invited to present the approach at a CCRWQCB meeting, where the approach was well received and apparently effective for informing the finally-approved (in spring 2021) Ag Order 4.0, which includes a structure to target programs to the most-affected sub-watersheds in the region.

Pilot watershed group organization in Santa Rita and Alisal Creek sub-watersheds:

Starting in 2018, GSA and project partner, Central Coast Water Quality Preservation Inc (Preservation Inc), collaborated on development of two new pilot watershed water quality groups as a model for cooperative farm water quality regulatory compliance. The project team focused cooperative development effort on Santa Rita Creek and Alisal Creek (both ultimately tributaries to Tembladero Slough), two sub-watersheds that GSA and Preservation Inc identified as providing the most likely effective demonstration for purposes of educating and engaging both regulators and farmers. Initial group meetings with area producers along with site visits pre-pandemic were followed in 2020 by multiple meetings via Zoom with the larger CIG project team to understand how to integrate our cooperative approach to project implementation with a larger cooperative effort to be managed by Preservation Inc that would extend beyond the CIG project term. In support of this effort, CMSF and TNC staff collaborated to review geospatial data with Preservation Inc's Cooperative Monitoring Program (CMP)[5] relative to information needs and precision. CMSF staff developed a process for using recent data from the CCRWQCB Irrigated Lands Regulatory Program (ILRP; that enforces and oversees the 'Ag Order') along with watershed boundary definitions updated by TNC in order to develop an accurate grower identification process by sub-watersheds with Preservation Inc. CMSF staff updated the grower contact process for sub-watersheds to make it transferable to the CMP or other Preservation Inc cooperative efforts.

Additionally, CMSF staff reviewed priority areas needed for watershed grower identification, updated the CCRWQCB ILRP records, and developed management practice forms for use by the CMP in grower interviews. As part of Ag Order compliance, the ILRP collects information from growers about their best management practices (BMPs). In order to support identification of BMPs already utilized by growers and improve recognition of these practices by the Regional Board, CMSF staff compiled information about BMPs related to four types of pollutants (nutrients, sediment, pesticides, and irrigation). The template was developed and automated so that it could rapidly produce a document for discussion with growers regarding what BMPs they are currently using for onsite validation and for recommending improvements or additional BMPs that better address water quality objectives.

Off-farm/farm-edge water quality treatment project designs for Alisal Creek watershed:

In these two watersheds, primary emphasis of water quality management methods was placed on in-field water and nutrient management practices in order to prioritize groundwater quality concerns in those areas, although the team also identified and scoped surface water quality treatment opportunities. Project partners and Preservation Inc drafted a plan for strategic placement, design, and funding for collective water quality treatment projects in the Alisal Creek

[5] Based on a legislative mandate signed into law in 1999 related to California's Porter-Cologne (Clean Water) Act, the State Water Resources Control Board (SWRCB) was required to review waivers of water quality monitoring for irrigated agriculture and either renew them or adopt Waste Discharge Requirements (WDRs). In 2004, the Central Coast Regional Water Quality Control Board adopted a conditional waiver of waste discharge requirements for discharges from irrigated lands within the Central Coast Region. Given the large geographical range of the region, growers formed a non-profit organization to implement a Cooperative Monitoring Program (CMP) that would perform the surface water monitoring and reporting requirements for enrolled growers. The CMP monitors 50 sites across the Central Coast region on a monthly basis. Monitoring sites are generally located at downstream locations in watersheds with substantial or predominant agricultural land use and known water quality impairments.

watershed based on farmer site visits and meetings held in 2019 and 2020. With support from the project team, TNC conducted a solicitation process and selected a local engineering contractor using matching funds to draft concept level plans for up to four sites within the Alisal Creek watershed just southeast of Salinas, CA (Figure 2 & Appendix A). Several of the concepts were modified, and three final project concepts were agreed upon for further development, with the intent that the associated landowners will evaluate the different projects' benefits and costs and initially select one or more to jointly fund and implement to meet water quality targets in their sub-watershed.

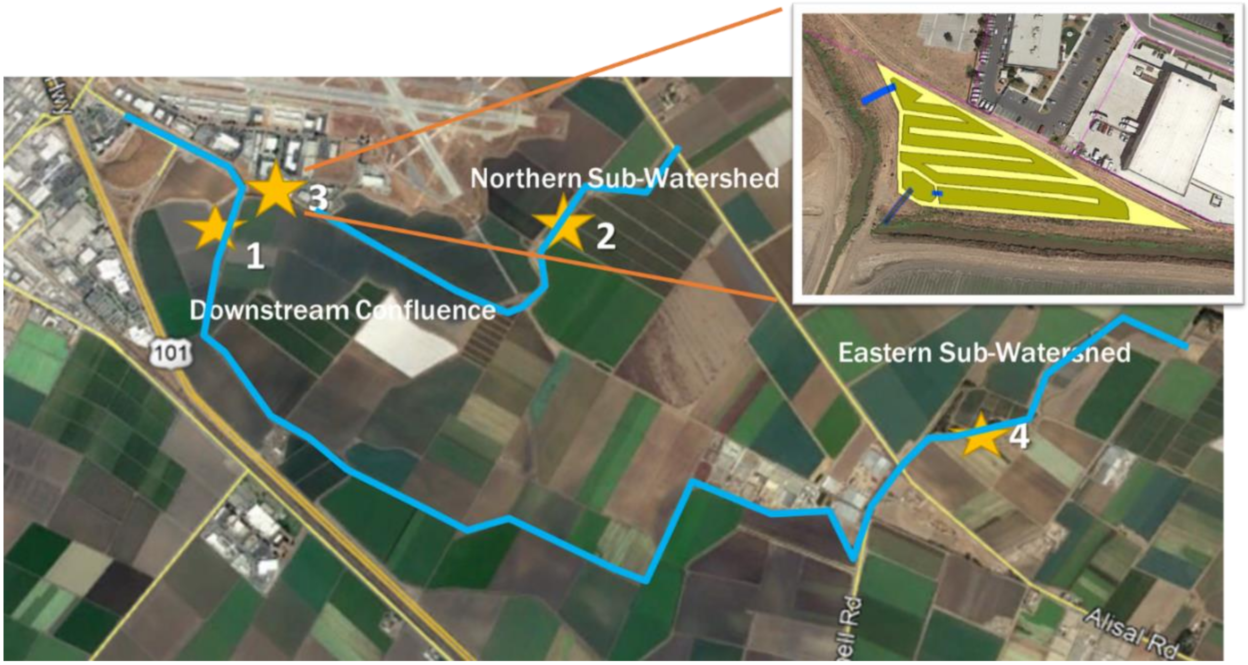

Figure 2. The four initial project areas selected for design of treatment systems.

Informing water quality regulations:

Throughout our efforts to develop pilot watershed groups, project partners found that most farmers were hesitant to participate without some assurance that regulators would recognize or give credit for their involvement towards regulatory compliance in a tangible manner. Correspondingly, it was not until a stable regulation (in this case, Ag Order 4.0) was nearly in place that we had the most success in engaging more than just a few farmer participants in the subject watersheds. To get to this point, CIG team partners participated in team calls and outreach calls with the CCRWQCB about the nutrient management cooperative approach throughout the project period. Partners presented at fall 2018 CCRWQCB regulatory hearings to convey the merits of a cooperative approach in working with farmers to improve water quality as CCRWQCB was preparing its Ag Order 4.0 update. Project partners additionally communicated with other regional partners (Sustainable Conservation, UC Cooperative Extension, other RCDs, etc.), CCRWQCB staff, and individual board members regarding the draft regulation. The communication was necessary to ensure our work with farmers was most relevant to meeting regulatory mandates and to provide technical feedback to the CCRWQCB in support of feasible and effective water quality management strategies. Other topics communicated with the CCRWQCB emphasized ensuring there was space and incentive within the regulation for cooperative water quality management solutions such as we were focused on in this project.

During this process, we used the pilot cooperative model to inform how the CCRWQCB could structure a sub-watershed program to achieve and verify water quality improvements while addressing key concerns from the agricultural community. The CCRWQCB ultimately adopted new agricultural water quality regulations (Ag Order 4.0) in 2021 that included a third-party cooperative structure as a compliance pathway, which we interpret as an indication of the effectiveness of our efforts.

Task 2. Implement priority irrigation and nutrient management practices across cooperative members

Off-farm water quality treatment in the Moro Cojo watershed:

Castroville treatment wetland expansion: In 2017, the CCWG reviewed draft plans and budget with the tenant farmer, received approval, and initiated project implementation (Phase II expansion of the 10-acre Castroville treatment wetlands and bioreactor) for a new 8-acre treatment wetland on Pacific Gas & Electric Co (PG&E)-owned lands within the Moro Cojo Slough watershed using CIG funds. After the 8-acre treatment wetland site preparation was implemented, the restoration crew with CC&R installed native plants in 2017 and 2018. Periodic maintenance of the treatment wetland included the removal of cattails, hand weeding, clearing out the bioreactor chambers and replenishing wood chips. In 2019, restoration actions continued at the expanded 18-acre treatment wetland complex, including clearing the bioreactor chambers in need of repair, massive hand weeding and weed whacking of invasive plants, clearing sediments from the wetland exit to increase flow out of the system, and mulching and watering native plants as needed. In 2020, the restoration crew planted 3,402 additional plants at the Castroville treatment wetland complex and surrounding habitat ponds. In 2020, CCWG conducted maintenance on the multi-chamber bioreactor. This involved maintaining the HYDRA

Figure 3. Location and design of the multi-chamber bioreactor and the downstream treatment wetland installed within the Moro Cojo Slough watershed, along with other treatment wetland projects in the vicinity.

in-situ water sampling array, weeding the channels, adjusting the flow of the channels, responding to rodents chewing holes in the pond liner, and maintaining berms of the wetland (Figure 3).

Effectiveness monitoring: CCWG continued to support load reduction analysis of multiple treatment systems at the multi-chamber bioreactor and the downstream treatment wetland throughout the CIG project term. Summer and fall 2018 sampling frequency was increased to better study increased nutrient reduction observed with higher ambient temperatures and deal with increasing fluctuations in nutrient load from the upstream drainage areas. For 2018, a total of 524 nutrient samples and water quality samples were analyzed and reported back to CCWG. Those data were used for load reduction estimates to support further adoption of various practices by adjacent farmers and to benefit regulatory expectations. The data were also used to generate load reduction rate calculations that CCWG used to create an online bioreactor sizing calculation tool (see 'Technical Resources,' page 17) and were fully documented in a journal article submitted to *Water Supply*. In November 2021, the article received positive feedback from reviewers and was selected for publication with minor revisions (Appendix B).

New site designs: During the project term, CCWG met with a new tenant farmer and landowner adjacent to the Castroville treatment wetland to discuss off-farm nutrient systems. As a result, the landowner agreed to let CCWG staff design and install a small treatment wetland on the edge of his farm, adjacent to another soon-to-be restored natural wetland project similar to the Castroville project design (Tottino Wetland; see Figure 3). Additionally, the landowner installed new pumps at the older 'Sea Mist' bioreactor nearby, leading to reactivation of the system.

In 2018 & 2019, CCWG contracted with WaterWays Consulting to draft design plans for a treatment wetland along the Old Salinas River Channel, near the bottom of the Lower Salinas Watershed. CCWG presented the preliminary design plans to the property owner to review in 2019 (Appendix C) and held a follow-up meeting with the landowner in February 2020. At that time, the landowner was not ready to proceed for two reasons that remain a persistent challenge to farm treatment wetland projects in the Central Coast region. 1) The farmer was very concerned about commitment to such a project with habitat features due to the food safety outbreak in romaine from the Salinas Valley at the time. 2) The landowner indicated that unless the treatment wetland could in some way provide the farmer with regulatory relief (recognition or credit of some sort) from the state water quality agency (CCRWQCB, see Task 1 discussion) then he was not interested in committing. The message regarding the second concern regarding the lack of regulatory acknowledgement (credit/relief) was relayed to CCRWQCB staff during CIG project team communications regarding the Ag Order 4.0 development process and aided our efforts to define strategies to credit farmers who adopt such projects.

Water quality treatment project for the Blanco Drain watershed:

While unanticipated in the original CIG application, RCDMC was able to leverage state funding to design and construct one woodchip denitrification bioreactor in the Blanco Drain watershed and initiate development (with construction funding secured) of a second 'mobile' demonstration bioreactor for use in the region. Early in the CIG project period, RCDMC completed designs and environmental permitting consultation with local, state, and federal agencies for two woodchip denitrification bioreactor projects in the Blanco Drain watershed using matching CA State Coastal Conservancy funds. To fund permitting and construction, RCDMC successfully applied for State Water Resources Control Board 319h grant funding with partners CCWG and CMSF. The funding also supported improvements to the existing CCWG-managed multichamber bioreactor site noted above as well as engagement with the Monterey County Resource

Management Agency (our county planning department) for reducing permitting delays associated with such environmentally beneficial projects.

Figure 4. Of the RCDMC woodchip bioreactor projects, ultimately just one proceeded, with the second being scrapped and the funding shifted to support development of a demonstration unit for a novel plastic chip and biofilm bioreactor that project partner Preservation Inc will use with multiple producers in the coming years. Construction of the woodchip denitrification bioreactor began in July 2021 and was nearly complete as of December 1, 2021.

On-farm irrigation and nutrient management in the Moro Cojo Slough and Blanco Drain:

From 2017 to 2020, RCDMC tracked the irrigation and nitrogen management on cooperating farms that drained to wetland treatment project sites within the Moro Cojo Slough and Blanco Drain watersheds in order to assist with SWAT model calibration regarding standard practices, confirm farmer best practices, and identify opportunities for improvement where possible. RCDMC personnel coordinated with the different farm staff on those fields regarding water and nutrient applications, crop development, and harvest, and in some cases installed telemetry units to track soil moisture and irrigation timing. Crops included romaine, head lettuce, artichokes, broccoli, strawberries, cauliflower and brussels sprouts. Crop evapotranspiration (ETc = ETo x Kc) was estimated using the California Irrigation Management Information System (Spatial CIMIS) reference evapotranspiration (ET_o) values and Food and Agriculture Organization (FAO) Irrigation and Drainage Paper No. 56 crop coefficient (K_c) values. In all years, producers' irrigation nutrient applications were within or less than University of Oregon or University of California guidelines for the respective crops, with the exception of two fields of brussels sprouts and romaine lettuce in 2017 that exceeded N guidelines by 10-30% although irrigation was maintained at or below recommended amounts.

Each year, the growers received a report developed by RCDMC based on the data they provided. The reports provided links to resources related to crop irrigation and nutrient guidelines used to evaluate the applications for their crops. RCDMC provided advice for improvement when requested by the growers.

Task 3. Water quality monitoring in treatment systems and pilot sub-watersheds

Nutrient monitoring in the Moro Cojo Slough watershed:

Nutrient load reduction estimates of installed treatment systems were calculated using data collected at several of the treatment systems within the Moro Cojo Slough watershed (Table 1). These data have been used to estimate the load reduction of hypothetical systems in other sub-watersheds of the Salinas Valley.

System	System area (m2)	Daily flow (m3/d)	HRT (d)	Input c. mg/L (g/m3)	Output c. mg/L (g/m3)	Load removed (kg/y)	Load removed / area/year (kg/y/m2)
Sea Mist bioreactor	700	500	1	52.47	18.31	6,234	8.91
Sea Mist wetland	24000	500	3.5	18	2	2,920	0.12
Castroville bioreactor	216	200	1	38.5	18.2	1,482	6.86
Castroville wetland	11000	800	2	18.2	1.7	4,818	0.44
Molera Linear wetland	1852	163	3.5	21.4	13.6	464	0.25
Molera marsh area	3000	163	3.7	13.6	3.9	577	0.19

Table 1. Summary of nutrient load reductions calculated at several of the treatment systems within the Moro Cojo Slough watershed.

Sampling transects were completed for the entire Moro Cojo Slough main channel via canoe in 2017, 2018, 2019, and 2020 (Figure 5). Top and bottom water salinity and nutrient samples were successfully collected; this transects sampling protocol continued on a monthly or bi-monthly basis as needed. A flow meter was deployed to continuously collect flow data in the Moro Cojo Slough and a YSI sonde meter that collects temperature, depth, conductivity, chlorophyll, dissolved oxygen, and pH was deployed and maintained to continuously collect data as part of the monitoring platform. Data was downloaded every 2-3 weeks from the YSI sonde. The monitoring platform in the lower Moro Cojo Slough was maintained during the whole grant cycle.

Figure 5. Station locations of salinity water quality monitoring project in the Moro Cojo Slough.

CCWG deployed osmotic pumps in the Moro Cojo Slough watershed to collect water samples at a continuous rate for extended periods of time via an osmotic gradient. Sampled water was stored in Teflon tubing coils and prepped for analysis by draining one meter of tubing at a time into cuvettes. Composite samples were made by combining five cuvettes representing about 1 week of time, of which nutrient analyses were run. Osmotic pump sampling stations were deployed in three locations for multiple 6-week periods in late 2017 and early 2018.

Evaluating pesticide accumulation in wetlands in the Moro Cojo watershed:

During the project term, conservation landowners voiced concerns about whether directing agriculture runoff to protected lands augmented to include treatment wetlands could lead to the accumulation of pesticides within the soils of those wetlands, potentially counter to their prescribed conservation objectives. In response, CCWG organized a pesticide monitoring study to investigate those concerns within the Moro Cojo Slough watershed. Sediment samples were collected within treatment wetlands, agriculture drainage ditches and other dry conservation lands to investigate pesticide levels in various lands within the watershed (Figure 6). The study determined that treatment wetlands do not appear to be accumulating pesticides and may be breaking them down into less toxic elements. (See figure 6, below.) Specifically, the SeaMist Wetland saw a decrease in levels of DDT, DDD and DDE. Pesticide levels in an agricultural ditch with upstream treatment (site CAT-2, below) and a control site (CAT-3 below) were very similar and at or below reference levels. Findings suggest that there are moderate background levels of pesticides in the watershed outside of the wetland areas and that constructed wetlands help to degrade those ambient pesticides to less toxic chemicals.

Figure 6. Sampling sites used to assess accumulation of pesticides within soils of conservation lands in the Moro Cojo Slough watershed.

Monitoring at the Tembladero/Old Salinas River confluence:

At the lower end of the Lower Salinas Watershed, CCWG worked with farmers near the confluence of the Tembladero and Old Salinas River Channel sub-watersheds, a point which effectively represents the outlet of the entire Lower Salinas Watershed, including all of the subdrainages so far described except for the Moro Cojo Slough. Accordingly, this presented a strategic location for potentially tracking larger-scale ambient water quality improvements of projects in those sub-watersheds. In addition, creating a focus area near the Tembladero/Old Salinas River confluence provides an opportunity for large-scale nutrient treatment projects at the confluence of the tributary sub-watersheds of the Lower Salinas.

Documenting and evaluating the success of these efforts is very complex. To address this challenge, CCWG installed a monitoring system on a point of land at the confluence of the two drainages. From there they ran power to a sampling array platform with nutrient, salinity, and flow monitoring equipment. The system involves pumping water from the Tembladero and running it through the water quality probes on land, while a submerged flow meter located adjacent to the water intake monitors flow rate of the Tembladero. The monitoring array became operational in September 2021 and can now be used to calculate hourly load (nitrate concentration times discharge volume) coming out of the Tembladero watershed (and the tributary Santa Rita and Alisal creeks) (Figure 7). CCWG is working beyond the grant term to install a flow gauge on the Old Salinas River side of the confluence (draining from the Blanco Drain) in order to begin pumping water from there into the monitoring array to calculate the nitrate load in the Old Salinas River as well (Figure 8).

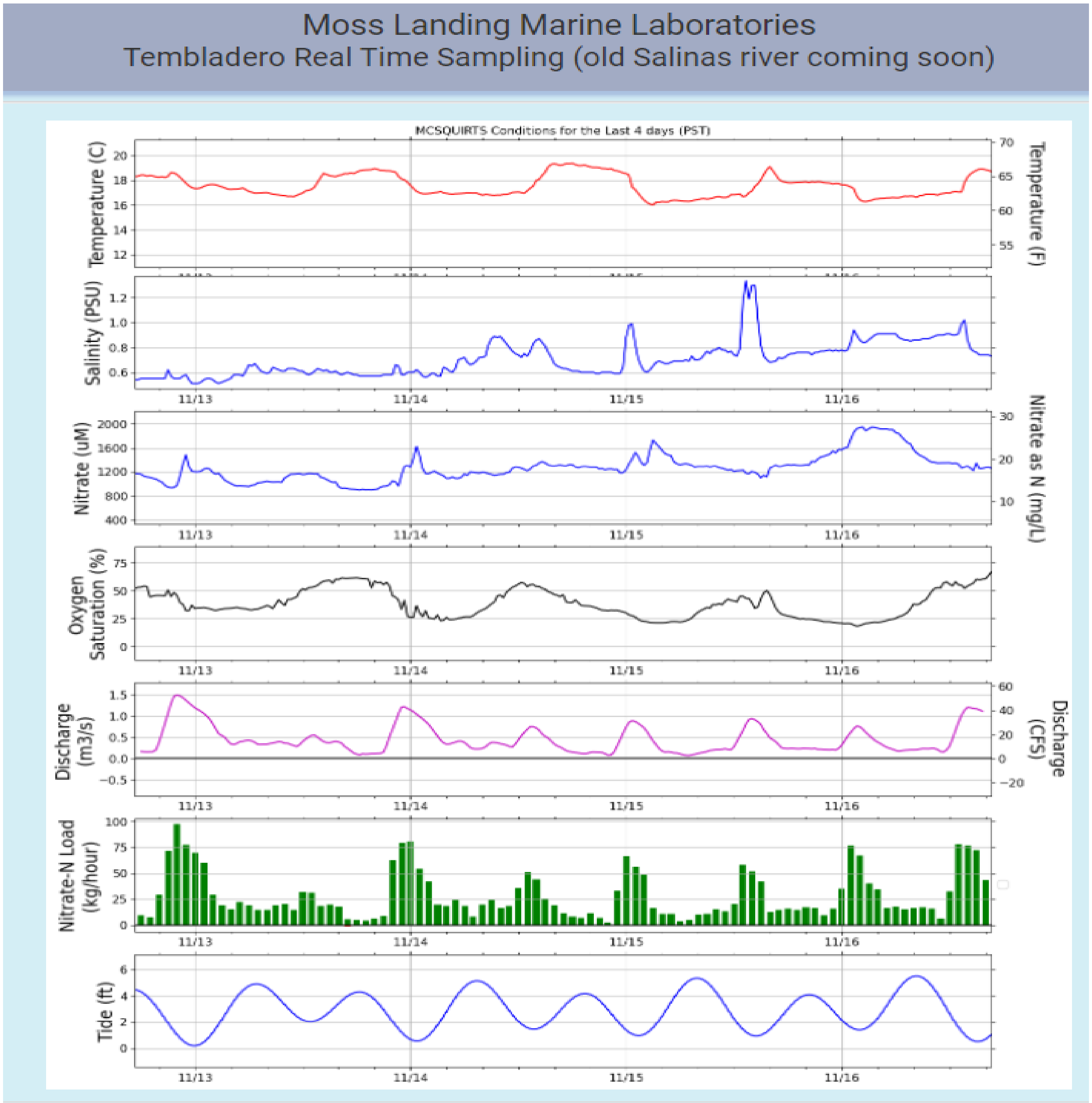

Figure 7. Real time data output from the Tembladero (and future Old Salinas River) monitoring sensor array and calculated hourly nitrate loading to the receiving water (http://pubdata.mlml.calstate.edu/osr/index.php).

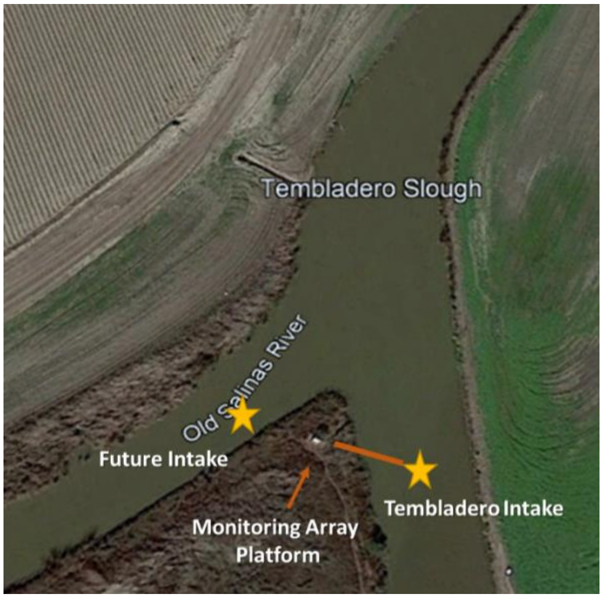

Figure 8. Location of the monitoring array platform at the confluence of the Tembladero and the Old Salinas River.

Task 4. Expand the nutrient fate and transport model and scenario analysis to the pilot sub-watersheds

The CIG project team initially chose the Soil and Water Assessment Tool (SWAT) to model nutrient transport in the Moro Cojo Slough watershed. The CCWG modelling lead used new data to update and calibrate the model. Calibrations and sensitivity analysis continued until sufficient results were met. CCWG staff analyzed weather and USGS flow data to determine potential calibration and validation periods; downloaded, collated and formatted nutrient data from the Land/Ocean Biogeochemical Observatory in Elkhorn Slough (LOBO) and the Elkhorn Slough National Estuarine Research Reserve (ESNRR) databases; attempted single site flow calibration with different parameterizations; and tested the implementation of vegetative filter strips and wetlands for their effects on flow and nutrient concentrations. Multiple iterations were attempted to improve calibration statistics for the SWAT model. Troubleshooting to calibrate the SWAT model included fine tuning parameter values with large and small ranges, running the model as independent wet and dry seasons to avoid model diversion, changing parameterization, and testing different gaging stations in calibrations.

Ultimately, SWAT models for the Moro Cojo and Lower Salinas watershed were not able to be successfully calibrated due to the limited flow data and challenges with alterations to natural watershed flow patterns, which the SWAT model assumes remain unchanged. Since we were unable to obtain continuous flow data at critical locations within the watershed, it was recommended to calibrate the model using USGS flow data from the Reclamation Ditch (the 'reclaimed' form of Gabilan Creek between Salinas and its junction with Tembladero Slough). Unfortunately, the modeling team completed 500 iterations of the calibration process, but it ultimately could not be optimized because drainage pathways had been too greatly modified.

In its place, CCWG chose to use a box model approach to estimate loading from various sub-watersheds using the four main parameters calculated during the SWAT model development. All the watershed input parameters (types of agriculture, irrigation types, irrigated acreage, farming practices, etc.) were directly entered into the new box model for each sub-watershed to estimate sub-watershed nutrient loading. Development included applying, determining, and combining sources and sinks of nutrients to each defined area.

In 2018, CCWG staff finalized the nutrient loading box model then utilized it for the project area to estimate the impact of specific potential wetland restoration actions to address nutrient loading in different sub-watersheds of the Lower Salinas. This enabled quantification and documentation of the modeled seasonal nutrient fate and transport within the Moro Cojo receiving waters. CCWG staff also utilized the nutrient fate and transport model for the Moro Cojo Slough to draft a 303(d)-delisting document for nitrates in the slough. The document was submitted to the Central Coast Regional Water Quality Control Board (CCRWQCB) for review (Appendix D; described further under Task 5).

Sub Watershed Basin	Project opportunities	TMDL category	Allowable concentration mg/l Dry (May 1-Oct 31)	total allowable annual load (kg/yr)	Total Load (kg/yr)	Load Exceeded (kg/yr)
1	Espinosa Wetland	Tembladero	6.4	9,908	21,124	11,216
2	Espinosa Lake	Espinosa	6.4	1,945	15,104	13,159
3	SanJon Detention	Rec Canal	6.4	4,510	33,163	28,653
4	Boronda	Rec Canal	6.4	6,222	5,321	-901
5	Natividad Rd.	Gabilan	2	0	30,787	30,787
6	Old Stage	Natividad Creek	2	898	545	-353
7	Old Stage South	Alisal	2	1,180	2,715	1,535
8	Old Stage Lower	Alisal	2	476	3,012	2,536
9	Castroville Pond	Tembladero	6.4	12,163	39,734	27,571
10	Carr Lake	G/N/A	2	28,936	158,876	129,940
11	Airport	Alisal	2	9,866	75,709	65,843

Table 2. Estimates of total nitrogen loading for each of the 11 sub-watersheds.

These nutrient load estimates from the Moro Cojo Slough were used to populate a watershed scale box model to extrapolate nitrogen loading from similar crop lands within the adjacent Gabilan Creek Watershed. Total loading was estimated for 2018 crop types (newest data available) (Table 2) for each of 11 sub-watersheds. We used load reduction data from our Castroville treatment wetland and bioreactors to estimate the size of treatment systems needed to meet water quality objectives established within the Lower Salinas River Watershed Nutrient TMDL (Table 3).

Sub Watershed Basin	Sub-watershed	Load Exceeded (kg/yr) N		Size of treatment (acres) to achieve 0mg/l N	
			Bioreactor	Wetland	Bioreactor
1	Espinosa Wetland	15,512	1.7	9.0	2.9
2	Espinosa Lake	15,882	1.8	6.3	2.0
3	SanJon Detention	31,535	3.5	12.7	4.1
4	Boronda	-734	-0.1	2.0	0.6
5	Natividad Rd.	36,606	4.1	16.8	5.3
6	Old Stage	63	0.0	0.3	0.1
7	Old Stage South	2,732	0.3	1.4	0.4
8	Old Stage Lower	6,628	0.7	2.5	0.8
9	Castroville Pond	33,466	3.8	16.2	5.1
10	Carr Lake	176,098	19.8	72.5	23.1
11	Airport	87,108	9.8	34.3	10.9
			45.5	**174.0**	**55.4**

Table 3. Estimated size of treatment systems needed to meet water quality objectives for each of the 11 sub-watersheds.

The select sub-watersheds collectively drain approximately 36,000 acres of irrigated agricultural land. Box model outputs suggest that the design and implementation of 174 acres of treatment wetland (or 55 acres of bioreactors) within those watersheds would address the needed water quality improvements. This model-proposed treatment wetland acreage constitutes less than 0.5% of available farmland in those areas that would need to be repurposed if all of the projects were installed. The proposed projects have been integrated into a number of regional planning processes including the 2019 *Salinas Valley Storm Water Plan* and the Salinas Valley Basin Groundwater Sustainability Agency's 2021 draft Groundwater Sustainability Plans.

Task 5. Knowledge Transfer

CIG Project partners extended project information and learnings through presentations, tours, numerous meetings with farmers and regulators, and through the development of technical tools, technical papers, regulatory documentation, and BMP decision support documents. These are each described below, with the most challenging 'transfer' (that of information to a regulator) noted first, as it is reflective of a consistent theme in this project's work—making tangible outcomes of collective farm water quality improvement efforts translate into tangible regulatory agency acknowledgement for those efforts.

Partial 303(d)-delisting of the Mojo Cojo Slough:

In May of 2020, the Central Coast Wetlands Group (CCWG) submitted a letter (referenced in the prior section as Appendix D) to the CCRWQCB outlining the numerous water quality and wetland restoration projects that have been voluntarily implemented in the Moro Cojo Slough watershed by farmers and conservation organizations and the resulting incremental water quality improvements that have been documented over the past 20 years. In that document, CCWG findings suggest that since the construction of the Castroville treatment wetland (completed in November 2016 and funded through a State Water Board grant program) the Total Inorganic Nitrogen concentrations (i.e. nitrate fertilizers) measured at the receiving water station near the mouth of the Slough (station '309MOR') have consistently been below seasonal water quality thresholds recommended within the Lower Salinas Valley Nitrogen TMDL. Their letter documents the incremental improvements to receiving water quality achieved as each project within the watershed was installed (Table 4).

Year Range	**Samples Collected**		**Number or Exceedances**			**Percent of Exceedances**	
	Wet Season	Dry Season	10mg/l	8mg/l Wet Season	1.7mg/l Dry Season	8mg/l Wet Season	1.7mg/l Dry Season
1989-2006	96	95	8	10	24	5.2%	12.6%
2006-2016	147	171	0	1	14	0.3%	4.4%
2016-2019	31	54	**0**	**0**	**0**	**0%**	**0%**

Table 4. Number and percent of water quality samples at the 309MOR monitoring station with total inorganic nitrogen values that exceeded seasonal water quality thresholds (8mg/L wet season and 1.7 mg/L dry season total nitrogen as N) before and after each treatment project/wetland were constructed. No seasonal nitrogen exceedances have occurred since construction of the Castroville wetland in 2016.

Although CCRWQCB staff were impressed by the data, they determined that it was premature to delist the watershed for nutrients because of currently existing biostimulatory responses that suggest nutrients continue to impair the waterbody. Because the water quality objectives within the TMDL have been met, however, CCRWQCB staff have identified several regulatory steps that will not apply to farmers in this watershed, so long as grower efforts to manage fertilizer applications continue and treatment systems are properly maintained and functioning.[6] In so doing, the CCRWQCB staff has recognized the importance of crediting growers for these accomplishments. Those staff have stated that due to grower effort and restoration activities, the nutrient levels in the Moro Cojo Slough have significantly declined and nutrient water quality objectives have been achieved, and thus, growers in this watershed can see a reduction in

[6] The CCRWQCB has established watershed priorities (or subareas of watersheds) where Ag Order 4.0 implementation is scheduled to begin prior to other watersheds. Portions of the Salinas and Santa Maria watersheds are highest priorities for implementation with a deadline to meet water quality objectives in 2032; however, the Moro Cojo portion of the watershed is not scheduled for full implementation until a decade later. *Growers within the Moro Cojo Slough watershed will benefit from knowing that some Ag Order 4.0 requirements have already been met and future regulatory burdens will be lessened*. It is the intent of CCWG to continue to demonstrate sustained low nutrient concentrations and probable reductions of pesticide concentrations and toxicity in receiving waters to ensure that growers in this watershed can avoid the most stringent and costly Ag Order 4.0 requirements, including edge-of-field monitoring for nutrients, pesticides and toxicity. As Preservation Inc's regional Cooperative Monitoring Program (CMP; see Task 1) develops procedures to credit growers with these documented water quality benefits, the CMP will be working within the adjacent "priority" watersheds to draft Third Party Watershed Strategies to achieve similar water quality results and obtain similar regulatory benefits for growers.

some aspects of Ag Order 4.0 reporting requirements that pertain to nutrient impairment in surface waters.

Technical resources developed

Tank-In-Series model: To support the CIG team and other technical service providers' efforts to assist producers in properly sizing woodchip bioreactors, CMSF personnel developed a Tank-In-Series (TIS) model for determining nutrient reduction rates in woodchip bioreactors (WBRs). Because nitrate removal depends on treatment time, a TIS model accounts for the different residence times a given parcel of water experiences. The work determined the most likely type of reaction for nitrate degradation, the best regional values for the zero-order degradation rate, and the temperature correction factor (theta) for temperature dependence in WBRs based on model runs. The work to develop the model was written into a manuscript that was submitted for publication (Appendix B). An online excel tool was developed and uploaded to GitHub for use by technical service providers in estimating open channel bioreactor volume needed to treat nitrate loads and achieve a target nitrate concentration. This model is available by signing into GitHub and querying "Woodchip Bioreactor Tanks in Series Model" (https://github.com/pkrone/Woodchip-Bioreactor-Tanks-in-Series-Model).

> *Note regarding model relevance to NRCS practice development:* NRCS has a practice standard for denitrifying bioreactors (605) that pertains to the design of subsurface woodchip bioreactors, but it is not applicable to open channel bioreactors receiving water pumped in from tile drain systems. The addition of design and sizing concepts for the open channel bioreactor to this practice standard could increase its utility for agricultural systems where high water tables and pumped tile drainage systems are common and this type of design is more appropriate.
>
> This Tank-in-Series model for size estimation of open channel bioreactors can serve this purpose. As a result of data collection by CCWG and data analysis for this project by CMSF, sufficient understanding of hydrology, nitrate removal processes and temperature dynamics in bioreactors was acquired to determine reaction type and nitrate reaction removal rates. This Tank-in-Series model can be used for estimating the sizing needs of open above-ground channelized bioreactors that can be used at the edge of tile drained agricultural fields. The model requires the user to input the nitrate concentration, amount of water needing treatment, and water temperature and then calculates the nitrate concentration at the outlet. The user can vary the volume of the bioreactor to either achieve a desired outlet concentration value or to match the field area available for the installation of the bioreactor.

Nitrate reduction rate calculator: As described under Task 2 on page 7, CCWG crafted a nitrate reduction rate calculation model to include in an online calculator to enable the user community to input known flow rates and nutrient loads to calculate the needed size of a bioreactor to reduce nutrient loads. The online calculator has been made public on the Central Coast Wetlands Group webpage (https://mlml.sjsu.edu/ccwg/). Along with the calculator, the website includes resources on how to design, construct and operate both treatment wetlands and bioreactors. The site also provides information on all the treatment systems within the Moro Cojo Slough watershed that are currently operational.

Review of innovative nutrient management methods: In the process of assisting growers with on-farm irrigation and nutrient management (Task 2), RCDMC staff identified the need to provide a compilation of current research on relevant nutrient management practices with growers in order to support their adoption of innovative practices. To address this, RCDMC personnel conducted a literature search to track recent on-farm nutrient management research and presentations in the Central Coast region and developed the attached report. While the report is not a comprehensive summary of all possible nutrient management practices, the document summarizes regionally specific information on innovative practices to help inform water quality conservation efforts of growers, consultants and conservation partners working in the region. Where possible, peer-reviewed, replicated research trials with appropriate controls are cited; however, final reports from informal experimentation are also included so that the insight and understanding garnered from that work is captured as well. The report is available on the RCDMC website and will help guide those tasked with managing working lands for the best possible conservation outcomes (Appendix E).

Nutrient management decision support tool for farmers: RCDMC and CMSF personnel collaborated with Preservation Inc to develop a simple decision support tool identifying and addressing nitrate in farm runoff throughout the Central Coast (Appendix F). The tool first guides the user through the process of: (1) calculating the amount of surface discharge leaving the farm; (2) determining the amount of nitrate in surface discharge; (3) identifying the primary sources of nitrate on the farm that are contributing to nitrate in discharge. Based on this information, the tool provides a decision tree to help the user determine the best course of action for limiting that nitrate movement. This primarily involves improving efficiency of water and nutrient applications; if there is still nitrate in runoff despite such efficiency improvements, the tool provides a series of suggestions for implementing vegetative (e.g., cover crops) and non-vegetative (e.g., treatment wetland) practices. This tool will be utilized by Preservation Inc staff while supporting farmers' efforts to reduce and improve the quality of farm runoff.

Conference presentations: As part of the CIG project, RCDMC Executive Director Paul Robins presented a project update and summary of lessons learned to the Soil and Water Conservation Society conference in Pittsburgh, PA in 2019. RCDMC also developed and submitted a poster for the virtual 2021 Soil and Water Conservation Society Conference that communicated project learnings and outcomes (Appendix G).

Summary of Outcomes

- Partial 303(d) de-listing of Moro Cojo Slough for Nitrogen and associated regulatory relief for farmers in the watershed resulting from document developed and sent by project team to Central Coast Regional Water Quality Control Board (Appendix D).
- Initiation of farm water quality watershed pilot groups in Moro Cojo Slough, Alisal Creek, and Santa Rita Creek/Tembladero Slough sub-watersheds with establishment of long-term third-party organization leadership recognized as a preferred path towards state water quality regulatory compliance.
- A Tank-In-Series (TIS) model for determining the nutrient reduction rate in woodchip bioreactors (WBRs). This can be found by on GitHub by querying "Woodchip Bioreactor Tanks in Series Model" (https://github.com/pkrone/Woodchip-Bioreactor-Tanks-in-Series-Model).
- An online calculator that enables users to input known flow rates and nutrient loads to calculate the needed size of a bioreactor to reduce nutrient loads (available on the CCWG webpage at https://mlml.sjsu.edu/ccwg/).

- A manuscript discussing woodchip bioreactor load reduction rate calculations that was submitted to *Water Supply*. In November 2021, the article received positive feedback from reviewers and was selected for publication with minor revisions (Appendix B).
- Preliminary design plans for a treatment wetland adjacent to the Old Salinas River channel, produced in collaboration with WaterWays Consulting (Appendix C).
- Preliminary design plans for treatment wetlands sites in the Alisal Creek watershed. (Appendix A).
- A poster presentation for the virtual 2021 Soil and Water Conservation Society Conference that communicated project learnings and outcomes (Appendix G).
- A literature review of recent research and presentations relevant to improving on-farm nutrient management practices in the Central Coast region (Appendix E).
- A simple decision support tool for identifying and addressing nitrate in farm runoff throughout the Central Coast (Appendix F).

Conclusion, Impacts, Next Steps

At time this project concludes, there is now an approved 'Third-Party Program Administrator' (TPPA) for organizing farm water quality cooperative regulatory compliance in our region, CIG project partner Central Coast Water Quality Preservation, Inc (Preservation Inc). With Preservation Inc as lead, the project team developed and vetted an iterative water quality solution/monitoring/reporting/ adaptive management structure with technical partners, farmers, industry, and regulators (the Central Coast Regional Water Quality Control Board) that Preservation Inc will employ (and adaptively manage) with water quality cooperative groups as they form, that will provide technical guidance and organize financial support for farmer-led water quality solutions on individual farms and in shared treatment systems. The technical tools outlined in the Task 5 Knowledge Transfer and Summary of Outcomes sections are all resources that the technical service providers and farmers will be able to access to that end.

So far, three pilot watershed farm water quality management groups have been developed within the Salinas Valley through this partnership. Each pilot exists in a different stage of development. As described in this report, the Moro Cojo pilot has already implemented projects and documented attainment of nutrient water quality objectives. Moving forward with this pilot effort beyond the CIG project term, RCDMC, CCWG and Preservation Inc will work with the CCRWQCB to expand guidance to growers regarding how individual farmers will receive credit for previous efforts. We will also work to identify where and how farmers can fine-tune their on-farm irrigation and nutrient management and contribute to the ongoing maintenance of treatment systems that are leading to regulatory compliance (Appendix H).

In the Alisal and Santa Rita Creek/Tembladero Slough pilot areas, the CIG Project Team has conducted the database work to organize and lead on-farm water quality problem-solving and tracking, and has identified potential areas for treatment projects and will continue to work beyond the CIG project term to carry them forward with Preservation Inc's leadership. The team will work with the farmers and CCRWQCB staff to establish a process by which these projects can be constructed, monitored and maintained such that participating growers receive credit towards regulatory compliance. The project team anticipates that additional planning and design funding will be needed to get these projects completed, for which the Team is actively collaborating to provide state and federal grant-writing and NRCS EQIP contract application support.

In the Blanco Drain sub-watershed, land managers and owners are organized around water reuse, with a surface water quality treatment project (bioreactor) nearly complete that has the potential to treat ~10% of the base flow of that waterway. However, given the timing related to other stressors in the region, especially related to groundwater management, the project team focused pilot water quality group formation efforts towards the areas described above. Preservation Inc and team partners will renew outreach to the Blanco Drain farmers and other potential watershed groups as we expand the TPPA-led water quality group coordination throughout the Salinas Valley region and beyond.

Although the nutrient management cooperatives did not proceed as originally envisioned, landowner and water quality regulator (CCRWQCB) interest in targeting water quality management and projects to impacted sub-watersheds suggests an opportunity for NRCS to expand programs that allow landowners to apply for funding jointly to pursue water quality projects. Even with a generous cost-share, new natural infrastructure projects to reduce contamination from tailwater require large amounts of capital and are difficult for individual farmers to fund, particularly small, young, or socially disadvantaged farmers. Expanding programs that allow funding of natural infrastructure projects and allowing joint applications across multiple landowners in a watershed could improve landowner access to NRCS funding and could be more effective in addressing this critical resource concern.

While this project focused on concerns and solutions situated the Central Coast of California, the TPPA structure and water quality solution development and evaluation model can potentially be valuable for other regions with non-point surface water quality management challenges. The technical tools and reviews summarized in the Outcomes section can also be adapted for use elsewhere in California and in the United States where similar resource concerns exist. California is unique in having state water quality regulations in addition to those of the federal Clean Water Act, but the interactions of people and agriculture with soil and water resources are a dynamic we share across state lines, with lessons we hope that can extend to others unanticipated.