TITLE PAGE

California Central Valley wetlands and groundwater management: Tools to guide effective use of water resources

Proposal for Water Smart Funding BOR-DO-19-F012

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TECHNICAL PROPOSAL AND EVALUATION CRITERIA

1. EXECUTIVE SUMMARY

Founded in 1965, **Point Blue Conservation Science is a 501(c)3 nonprofit located in Petaluma, Sonoma County, California and a Category B applicant**. As a boundary organization, we specialize in both conducting science and forming strategic partnerships with agencies, other organizations, and private landowners to implement science-based conservation actions. The proposed project is not located in a federal facility.

Need: Decades of groundwater overdraft have made effective, sustainable groundwater management a high priority for improving water supply reliability in California. As part of California's Sustainable Groundwater Management Act (SGMA), groups of groundwater users and other stakeholders in high priority regions (such as the Central Valley of California) must form Groundwater Sustainability Agencies (GSAs) to design and implement Groundwater Sustainability Plans (GSPs) to ensure that groundwater pumping and recharge are balanced. To date, wetlands have largely not been included in GSPs and thus their impact on groundwater (positive, neutral, or negative) goes largely unquantified, limiting the effectiveness of GSPs in improving water supply reliability. Inclusion in GSPs is hindered by a lack of relevant hydrological data for wetlands, and by the lack of technical expertise to synthesize such data. For the few GSAs that include wetland water use in their GSPs, plan development has required considerable investments in data collection and summary, thus limiting what is feasible in resource-limited GSAs. We propose to remedy these data gaps so that water managers across the State have accurate, robust estimates of wetlands water use.

Project Summary: Point Blue requests $150,000 from WaterSMART to match $90,000 from Audubon California, $50,000 from the Grasslands GSA (primarily composed of the Grasslands Water District), and $10,000 from Point Blue Conservation Science. Point Blue proposes to subcontract with Audubon California and partner with a long-term collaborator and **Category A partner**, the **Grasslands GSA**, to generate relevant wetland water use and management data to use in a wetlands water budget tool that provides monthly estimates of water use and recharge. This project will directly support WaterSMART management objectives to enhance water supply reliability by improving access to data that are critical for effective groundwater management. We will develop wetland hydrological data that will serve as inputs for a water budget tool using existing remote sensing classification models and spatial data resources. We will produce management-critical data products for the Central Valley of California including: (i) an updated wetland boundary map that incorporates the most recent 10 years of wetland restoration, (ii) maps of temporal and spatial variability in surface water and land cover which can be used to delineate the seasonal water budgets in different wetland management types, and (iii) an infrastructure (e.g., scripts and tutorials) to facilitate the work-flow for future GSP reporting. All products will be made accessible online through our existing infrastructure and the SGMA portal. Using matching funds, we will do extensive outreach to wetlands across the Central Valley and compare our stream-lined water use estimates to those made by an external, more-costly approach. This project meets the criteria for eligible project type, "**Projects to improve access to and use of water resources data, or to develop new types of data to inform water management decisions**" from solicitation section C.3.1.

Outcome: This project will help resource managers develop more effective groundwater management plans - a critical issue in the proposed project region - because they will be able to quantify water budgets in a previously understudied land cover type: managed wetlands. With the proposed data and tools, managers can track and analyze wetland water use and management throughout the Central Valley, incorporating this information into legally-mandated GSPs. By highlighting the value of our approach to the planning process through a case study with the Grasslands GSA, we expect that our outreach activities will lead to our methodology being widely adopted for more efficient and comprehensive estimates of wetland water use, advancing state efforts to address competing demands for water and improve groundwater supply reliability.

2. TECHNICAL PROJECT DESCRIPTION AND MILESTONES

To improve access to and use of hydrological data that are important to evidence-based water management decisions, Point Blue Conservation Science, a Category B applicant, proposes to partner with subcontractor Audubon California and the Grasslands Groundwater Sustainability Agency (Grasslands GSA), a Category A partner. The Grasslands GSA was formed from the Grasslands Water District in accordance with recent California legislation (see below). Our proposed work will integrate and improve several existing methods for analyzing remote sensing imagery to provide access to previously unavailable water resource data for managed wetlands in California's Central Valley. During this team's previous work with Grasslands GSA and Central Valley wetland managers, we discovered that accurate estimates of wetland water use were intractable due to the lack of sufficient site-specific wetland management data and the technical staff necessary to synthesize these data into comprehensive wetland water budgets. This project will help water resource managers more effectively manage groundwater, thereby improving water supply reliability and addressing competing demands for water - critical issues in the proposed project region - because they will be able to quantify water use in managed wetlands.

Overview. California's Central Valley is the breadbasket for the State and country. To maintain this agricultural productivity despite California's long, dry growing season, and particularly during periods of extended drought, farmers rely on groundwater. Decades of pumping groundwater faster than it is replaced has led to undesirable results, including depleted aquifers, significant land subsidence that threatens infrastructure (more than a foot of subsidence per year in some of the San Joaquin Valley; Farr et al. 2016), degradation of water quality, and reduced flow in interconnected streams and groundwater-dependent ecosystems. Consequently, water management to protect and improve groundwater supply reliability has become a key issue in California. California's 2014 Sustainable Groundwater Management Act (SGMA) mandated the formation of local Groundwater Sustainability Agencies (GSAs) and the development of Groundwater Sustainability Plans (GSPs) to stabilize groundwater levels and minimize these undesirable results within 20 years. The majority of high or medium priority groundwater basins for GSP development in California are found in the Central Valley (see Project Location map).

While managed wetlands are a critical user of groundwater, they are often overlooked in GSP development, potentially leading to incorrect estimates of groundwater inputs and withdrawals across the state. Over 90% of the Central Valley's historical wetlands have been lost, primarily due to conversion to agriculture, water diversion, and the construction of dams and levees for flood control (Frayer et al. 1989). The approximately 185,000 acres of existing public and private restored wetlands in the Central Valley are reliant on a site-specific combination of

surface water deliveries and groundwater pumping. These heavily managed wetlands provide important habitat for waterfowl, shorebirds, and other wildlife (including threatened and endangered species), as well as recreational opportunities and other ecosystem services for people (Zedler and Kercher 2005).

Because effective groundwater management is critically important to California's water supply reliability, it is essential to accurately quantify wetland groundwater withdrawal and recharge. However, the sheer number of private and public wetland managers in the Central Valley makes it difficult to gather basic information about wetland location, size, and water use. Remotely sensed satellite data offers the potential to fill this void in spatially-explicit, consistent, accessible wetland water management information. We propose to build tools and data that would allow water resource managers to track and analyze wetland water use and management throughout the Central Valley, to facilitate incorporating this information into legally-mandated GSPs.

Our Category A partner, the Grasslands GSA (located in Los Banos, Merced County, CA) was formed when the Grasslands Water District created their own GSA in accordance with SGMA. The Grasslands GSA, largely dominated by managed wetlands, expended considerable financial resources to develop a detailed hydrological model to support their GSP. In contrast, many smaller and private wetlands do not have these capabilities, and are largely overlooked by the GSAs into which they fall. While the Grasslands GSA is unusual in its size (one of the largest wetland complexes in the Western US) and unusual in its investment to quantify groundwater use and recharge, it is representative of Central Valley wetlands in its use of groundwater to support wetland management. Using Grasslands GSA as a case study for wetlands management throughout California's Central Valley, our proposal is designed to remedy the difficulties in quantifying wetland water use, improving access to previously unavailable hydrological data.

Specifically, we request WaterSMART funding to develop the following products (Figure 1 and described in detail below): (1) current map of the location and size of Central Valley wetlands, (2) maps of current wetland management type, vegetation type, and vegetation productivity, and (3) tools to provide wetland-specific summaries of seasonal and annual wetland hydrology. These products will be uploaded to the SGMA portal (Figure 1, task 4). With readily-available products on the SGMA portal, and cost-share funding, we will (5) demonstrate our products to Central Valley managers at large wetlands with critical importance to waterbirds, and (6) work directly with Grasslands as they prepare their GSP to validate our approach using external water use estimates. Through a combination of data synthesis and dissemination, our proposal will enable more robust and accurate water budgeting in California's Central Valley.

Task 1: Current Map of Central Valley Wetlands. First, we will develop a current map of wetlands throughout the Central Valley. The maps that are currently available either represent only property boundaries and not actual wetland area (e.g., DWR 2014), or represent a combination of remotely sensed and manually-edited maps of wetland restoration activities (e.g., Petrik et al. 2014). By developing an updated wetlands map, water resource managers across the state will have access to current information about the presence and size of public and private managed wetlands within their management units.

In the Central Valley of California, wetlands are typically visually and spectrally distinct from the surrounding patchwork of uniform agricultural fields and interspersed urban areas that compose the majority of the Valley. Because of their specific spectral and textural signature, wetland boundaries are better identified through segmentation-based landscape classification of

multispectral satellite imagery than more traditional maximum likelihood methods (Dronova 2015, Frohn et al. 2011, Kaplan and Avdan 2017, Shapero et al. 2017). Segmentation-based classification employs a moving window automated object-based classification where multi-spectral imagery is broken down into multi-pixel, homogeneous segments of spectrally similar objects. Objects are then classified into landscape categories. This classification method is useful in detecting and grouping landscapes from remotely sensed imagery based on a combination of the color and "texture" of sections of the image (Blaschke 2010, Rahman and Saha 2008, Shepero et al. 2017) and has been increasingly used to assess and classify wetland landscapes (Dronova 2017). We will use Landsat 8 Operational Land Imager with Thermal Infrared Sensor (11-band, 30 meter resolution) satellite imagery for this process.

The segmentation classification will be used to develop a set of categorical training polygons and a subsequent training raster to identify which spectral groups represent wetlands and which represent other landscape types. The training raster, segmentation classification, and satellite imagery will then combined to perform a supervised classification of landscapes. Classifications will initially be compared to existing (but out of date) wetland footprints to assess accuracy and inform retraining and classification, followed by select ground truthing in areas where wetlands have recently been constructed and where there are no wetlands. We will use this ground truthing to assess the precision and accuracy of the classification, further refine the classification if needed, and provide accuracy measures for the final wetland footprint classification.

Task 2: Classification of Wetland Management and Vegetation Types. Once the updated footprint of managed wetlands has been defined, we will develop a generalized workflow - a systematic, repeatable set of processes, imposed largely through open-source R scripts - to consistently apply previously-developed models that use remote sensing imagery to classify wetlands by their current water management and vegetation types. In particular, we will create maps that describe the types of managed wetlands within a management unit - e.g., seasonal or semi-permanent - which is largely defined by the flooding schedule and wetland vegetation. By making these updated maps readily accessible and publicly available, we will provide managers with information essential to estimating wetland water use, including: (i) the extent of different wetland management classes and vegetation types, each of which have their own water demand, and (ii) the timing of irrigation that supports that cover class.

To develop these maps, we will first apply the classification algorithm developed by Matchett et al. (2018), which uses data on hydrological patterns (www.pointblue.org/watertracker; Reiter et al. 2018) to distinguish managed wetlands (i.e., seasonally flooded and semi-permanent wetlands) from other common unmanaged land cover types within a broader wetland complex (e.g., uplands, riparian). By extracting the managed wetland areas, we will have a more refined understanding of where water is intentionally applied and the resulting inundation footprint.

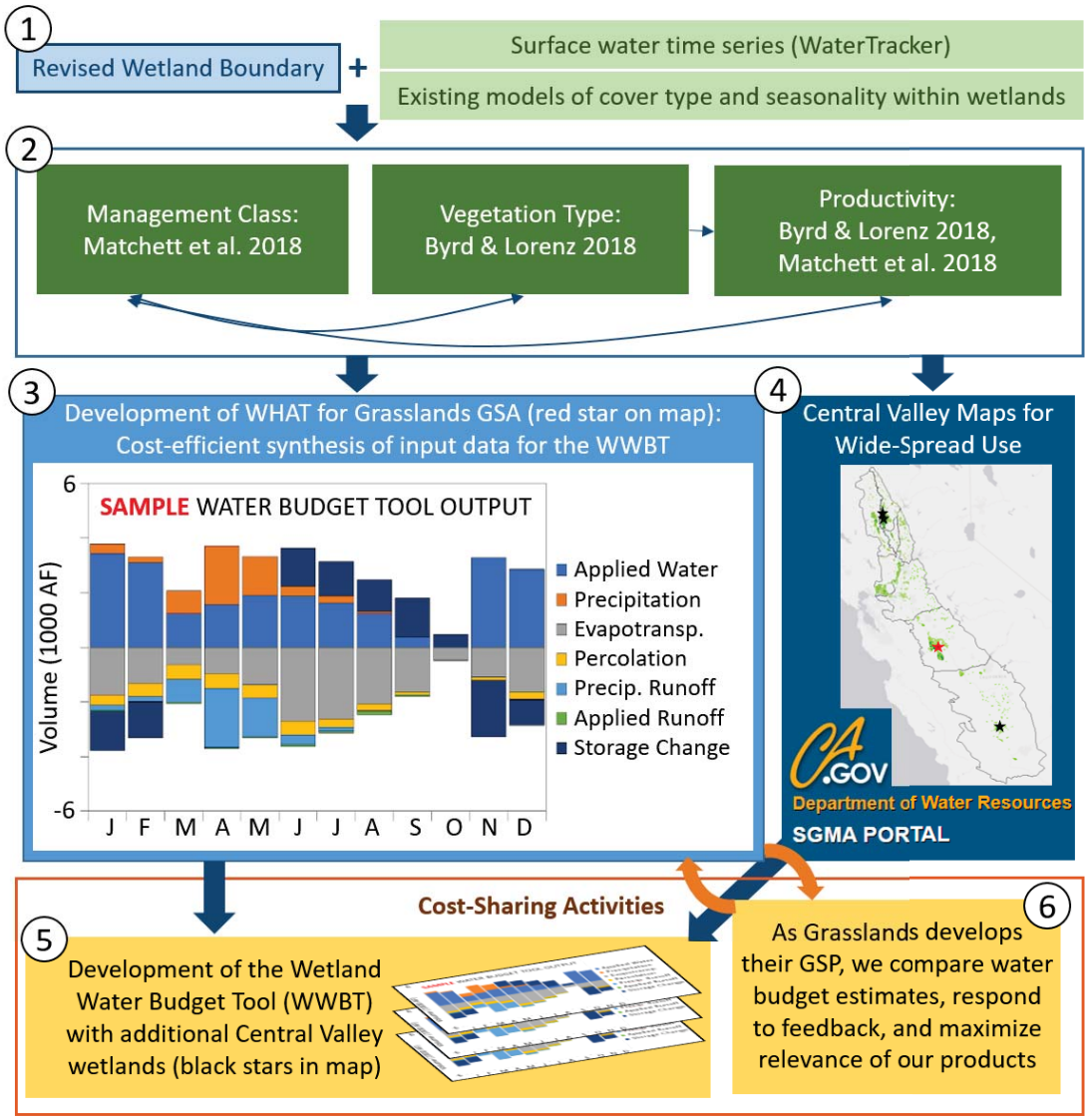

Figure 1. Proposal tasks and products: (1) Develop new managed wetland boundary layer for the Central Valley (upper light blue box); (2) Apply existing remote sensing classification models (upper light green boxes) to distinguish between wetland management regimes (irrigated and non-irrigated seasonal, semi-permanent, permanent), vegetation types (moist-soil seed plants, tule/cattail, cocklebur and invasive grasses), and moist-soil seed productivity (middle green boxes); (3) Develop the Wetland Hydrological Analysis Tool (WHAT) to extract annual wetland hydrological data from tasks 1 and 2 for use in Grasslands GSA modeling (lower left, light blue box) and, (4) upload maps to online platforms for widespread use across the Central Valley (lower-right, darker blue box). Cost-share funding will (5) further the wetland water budget tool development within participating wetlands (black stars in the map: Upper Butte Basin and Gray Lodge Wildlife Areas and Kern wetland complex), and (6) allow for technical support for our Category A partner, the Grasslands GSA (red star on map), on maximizing product applicability to water use reporting. Synergies between the products in (2) will lead to better overall wetlands spatial data (see below).

Next, because the vegetation type within a wetland affects the rates of evapotranspiration, influencing the overall wetland water budget, we will extend a wetland vegetation classification model developed by Byrd and Lorenz (2018) to the updated Central Valley wetland map. This model distinguishes (1) emergent vegetation (e.g. cattail *Typha* spp.; bulrush *Bolboschoenus* spp.; spikerush *Eliocharis* spp.; rush *Juncus* spp.; sedges *Carex* spp.; nutsedge *Cyperus* spp.); (2) swamp timothy, *Crypsis schoenoides*; and (3) watergrass and smartweed, *Echinochloa crusgalli* and *Polygonum* spp. Within swamp timothy and watergrass regions, we will calculate moist soil seed yield and biomass productivity (proxy for yield), to capture the extent of irrigated wetlands.

Understanding vegetative cover and productivity can help fine-tune maps of wetland management class and flood timing - critical information to constructing a wetland water budget. For example, managers often apply additional water as spring irrigation to grow moist soil seed plants (swamp timothy, watergrass, smartweed). Data suggest that irrigated wetlands produce more than double the plant biomass of non-irrigated wetlands (Naylor 2002) and may support a higher proportion of watergrass, which is less drought tolerant than swamp timothy. Thus, combining maps of vegetation type and productivity can help distinguish between irrigated and non-irrigated wetland units. A previous model quantifying irrigation in managed wetlands used hydrological patterns and plant greenness indices (i.e., Normalized Difference Vegetation Index) to successfully predict irrigated seasonal wetlands in the northern part of the Central Valley (Sacramento Valley; Matchett et al. 2018). However, this model predicted poorly farther south in the San Joaquin Valley, where the warmer and drier climate likely requires a more finely-tuned model. We will work with wetland managers in the San Joaquin Valley to obtain additional ground-truth data so that our model of irrigated seasonal wetlands in Sacramento Valley can be applied to the Southern portion of the Central Valley. We will also test whether we can use existing model of wetland moist soil seed plant productivity (Byrd and Lorenz 2018) as well as vegetation types to distinguish between irrigated and non-irrigated wetlands.

Task 3: Wetland Hydrological Analysis Tool Development. Working with the Grasslands GSA, our Category A partner, we will develop a Wetland Hydrology Analysis Tool (WHAT) - published as an open source R package - that provides a generalized workflow for consistently integrating the maps created above with real-time hydrological data (pointblue.org/watertracker) to summarize seasonal and annual wetland hydrological data for a given management unit. The goal of WHAT will be to produce the necessary data inputs for the hydrological modeling used in developing GSPs, such as: the total acreage of wetlands within the management unit for a given water year, summarized by vegetation and management type (from the updated maps produced above), along with the estimated timing of different operational modes that reflect water use, including flood up, maintenance of full ponds, drawdown, irrigation, cropped, or no water supply. We will work closely with Grasslands GSA to generate these estimates for wetlands in their jurisdiction, and compare them to the more labor- and cost-intensive estimations they already developed for three (average, wet, and dry) water years. After refining and validating our workflow, WHAT will be readily applicable to other wetlands, providing cost-effective syntheses of the data necessary for developing GSPs and mandatory annual and 5-year reports.

Although WHAT will produce data useful for any hydrological model, we will specifically design WHAT to be compatible with the Wetland Water Budget Tool (WWBT) we have recently developed in partnership with Audubon California and Davids Engineering. The WWBT

estimates all major components of wetland water budgets in alignment with SGMA's GSP regulations, and is largely based on the same methods to estimate wetland water budgets that are incorporated into the CalSimHydro model developed by the California Department of Water Resources. However, as a spreadsheet-based tool, it is designed to be more accessible for use by non-specialists, allowing wetland managers and water resource managers to more easily synthesize wetland water use data that can be used in GSP development. The WWBT uses information about wetland location, size, and management schedules to pull in information about local soil properties and historical weather data. WWBT then estimates how much water must be applied to meet a given wetland management schedule under a range of historical hydrological conditions, including expected evapotranspiration, run-off, and percolation. Our proposed development of WHAT will further enhance the utility of the WWBT by providing a consistent method for synthesizing the input data required to run the WWBT within a GSA. In addition, our proposed work also complements efforts (described below) to compare the WWBT water budget estimates for Grasslands GSA to the more labor- and cost-intensive water budget estimates they have already generated. Similarly, we will compare WHAT estimates of wetland location, size, and management schedules (as inputs to the WWBT) to estimates from Grasslands GSA's more intensive efforts. Together, WHAT and WWBT will provide a cost-effective, consistent method for Grasslands GSA and other water resource managers in California's Central Valley to incorporate wetland water use into groundwater management plans.

Task 4: Data Accessibility. We will take several approaches to maximize the accessibility and relevance of our products to California resource managers, including: housing all maps on our current system for delivering real-time surface water data (pointblue.org/watertracker), pursuing placement of products on the Department of Water Resources SGMA Data Viewer, and storing code on the Github software repository (see Data Management Section below). Our funding request will support three meetings to demonstrate the functionality and relevance of our data products and solicit feedback from wetland managers at the Grasslands GSA and throughout the Valley. Finally, we will leverage our complementary, state-funded work to engage GSAs and wetland managers, to share these novel resources to improve groundwater management.

Task 5: Wetland Water Budget Development. With cost-share contributions, we will continue the application of the WWBT (described above) to participating wetlands such as the Gray Lodge and Upper Butte Basin Wildlife Areas, the wetlands in and surrounding the Kern Wildlife Refuge, and the Bureau of Land Management's Atwell Island. These three wetlands, along with the Grasslands GSA, consist of larger wetland complexes that are pivotal for birds along the Pacific Flyway. Through this complementary effort to improve access to wetland water budgets, we will facilitate coordination with technical model developers and wetlands managers to ensure local, on-the-ground knowledge is included in the detailed water budgets. Our goal is to calibrate the WWBT to the specific conditions present at each of our representative wetlands, fine-tuning the tool and available data to provide accurate estimates across the spatial heterogeneity of wetlands, soil properties, and hydrological conditions in the Central Valley. To do this, we will conduct workshops or meetings to beta test our data products and synthesizing tools. We will refine and validate the output from the WWBT by comparison to water budget estimates previously developed by the Grasslands GSA for three water year types: wet, dry, and average. In addition, because the components of wetland water budgets vary with precipitation and temperature (e.g., evapotranspiration and applied water), we will incorporate climate change projections into the WWBT to facilitate evaluation of wetland water budgets into the future.

Task 6: Technical Support of GSP Development and Outreach. Using cost share contributions, we will work with our Category A partner, Grasslands GSA, to refine our products so that they provide the necessary hydrological data to produce robust water budget estimates for GSP development. There are two main components to this task: (i) comparing the estimates of wetland water budget components produced by the WWBT (described above in Task 3) to those produced for the Grasslands GSA by a separate team of engineers, and (ii) collaborating with the Grasslands GSA to fine-tune our products as they develop, refine, and implement their GSP.

In task 3 above, we develop the WHAT, a tool to synthesize spatially-explicit wetland location and management data created in tasks 1 and 2 and integrate it with real-time hydrological data to summarize the location, size, and management schedules of specified wetlands. Among a variety of potential uses for these data, they will be used by the Grasslands GSA as inputs to the WWBT for estimating wetland water budget components, such as applied water, evapotranspiration, run-off, and deep percolation. In task 3, we compare WHAT estimates of wetland location, size, and management schedules to those derived by a separate team of engineers for the Grasslands GSA. In task 6, we will also compare WWBT estimates of water budget components to those calculated by a separate team of engineers contracted by the Grasslands GSA. Comparing the two separately-derived water budgets will offer insights into fine-tuning our two respective methods to yield more accurate, comprehensive estimates of wetland water budgets.

The need for tasks 1-6 arose from our initial efforts to develop the WWBT, an ongoing co-production of science-based management tools (as recommended in Beier et al. 2017). In conversations with Grasslands GSA and Central Valley wetland managers, we discovered that incorporating wetlands into GSPs was difficult due to the lack of current, accurate, and comprehensive data on wetland location, size, and water use, and the lack of technical staff necessary to synthesize these data to estimate wetland water budgets. Thus, the match from Grasslands GSA will ensure continued collaboration to provide actionable data and tools.

Proposed Timeline and Milestones. The following timeline displays milestones in the project:

	Year 1 (April 2020-21)				Year 2 (April 2021-22)			
Tasks	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. Revise Central Valley wetlands map		**(1)**						
2. Wetland management and vegetation type classification				**(2)**				
3. Development of WHAT with Grasslands						**(3)**		
4. Data dissemination: e.g. SGMA portal								**(4)**
5. Cost sharing: WWBT deployment					**(5)**			
6. Cost sharing: GSP development and product relevance feedback					**(6)**			

Summary. Capitalizing on recent investments in developing remote sensing methods and models, and on our initial efforts to develop the Wetland Water Budget Tool, our proposed project will advance effective groundwater management by improving access to hydrological data for accounting managed wetlands, a land cover class that currently is largely missing from

GSPs in California's Central Valley. With our cost share, we will engage in outreach to demonstrate the functionality of our products throughout the Central Valley.

3. PROJECT LOCATION

Our project focuses on the majority of California's high and medium priority groundwater basins as identified by SGMA (red and orange areas in Figure 2) and specifically, the basins within the Central Valley (black boundary in Figure 2). For areas within this boundary we will compile comprehensive wetland water use and management data and make it readily available for wetland managers throughout the Central Valley. Our proposed work starts by updating the existing wetlands boundary (blue areas in Figure 2) created by Ducks Unlimited using data through 2009 (Petrik et al. 2014). Working with our Category A partner, the Grasslands GSA (black boundary in Fig 2 inset), we will synthesize these data to better understand the groundwater use in wetland management.

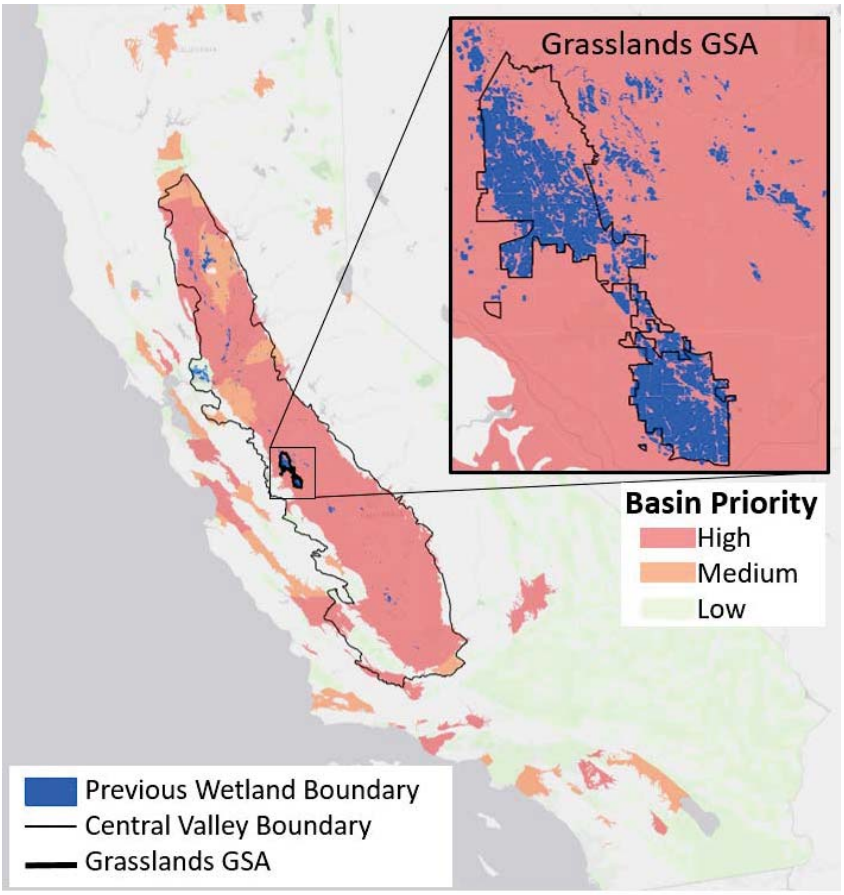

Figure 2. Project Boundary within California: Map products will be produced for California's Central Valley (black boundary) and applied to the Wetland Hydrological Analysis Tool (WHAT) and the Wetland Water Budget Tool (WWBT) to synthesize hydrological information for the Grasslands Water District (thick black boundary in the inset).

4. DATA MANAGEMENT PRACTICES

Our proposal will use existing methods and standards to produce several spatially explicit data sets of immediate interest to Central Valley water resource managers, including: an updated wetlands footprint that reflects wetland restoration completed since 2009 (the most recent map

available) as well as wetland management and vegetation type, code to consistently reproduce and update the analyses generating these spatial data, and the code for the Wetland Hydrological Analysis Tool to consistently extract hydrological data for a management unit by integrating the new wetland map with real-time, open-source hydrological data (pointblue.org/watertracker). Metadata will be provided for all data products.

Spatially explicit data. All spatially explicit data developed by this project will be added to our current system for delivering real-time, open-source hydrological data. Data are archived in Amazon Web Services and made easily accessible for display and download via the Water Tracker website (www.pointblue.org/watertracker). All data stored in this system have full metadata conforming to industry standard formats that are compatible with GIS platforms.

Reproducible code. Code needed to reproduce and regularly update analyses will be published as one or more open-source R software packages, making them freely available and accessible to resource managers. R is a free software environment for statistical computing that works on a wide range of operating systems, and custom software packages can be readily developed for reproducing specific analyses. The R package(s) will be subjected to an automated process that checks for missing metadata, documentation, and other errors before the package can be successfully distributed. The R package(s) will be stored and available for download via the international Github software repository, and formally published and archived via Zenodo, a data repository hosted by the intergovernmental organization CERN.

Accessibility to GSAs and water districts. To maximize the accessibility of our data products to resource managers in California, including GSAs and water districts, we will pursue placement on the California Department of Water Resources (DWR) SGMA Data Viewer. This platform provides statewide spatial resources to GSAs to assist in GSP development and groundwater management. Current datasets hosted on the SGMA Data Viewer include agricultural crops, jurisdictional boundaries, groundwater levels data, land subsidence data, and recharge potential. Because DWR does not currently have managed wetland spatial data in its SGMA resources, GSAs and water districts are not able to accurately include wetlands in subbasin water budgets. By working with DWR to host our wetland spatial layer, we will ensure this resource is readily available to GSAs and will close the current wetland water budget data gaps in GSPs.

5. EVALUATION CRITERIA

Evaluation Criteria A - Benefits to Water Supply Reliability

Water Management Issue Addressed. Water management is a primary concern in California, where long, dry seasons limit water supplies to agriculture, urban areas, and environmental flows necessary for endangered species and other wildlife habitat objectives (Hanak et al. 2019; Hanak and Lund 2012). Prolonged multi-year droughts, like the recent 2012-2016 extreme drought, are projected to become more frequent, adding further stress to California's water systems (Diffenbaugh et al. 2015). When surface water supplies are limited, Californians have increasingly turned to pumping groundwater, but not without severe consequences. Falling groundwater levels require ever deeper wells, while substantial land subsidence (Farr et al. 2016) has damaged roads and bridges, and threatens the integrity of the canal system that delivers water around the state (Faunt et al. 2016). Consequently, effective groundwater management is a key issue in California, and one that our project will address.

Our project will focus on the needs of California GSAs to effectively manage competing demands for groundwater, improve groundwater supply reliability, and comply with SGMA. Specifically, our project will improve access to previously unavailable hydrological data on the water used by the approximately 185,000 acres of managed wetlands in California's Central Valley. To effectively manage competing groundwater demands within and beyond their borders, GSAs require accurate data with which to build comprehensive water budgets that include groundwater pumping and recharge rates by *all* users within their management area. In our engagement with GSAs to date, water budgets primarily reflect agricultural and domestic water use, but often overlook wetland water demands and recharge contributions. The sheer number of private and public wetland managers in the Central Valley makes it difficult to obtain basic information about wetland location, size, and water use, suggesting remote-sensing as the most promising approach to filling these information gaps.

The Central Valley is considered among the most important yet most threatened waterfowl habitats on the continent, largely due to the unreliable water supply (Ducks Unlimited website). Although approximately 90% of the historical wetlands in the Central Valley have been lost (Frayer et al. 1989), the remaining wetlands provide important habitat for millions of waterfowl, hundreds of thousands of shorebirds, and several threatened and endangered species (CVJV 2006; Dybala et al. 2017). They also supply recreational opportunities for duck hunters and wildlife watchers, and generate substantial economic activity (Carver and Caudill 2013). Central Valley wetlands rely on a site-specific combination of surface water deliveries and groundwater pumping to meet their management objectives. By ignoring wetland water use in their water budgets, GSAs risk overestimating the amount of groundwater that can be safely pumped per year, threatening reliable groundwater supplies. On the other hand, because some wetlands import surface water from other parts of the state, which may then percolate into the local aquifer, the net contribution of wetlands to local groundwater recharge may be underestimated. Further, because allocations of available groundwater to GSAs may be determined in part by historical use, ignoring wetland water use may limit wetland managers' access to groundwater, leading to loss of wetland wildlife habitat and recreational opportunities.

How this Project Will Support Management Issue. Our project will improve access to previously unavailable wetland water use data and provide tools for synthesizing that data. With our products, GSAs can accurately account for wetland water use in accordance with SGMA, thus improving groundwater supply reliability, advancing drought management, maximizing efficient conjunctive use, and providing conservation co-benefits. Specifically, our proposal addresses:

***Water Supply Reliability*.** Without current, accurate estimates of wetland water use, GSAs risk overestimating the amount of groundwater that can be reliably pumped each year, threatening groundwater supply reliability. Currently, wetland water use data are difficult for GSAs to access and individual efforts to develop these data (such as by Grasslands GSA) are labor- and cost-intensive. Our proposed project will integrate existing data and models to improve GSAs' accessibility to wetland water data and provide tools for synthesizing these data for inclusion in GSPs. Using our products, GSAs will develop more accurate water budgets and groundwater management plans to improve groundwater supply reliability.

***Drought Management*.** Effective groundwater management is especially critical during extended droughts, when surface water becomes largely unavailable and demand for groundwater rises. Our project will improve accessibility to historical wetland water use data over a range of

hydrological conditions, including during the recent extreme drought, allowing GSAs to account for any changes in wetland water use under droughts and incorporate these data into their water budgets and groundwater management plans. Our project will also improve access to the most up-to-date wetland water use data available, allowing GSAs to track changing conditions and adjust groundwater management decisions as needed.

Conjunctive use of ground and surface water. Effective groundwater management requires explicitly accounting for the interconnections between ground and surface water, to avoid the depletion of surface water by groundwater pumping. By improving access to wetland water use data in wet and dry water years, our project will provide data and tools to allow managers to explore conjunctive use scenarios as a function of surface water availability.

Conservation and efficiency. We will produce Valley-wide spatially explicit maps for the following: (i) wetlands boundaries, (ii) seasonal surface water cover, and (iii) vegetation cover and productivity of moist soil seeds that provide grain for waterfowl (see Fig 1 and Technical Section). These GIS layers will be uploaded to our existing infrastructure and the SGMA portal, making them accessible to all GSAs and wetlands managers. In doing so, we will create another method by which wetlands managers can explore their activities in the context of their adjacent wetland neighbors. These data will provide the first step towards managers working together across a broader spatial context to allocate scarce resources. For example, in a year in which wetlands managers have to make compromises as to the extent of flooding, two spatially adjacent wetlands can be flooded early and late, respectively, so that waterfowl populations remain supported throughout the year. This kind of multi-GSA coordination has been underutilized in part due to the lack of data, a problem this proposal seeks to remedy.

Our proposal also benefits individual wetlands by providing a more streamlined mechanism for individual GSAs that contain wetlands to calculate water use. By making water use estimates easier and more economical, we anticipate (i) considerable resource savings within wetlands that can be directly applied to wildlife management and (ii) more wetlands managers to engage in GSP development, leading to more robust groundwater use estimates across the Central Valley.

Ability to meet endangered species requirements. Effective groundwater management under SGMA requires limiting “undesirable results,” including depleting interconnected surface waters. The amount of depletion allowed is often defined by the habitat needs of endangered species in California’s rivers and streams, including salmonids. By improving access to wetland water use data, our project will improve the accuracy of the hydrological models GSAs are using to determine how much groundwater pumping can be sustained without depleting flows in these rivers and harming the endangered species that rely on them. Therefore, our project will improve the ability of GSAs to meet endangered species requirements.

In addition, by enabling GSAs to explicitly quantify their groundwater needs in their management plans, our project will contribute to improved groundwater access in managed wetlands, particularly in state and private wetlands that often have less protection than federal wetlands. By articulating groundwater need in wetlands, managers are more likely to be able to secure continued access to the resources they need to provide critical habitat for wildlife, including wetland-dependent endangered species. For example, the Grasslands GSA, our Category A partner, contains the 240,000-acre Grasslands Ecological Area, which is the largest contiguous wetlands in the western United States and is home to the federally threatened giant garter snake (*Thamnophis gigas*) and the California threatened tri-colored blackbird (*Agelaius*

tricolor). The giant garter snake requires the slow-moving water of wetlands for hunting, and tricolored blackbirds nest in the thick stands of tules and cattails on the edges of wetlands.

Magnitude of Proposed Project Benefits. We lack answers to critically important questions regarding wetlands groundwater management, such as: (i) what fraction of wetland area is reliant on groundwater? (ii) what fraction of pumped groundwater is going to wetlands in typical and extreme years? and (iii) how much do wetlands recharge groundwater by shifting surface water to standing pools that increase on-site percolation? Thus, it is hard to quantify the significance of including wetland water use in groundwater management plans, nor the downstream benefit to effective groundwater management of more accurate GSPs. For at least four wetlands, our proposal will provide novel estimates for answering questions (i) and (iii), allowing us to extrapolate an initial estimate for (ii). As our products become available to managers across the Central Valley, we will learn more about the long-term magnitude of our project's benefits to groundwater management. In the short-term, we will use several predictive metrics as indicators of this magnitude. For example, we will quantify user downloads of our maps from online platforms; we will survey wetland managers to quantify the number of people using our products; and we will observe the trend in GSPs including wetland water use. We anticipate that these metrics will show significant benefit of this project beyond the funding timeline.

At the local level, our project will also have immediate benefits to the Grasslands GSA in the form of time and money savings spent developing, revising, and reporting on their GSP, where savings are anticipated to be worth at least the annual rate of matching funds they are contributing to the project. These savings can be diverted to the Grasslands Ecological Area's mission to provide wildlife habitat and recreational opportunities. Further, improving access to reliable, regularly updated hydrological data allows Grasslands to manage groundwater supply more reliably, maximizing conjunctive management of surface water and groundwater.

Complementarity with Existing Work. Our proposed project complements a long-standing partnership between our Category A partner (Grasslands GSA), Point Blue Conservation Science, and Audubon California. All three partners have been engaging with GSAs to understand groundwater management needs and develop information to improve groundwater management plans. Together, we have identified the inaccessibility of wetland water use data as a critical need. Having identified that wetland water use is commonly overlooked by GSAs, Audubon California and Point Blue Conservation Science worked together to develop an easy-to-use Wetland Water Budget Tool based on wetland management information collected directly from interviews with wetland managers. Our project complements this existing work, to integrate, streamline, and make accessible data products and synthesis tools for GSAs across the Central Valley. In addition, we will leverage Grasslands GSA's existing, independently-developed hydrological data to validate and refine our efforts.

This project also leverages considerable work done through a NASA-funded project (*Integrating Remote-Sensing and Ecological Forecasting into Decision-Support for Wetland Wildlife Management and Ecosystem Services in the Central Valley of California: Optimizing Across Multiple Benefits* [NNX17AG81G]) to quantify waterbird resources in the Central Valley of California. Through this project, the foundational analyses were completed to produce the spatial maps of the surface water footprint, surface water seasonality, wetland vegetation type, and moist soil seed productivity across the Central Valley (see Fig. 1 in the Technical Section). This

proposal will apply these models, create an automated workflow to update maps, and upload maps to the SGMA portal, where they will be broadly accessible to GSAs and wetland managers.

Finally, in addition to SGMA, there are a number of California plans to manage and protect water and wildlife that will benefit from improved wetland water management, including: (i) California Water Action Plan that identifies declining groundwater as a primary challenge, (ii) the Central Valley Joint Venture partnership of stakeholders, agencies, and organizations that protect, restore and enhance wetlands, (iii) California's Climate Adaptation Strategy to protect habitat resilience for waterfowl, shorebirds, wading birds, Swainson's Hawks (state threatened), Tricolored Blackbirds (state threatened), and Giant Garter Snakes (federal threatened), (iv) the State Wildlife Action Plan that spotlights freshwater marsh as critically important to the Valley Ecoregion, (v) California's Areas of Conservation Emphasis (ACE) that highlights the importance of wetland biodiversity, and (vi) the Climate Change Vulnerability Assessment of At-Risk Birds which focuses wetland habitat as particularly threatened.

Evaluation Criteria B - Need for Project and Applicability of Project Results

Water Resource Manager Need. The proposed project would directly and immediately benefit the Grasslands GSA, our Category A partner, who has been working with Point Blue and Audubon for over a decade. In conversations supporting the development of the WWBT, the Grasslands GSA identified the need for improved access to wetland water use data and the tools to readily synthesize these data. In the absence of a water budget tool, Grasslands hired consultants for extensive, labor- and time-intensive efforts to compile these data. Because Grasslands GSA (and other GSAs) will be required to produce annual reports and 5-yr updates, easier access to these data will facilitate reliable and updated groundwater management plans in compliance with SGMA reporting requirements. Please see Grasslands GSA's letter of support.

While the initial need was narrowly focused on the Grasslands GSA, we realized that the Grasslands GSA was representative of Central Valley wetlands and that the work proposed here would be broadly relevant. Because of the lack of data, wetlands have largely been ignored in GSP development, leading to inaccurate estimates of groundwater inputs and withdrawals, and hindering groundwater supply reliability. The passage of SGMA explicitly recognizes the need for effective groundwater management in California to ensure groundwater supplies and limit the damage caused by continued groundwater overdraft, an urgent need our proposal will address. Further, our cost share contributions will ensure that these products reach the managers they are designed to serve, contributing to more accurate water use reporting and better management.

Applied Science Tools with Immediate and Broad Relevance. Our products will include an updated map of wetlands in California's Central Valley, methods for annually updating spatial data and storing data on publicly accessible online platforms, and an open-source R package Wetland Hydrological Analysis Tool for consistently extracting seasonal and annual wetland hydrological data. Following their release, these products will be available for immediate use by Central Valley GSAs to examine the location, size, and water use of wetlands within their jurisdictions. We will leverage our complementary projects, supported with matching funds, to continue engaging with GSAs and share these products to promote their wide-spread use.

Product Intent. These products will be used by GSAs throughout the Central Valley for developing and refining groundwater management plans to incorporate a previously neglected water-use sector: wetlands. Four wetlands - Upper Butte Basin Wildlife Area, Gray Lodge

Wildlife Area, the Kern wetland complex, and our category A partner Grassland GSA - will use our spatial products and WHAT tool to synthesize wetland hydrological data. With matching funds, we will use these data to help these wetlands produce water use estimates with the WWBT. We will also conduct outreach to GSAs to make the products available for their annual reporting and 5-yr updates on groundwater management plans (i.e. GSPs), as mandated by the Sustainable Groundwater Management Act.

Immediate Management Use. The products proposed here will be made available immediately upon production because of our wetlands partners' urgent need to complete their water use budgets. Matching funds will provide opportunities for beta testing our products and tools. By providing access to previously unavailable hydrological data for wetlands, we expect that our products will provide information on the relative balance of surface water versus groundwater across different precipitation regimes. This information is directly related to management decisions surrounding drought and conjunctive use. Because we are helping managers to reliably supply water to scarce wildlife habitat, our products will inform decisions about wildlife management, supporting a variety of existing efforts in California (see Evaluation Criteria A).

Transferability. While the wetland complex within the Grasslands GSA is uniquely large within the Central Valley, it is representative of wetlands throughout the State in that it has an urgent need to sustainably manage the groundwater it relies upon. Thus, we are using Grasslands GSA as a case study to produce spatial layers for the entire Central Valley, taking a variety of approaches to maximize the accessibility and relevance of our data products to resource managers. Specifically, we will house maps on our current system (pointblue.org/watertracker) and the SGMA Data Viewer. The R code stored at Github will allow each wetlands to quantify a specific set of summary statistics important for groundwater reporting and management.

Collaboration with Primary Beneficiary. We have worked with Grasslands GSA to identify the widespread need for these products, and will continue to work with them to ensure the accessibility and utility of our products for their needs. As evidenced by their match commitment, Grasslands will collaborate with us to validate our products, synthesize hydrological information, and budget wetland water use. We will continue to meet regularly with Grasslands GSA, in person and remotely, to ensure these activities are completed.

Evaluation Criterion C — Project Implementation

Objectives. The overarching goal of our proposed project is to improve groundwater management in California's Central Valley, with two primary objectives: (1) to provide our Category A partner (Grasslands GSA) with previously unavailable data and tools to consistently synthesize current wetland hydrological data, and (2) to make these data and tools available to GSAs throughout California's Central Valley. These data and tools include: (i) maps of the current wetland footprint, (ii) maps of wetland management and vegetation types, and (iii) tools to consistently summarize wetland water use information within a GSA. All products will be made publicly available online and their availability will be advertised broadly through outreach activities made possible through matching funds. Together, these data and tools will facilitate more accurate groundwater management planning, and therefore improve groundwater supply reliability. In addition, these products will facilitate compliance with the annual reporting and 5-yr plan updates mandated by SGMA. With more accurate reporting of water use in a sector -

wetlands - that, to date, has been mostly overlooked, California agencies can make more confident predictions of groundwater sustainability into the future.

Methodology and Work Plan. As described in detail in the Technical Section, we will integrate several existing tools and methods developed in previous projects (e.g. satellite imagery to identify wetlands) to reliably detect surface water, and determine wetland vegetation types. Wetland classification models will be validated/refined with ground-truthing and cross-referencing to utdated wetland maps and local experts (wetland managers). Once these products have been developed we will develop the Wetland Hydrological Analysis Tool (WHAT), a generalized workflow for extracting annual hydrological information for a specific planning unit. We will initially focus WHAT development on the Grasslands GSA, but generalize the tool for application to GSAs across the Central Valley. We will also do extensive outreach to demonstrate the functionality of our products, supported with matching funds. In justification for our approach, we have found that remotely sensed data provided accurate wetlands estimates across large spatial areas. However, using matching funds, we will continue to provide support and validation for our methods by comparing our estimates to previous, independently developed estimates. In the next section we list the products and their anticipated completion dates.

Products and Deliverables. We will produce the following maps and R code for synthesizing hydrological data for SGMA reporting and water budgeting. The creation of each of these products will incorporate accuracy testing, code to consistently reproduce and update the analyses, metadata that describes methodology, and a plan for accessibility and archiving.

Wetlands Boundary (anticipated completion: November 2020, assuming an April 1, 2020 start date). Created from segmentation-based classification on recent satellite imagery (Landsat 8), this will revise the current wetlands boundary map created on data that is now nearly a decade old. A new wetlands boundary will help identify sites of recent restoration, locations to apply our downstream data products, and potential, previously-neglected partners in wetland and water management. (Method reference: Blaschke 2010, Frohn et al. 2011, Rahman and Saha 2008).

Wetlands Classification (anticipated completion: April 2021). Water management varies substantially by wetland type. We will produce a map that broadly differentiates between seasonal and semi-permanent wetlands while providing more specific flood-timing information within these categories. The spatial extent and timing of flooding is critically important information in SGMA-mandated water use reporting and budgeting. (Method references: Reiter et al. 2018, Matchett et al. 2018).

Vegetation Type (anticipated completion: April 2021). We will apply existing wetlands vegetation type modeling within the above-described wetlands boundaries to produce maps of vegetation type across the Central Valley wetlands. In particular, the model distinguishes between (1) emergent vegetation (see list of species in Technical Section); (2) swamp timothy ; and (3) watergrass and smartweed. Since different vegetation types have different irrigation demands, vegetation type can fine-tune and validate the wetlands classification layers described above. Further, our products provide information critical to the management of waterbirds, the ultimate purpose of water deliveries and management. (Method reference: Byrd et al. 2018 and existing partnership on NASA funded work through PI Matt Reiter.)

Moist Soil Seed Productivity (anticipated completion: April 2021). Similar to vegetation type, we will provide maps of moist soil seed (namely swamp timothy seed yield and watergrass and

smartweed biomass) productivity cross Central Valley wetlands. These layers provide information on irrigation timing and quantity within wetlands, where irrigated wetlands have been shown to produce more than double the plant biomass of non-irrigated wetlands (Naylor 2002). As with vegetation type, wetlands managers are intently interested in the seasonality and productivity of adjacent wetlands because they help leverage a network of wetlands providing bioenergetic resources (e.g. Dybala et al. 2016, 2017) for waterbirds. (Method reference: Byrd et al. 2018 and existing partnership on NASA funded work through PI Matt Reiter.)

The above maps will be accessible online through existing infrastructure and the SGMA portal.

Wetland Hydrological Analysis Tool (anticipated completion: November 2021). Working with the Grasslands GSA we will produce a generalized workflow R package to produce annual estimates of wetland hydrological info within a planning unit. Grasslands will serve as a case study, for which we will generate estimates over several water years to compare to estimates made by consultants working for Grasslands, to refine and validate our workflow. This hydrological synthesis is critical information for the development of GSPs and input to hydrological models and other tools like the Wetland Water Budget Tool. We will design the workflow to provide the necessary inputs to the WWBT. This case study will serve as a broadly relevant, cost-efficient methodological workflow for all Central Valley wetlands managers. With matching funds, we will demonstrate the tools' functionality in outreach efforts to an additional three wetlands. (Method reference: Davids Engineering 2019; Wickham 2015)

Grasslands GSA Water Budget Estimate (anticipated completion: November 2021). Using the output from the above workflow and matching funds, we will create a Grasslands GSA water budget using the WWBT. The WWBT produces estimates of water budget components such as total annual evapotranspiration, run-off, and percolation, necessary for including wetlands in GSPs. (Method reference: Davids Engineering 2019)

Outreach and Reports (anticipated completion: April 2021)**.** As products become available we will be placing them on our existing spatial archiving infrastructure (WaterTracker) and the SGMA portal. Because of our matching funds and existing relationships with Grasslands GSA and other wetland managers (specifically those from Upper Butte Basin Wildlife Area, Gray Lodge Wildlife Area, the Grasslands GSA, and the Kern wetland complex), we will be meeting with these users to demonstrate the functionality and relevance of our tools and solicit feedback.

Availability of Existing Data and Models. The products described above are well supported by existing remotely sensed data archives and peer-reviewed published models. Specifically, references for the methods for each product are listed at the end of each item above.

Staff. Point Blue and Audubon have been working with the wetlands manager at the Grasslands GSA (and Grasslands Water District) for over a decade. With the exception of a recent addition to the team, the staff listed below have worked together with the Grasslands GSA on projects specifically addressing wetlands management and conservation. Beyond Grasslands, all individuals have a breadth and depth of experiences working on wetland management in the Central Valley and beyond. Their individual qualifications are listed below.

Dr. Erin Conlisk is a Quantitative Ecologist in the Pacific Coast and Central Valley Group of Point Blue and will serve as project manager for this work. For over 15 years, Dr. Conlisk has worked on a variety of spatial ecology projects across a variety of California ecosystems. She is

currently working on a NASA-funded project to create and apply previously-developed remote sensing models to describe waterbird habitat suitability. Her previous work uses a variety of approaches to dynamically model the impacts of climate change, in combination with other stressors, on high elevation forests, bird populations, small mammals, and California shrublands. Dr. Conlisk is adept at spatial analysis and coding and can support the tasks proposed here.

Dr. Matthew Reiter is a Research Director in the Pacific Coast and Central Valley Group of Point Blue. Dr. Reiter has served on and chaired local, national, and international science committees, including work on the Central Valley, San Francisco Bay, and Sonoran Joint Ventures, the Pacific Flyway Council, National Wildlife Refuges, and the California Landscape Conservation Cooperative. His work includes extensive experience modeling the distribution of surface water and wetlands in the Central Valley of California (www.pointblue.org/watertracker). He is Principal Investigator of a project to develop annual forecasting models of available wetland habitat that guide optimal multi-benefit water management in the Central Valley. He also leads a long-term, 12-country research and monitoring network, the Migratory Shorebird Project, which quantifies trends in migratory shorebird abundance, assesses factors influencing their populations, and applies the data to inform coastal wetland conservation and management.

Dr. Kristen Dybala is a Principal Ecologist in the Pacific Coast and Central Valley Group of Point Blue. Dr. Dybala has worked extensively with the Central Valley Joint Venture and other partners to develop conservation strategies and conduct research in riparian and wetland ecosystems in California's Central Valley. She is currently the Principal Investigator for a project quantifying co-benefits and trade-offs of landscape change scenarios on bird communities and ecosystem services in the Sacramento-San Joaquin River Delta in California. Her work has also included extensive modeling of bird population and community responses to restoration, climate change impacts, and trade-offs with carbon sequestration. Dr. Dybala also supervises long-term research programs at Point Blue's Palomarin Field Station and has extensive experience managing, archiving, and publishing data and code (www.kristendybala.com/open-science.html).

Dan Orr is a Senior Analyst at Audubon. With over ten years of experience in ecology, natural resource monitoring and assessment, Dan's unique expertise in remote sensing classification justify our need to subcontract with Audubon. This includes spatial and multi-scale modeling and analysis of physical and biological systems as they pertain to natural resources. Dan conducts multi-agency long term ecosystem monitoring, contributing to the baseline community and biodiversity assessments of protected areas, habitat and population assessments of endangered species and natural resource damage assessments. He has ongoing studies of avian population changes, habitat analysis and landscape changes at the Salton Sea. Dan received his B.S. in Marine Biology from the University of California, Santa Cruz and his M.S. in Applied Marine and Watershed Science from California State University, Monterey Bay.

Samantha Arthur joined Audubon California as Conservation Project Director in 2014. Her work with landowners and agencies to improve wetland and farm management for the benefit of bird species in the Central Valley makes her an indispensable part of the team, providing justification for our need to subcontract with Audubon. She has led the Tricolored Blackbird Regional Conservation Partnership Program Project since 2015, including securing $1.8 million in funding, leading diverse partners to joint conservation-industry objectives, and conducting all tracking and reporting. Samantha will provide oversight and management of the subcontract with

Audubon California. Samantha has a Masters of Environmental Science and Management from the Bren School at UC Santa Barbara.

Evaluation Criterion D — Dissemination of Results

Communication Within Grasslands Water GSA. This project builds on over a decade of communication between Point Blue, Audubon, and the Grasslands GSA. We will continue to adaptively solicit and incorporate feedback amongst our three organizations, with emphasis on the applicability of our products to Grasslands GSA, our Category A partner. Historically, we have used a combination of in person meetings and written reports to describe the methods and applicability of our results. Given our past working with Grasslands GSA on the initial construction of the water budget tool, we found these techniques to be the most effective way to disseminate this information to our Category A users.

Additionally (as described in the Data Management section), we have built existing infrastructure to display our map products to Grasslands GSA managers. Code and models will be archived in GitHub. We will also put maps, data, code, and reports on the SGMA portal so that the Grasslands GSA is communicating to the GSA community about its efforts in water management. These efforts provide multiple platforms for information within the Grasslands GSA and a referenceable archive for future work.

Communication Across Central Valley Wetlands. Our matching funds will largely be spent on outreach to wetlands beyond the Grasslands GSA specifically to the wetland managers at Gray Lodge and Upper Butte Basin Wildlife Areas, and the wetlands in and surrounding the Kern Wildlife Refuge (including the BOR's Atwell Island). These three wetlands, along with the Grasslands GSA, consist of larger wetland complexes that are pivotal for birds along the Pacific Flyway. In meetings and webinars, we will demonstrate the functionality of our tools and specify that all products are available online. As described in the Data Management section, we will make Central Valley-wide spatial maps available through our current system for delivering real-time, open-source hydrological data, publish our Wetland Hydrological Analysis Tool on Github, and place our products on the SGMA portal. We believe that a combination of meetings and making the data available online to users already familiar with the WaterTracker and SGMA portal platforms will be the most effective way to communicate our results to a broad audience.

Evaluation Criterion E — Department of the Interior Priorities

Our work supports the following Department of Interior priorities:

Conservation Stewardship. Our data is designed to support water reliability and management with a Category A partner engaged in wetland management for wildlife. As such, we are using scientific, evidence-based practices to manage limited water resources to benefit waterbirds and other wildlife. Beyond the benefits to wildlife, our proposal provides tools for more robust estimates of groundwater use and recharge to benefit long-term reliability in water supply. By improving access to wetland water use data, our project will help determine how much groundwater pumping can be sustained without depleting flows in rivers and harming the endangered species they contain. By making broadly relevant data accessible across the Central Valley, we foster relationships among conservation organizations working within GSAs, helping managers collaborate across wetlands boundaries. Conservation of waterfowl benefits a variety of hunting and recreational activities in California.

Utilizing Natural Resources. The goal of SGMA is to ensure that there is sufficient future groundwater to support California's prosperous agricultural industry and invaluable biodiversity. Our proposal is designed to facilitate quantification of water use within wetlands, a land class that is often omitted from SGMA reporting.

Restoring Trust with Local Communities. By mapping the entire Central Valley of California and using our match funding towards outreach, we are encouraging communication and networking among GSAs and wetland managers to leverage scarce water and natural resources. In the most recent drought we heard from wetland managers across the State that they wanted a better understanding of what neighboring wetlands in their region were doing, i.e. a more comprehensive spatial picture that included the timing of flooding and the productivity of vegetation used to feed waterfowl in adjacent wetlands. Our proposal will improve the accessibility of these data. Further, we are making our work publicly available through the SGMA portal, using this governmental platform to facilitate communication and trust between local GSAs, stakeholders, and state agencies.

Striking a Regulatory Balance. This proposal is designed to reduce the regulatory burden imposed by SGMA by providing access to more current data and providing tools to automate and streamline the analysis of those data. While it is necessary that California balance groundwater withdrawal and recharge, estimating water use across a variety of land uses and economic sectors can be difficult and costly without tools like ours that specifically leverage our expertise on water use within a particular land class. Our work in wetlands has been motivated by the need to conserve the state and federally endangered and threatened species within the Grasslands GSA.

Modernizing Our Infrastructure. Using informatics and remote sensing we are modernizing the approach to management and planning. We will make our data available online through the SGMA portal, a governmental platform to increase informational infrastructure towards science-based water resource management.

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PROJECT BUDGET

Letters of Funding Commitment – 3 letters are attached at end of application package.

Table 1. Total Project Cost Table

Source	Amount
Cost to be reimbursed with the requested Federal funding	$150,000
Costs to be paid by the applicant	$10,000
Value of third-party contributions	$140,000
TOTAL PROJECT COST	**$300,000**

Table 2. Budget Proposal

Budget Item Description	COMPUTATION		Quantity	TOTAL
	$/Unit	Quantity	Type	COST
Salaries and Wages				
Matt Reiter, Quantitative Ecologist	7,652	1	months	$7,652
Erin Conlisk, **Project Manager**	6,343	2	months	$12,686
Kristen Dybala, Principal Ecologist	7,602	1.75	months	$13,304
Fringe Benefits (46.5%)				
Matt Reiter, Quantitative Ecologist				$3,558
Erin Conlisk, **Project Manager**				$5,899
Kristen Dybala, Principal Ecologist				$6,186
Travel				
Team meetings, partner meetings and ground truth				$2,752
Supplies and Materials				
Contractual/Construction				
National Audubon Society (staff: Samantha Arthur, Dan Orr)				$71,000
Cost Share Contributions				
National Audubon Society				$90,000
Grassland Water District				$50,000
S.D. Bechtel, Jr. Foundation				$10,000
TOTAL DIRECT COSTS				$273,037
Indirect Costs				
Indirect Cost Negotiated Rate	35%	$77,037		$26,963
TOTAL ESTIMATED PROJECT COSTS				**$300,000**

BUDGET NARRATIVE

Salaries and Wages

Point Blue will have three key personnel working on the proposed project and they will lead the following set of tasks.

Personnel
Point Blue Quantitative Ecologist, Dr. Erin Conlisk, will serve as the overall **project manager** as well as lead the application of existing wetland models to the new wetland footprint. Point Blue Principal Scientist/Quantitative Ecologist, Dr. Matthew Reiter developed most of the existing models and will work with Dr. Conlisk to develop the needed data to use the classification models for prediction. Drs. Conlisk and Reiter will develop the code to streamline future generation of wetland classification data. Point Blue Principal Ecologist, Dr. Kristen Dybala will lead the development of the Wetland Hydrological Analysis Tool to harvest the needed summaries from the wetland spatial data layers to use in the Wetland Water Budget Tool. Dr. Dybala will conduct a retrospective assessment of the water budget for our Class A partner, the Grasslands Water District for wet, dry and average years types that can be used to compare to alternative, often more costly, approaches for estimating the needed data for SGMA reporting. The project manager's time in this project (see percentages below) is inclusive of all estimated time needed for compliance with all contractual requirements, including the final financial and performance reports.

Task 2: Classification of wetland management and vegetation types
Conlisk will work one month (4.2% of time over 24 months) at a rate of $6,343/month to direct the Project and lead the development of the wetland classification data layers. She will also contribute one month (4.2% of time over 24 months) at a rate of $6,343/month to develop code to enable future development of the wetland data layers.

Reiter will work a half month (2.1% of time over 24 months) at a rate of $7,652/month to consult on the development of the wetland data layers and help calibrate the existing wetland classification models using new ground-truth data. Reiter will also contribute a half month (2.1% of time over 24 months) at a rate of $7,652/month to help with code development and reporting.

Task 3: Development of the Wetland Hydrological Analysis Tool
Dybala will work 1.75 months (7.3% of time over 24 months) at a rate of $7,602/month to lead the analysis of annual hydrological data at Grasslands GSA. This will include the validation of these estimates against previous estimates Grasslands has developed for three water year types, as well as developing these analyses into a generalized Wetland Hydrological Analysis Tool that can be used by other GSAs, published as an open-source R package code. The tool will be designed to provide all of the inputs required by the Wetland Water Budget Tool, in development with match funding, to facilitate estimation of wetland water budgets.
Salary for Erin Conlisk = $12,686
Salary for Matt Reiter = $7,652
Salary for Kristy Dybala = $13,304
Total Salaries = $33,642

Fringe Benefits

Point Blue provides benefits to employees at a rate of 46.5% on listed salaries.

Total Salaries for Point Blue = $33,642
Total fringe for Point Blue salaries (46.5%) = $15,643
Total salaries plus fringe = $49,285

Travel

We anticipate the following travel budget for meetings with wetland managers to solicit feedback on map products and synthesis tools.

Project kick-off meeting with all partners in Los Banos, California.
Mileage = 1000 miles x $0.58/mile = $580
Hotel = $90/night x 2 people = $180
Food = $53/per day x 2 people/days = $106
Los Banos Total = $866

Acquisition of ground truth data from wetland managers in the San Joaquin Valley.
Mileage = 1000 miles x $0.58/mile = $580
Hotel = $90/night x 1 people = $91
Food = $53/per day x 1 person/day = $53
San Joaquin Valley Total = $724

Project team meeting in Sacramento
Mileage = 451 miles x $0.58/mile = $262
Parking = $25/day x 3 cars = $75
Sacramento Total = $337

Project closing meeting with all partners in Los Banos, California.
Mileage = 1000 miles x $0.58/mile = $580
Hotel = $90/night x 2 people = $180
Food = $53/per day x 2 people/days = $106
Los Banos Total = $866

Total Travel = $2,752

Contractual

Based on extensive previous work and jointly acquired matching funds that are being applied towards this project, Point Blue will subcontract with Audubon California on the following tasks.

Personnel

Senior Analyst, Dan Orr, will lead the efforts to revise the current wetland footprint map to reflect wetland restoration efforts ongoing over the past decade. Working Lands Program Director, Samantha Arthur, will lead data dissemination efforts and outreach efforts provided as match funding for this work.

Task 1: Current Map of Central Valley Wetlands
Through a contract with Audubon California, Senior Analyst, Daniel Orr, will develop the new wetlands footprint map from multispectral satellite imagery and validate the results of the segment-based landscape classification with comparison to previous wetlands footprint maps. Orr will work to direct the Project and lead the development of the wetland footprint data layer, provide support for his spatial layer as it is used to produce additional spatial products, and will coordinate with the rest of the project team to support Tasks 2, 3, and 4. Point Blue will contract with Audubon for $40,997.36 for Task 1, which includes $22,344.75 in salaries and wages, $7,150.32 in fringe benefits, $750 in travel, and $10,752.12 in indirect costs.

Task 4: Data Accessibility
Through a contract with Audubon California, Samantha Arthur, Working Lands Program Director, will work to maximize the accessibility and relevance of our data products to water resource managers in California, including the placement of products on the California Department of Water Resources SGMA Data Viewer. Arthur will meet with managers to provide input and feedback to fine-tune our project deliverables and demonstrate how our hydrological syntheses can be used to create accurate water budgets in accordance with the SGMA process. Point Blue will contract with Audubon for $30,002.64 for Task 4, which includes $16,200 in salaries and wages, $5,184 in fringe benefits, $750 in travel, and $7,868.64 in indirect costs.

Total Audubon Subcontract = $71,000

Cost Share Contributions

Task 5: Wetland Water Budget Development
Audubon California will contribute matching state funds of $60,000 for the application of the Wetland Water Budget Tool (WWBT) beyond Grasslands GSA, improving access to wetland water budgets and thereby groundwater management. These tasks include: (1) further refinement and validation of the outputs of the WWBT (e.g., total annual evapotranspiration and deep percolation) by comparison to water budget estimates previously developed by the Grasslands GSA for three water year types, (2) incorporating climate change projections into the WWBT to facilitate evaluation of wetland water budgets under future weather conditions, and (3) working to calibrate the WWBT to their specific conditions in collaboration with wetland managers across the Central Valley (specifically targeting larger wetland complexes important to the Pacific Flyway, such as Gray Lodge north of Yuba City, the Upper Butte Basin Wildlife Area, and the Kern Wildlife Refuge and surrounding private and public wetlands - including Central Valley Project Improvement Act Refuges who receive surface water deliveries from the Bureau of Reclamation).

Task 6: Technical Support of GSP Development and Outreach

With matching funds ($50,000) supplied by our Category A partner, the Grasslands GSA will work with the Point Blue and Audubon teams to ensure that our products can provide streamlined, local, on-the-ground hydrological information for wetlands within GSPs. Matching funds from Grasslands GSA will be directed towards their GSP development. Because Grasslands GSA services a large complex of private and public wetlands, their GSP development will serve as a model for groundwater planning and management under SGMA. As Grasslands synthesizes and reviews the Grasslands GSP, Point Blue will provide matching funds ($10,000) to compare water budgets created through our products and workflow to those created separately by contractors hired by the Grasslands GSA. Using $30,000 in matching funds as part of a project funded by the Wildlife Conservation Board, Audubon California, will provide guidance and technical assistance to GSAs and wetland managers to integrate water budget data for wetlands into GSPs. These outreach efforts will maximize the applicability of the proposed data products to the SGMA process.

Indirect Costs

Point Blue will use their federally approved indirect cost rate of 35% to the entirety of the Point Blue budget ($52,037) and to the first $25,000 of the subcontract to Audubon.

Total Direct Point Blue Budget (Salaries + Travel) = $52,037
Total Indirect for Point Blue Budget (35%) = $18,213
Total Indirect for first $25,000 on $71,000 Audubon Subcontract (35%) = $8,750
Total Indirect = $26,963

Total Budget

Summing the various categories above, the total budget for this proposal is as follows:

Total Point Blue Salaries + Fringe (Tasks 2 and 3) = $49,285
Total Travel = $2,752
Total Audubon Subcontract (Tasks 1 and 4) = $71,000
Total Indirect = $26,963
Total WaterSMART BOR-DO-19-F012 Request = $150,000

Audubon Cost Share (Task 5) = $60,000
Audubon Cost Share (Task 6) = $30,000
Grasslands GSA Cost Share (Task 6) = $50,000
Point Blue Cost Share (Task 6) = $10,000
Total Cost Share = $150,000

TOTAL BUDGET = $300,000

ENVIRONMENTAL AND CULTURAL RESOURCE COMPLIANCE

Because our proposal requires a small amount of ground-truthing field work we answer the following environmental and cultural resource questions.

Will the proposed project impact the surrounding environment (e.g., soil [dust], air, water [quality and quantity], animal habitat)? Please briefly describe all earth-disturbing work and any work that will affect the air, water, or animal habitat in the project area. Please also explain the impacts of such work on the surrounding environment and any steps that could be taken to minimize the impacts.

Our project relies primarily on remotely sensed (satellite based) information. We will employ limited ground-truthing of our modeling, but we do not anticipate that these efforts, or our project as a whole will impact the surrounding environment.

Are you aware of any species listed or proposed to be listed as a Federal threatened or endangered species, or designated critical habitat in the project area? If so, would they be affected by any activities associated with the proposed project?

There are two species of concern at the Grasslands GSA: the federally threatened giant garter snake (*Thamnophis gigas*) and the California threatened tricolored blackbird (*Adeliaus tricolor*). Because we do not expect their habitat to be affected by our primarily remote-sensing based project, we do not expect any adverse effects to these species. We expect that our project will provide beneficial information to water managers who are conserving these species.

Are there wetlands or other surface waters inside the project boundaries that potentially fall under CWA jurisdiction as "Waters of the United States?" If so, please describe and estimate any impacts the proposed project may have.

Wetlands are in our project boundary but we will be primarily sampling them through remotely-sensed (satellite-based) information. Our project is not anticipated to have negative effects on wetlands but instead will provide beneficial information to water managers who are managing these highly valuable biodiversity and recreational areas.

When was the water delivery system constructed?

Not applicable; we will not be altering water delivery infrastructure.

Will the proposed project result in any modification of or effects to, individual features of an irrigation system (e.g., headgates, canals, or flumes)? If so, state when those features were constructed and describe the nature and timing of any extensive alterations or modifications to those features completed previously.

No; we will not be making any modifications to the irrigation system.

Are any buildings, structures, or features in the irrigation district listed or eligible for listing on the National Register of Historic Places? A cultural resources specialist at your local Reclamation office or the State Historic Preservation Office can assist in answering this question.

The Grasslands Water District contracted AECOM to conduct a cultural resources inventory (*North Grasslands Water Conservation/Water Quality Control and Level 2 Refuge Water Exchange Project: Final Environmental Assessment 16-23-MP, US Department of the Interior Bureau of Reclamation. April 2017.* https://www.usbr.gov/mp/nepa/includes/documentShow.php?Doc_ID=28381). Five cultural resources were identified within the area: Santa Fe Canal segment (P-24-001893), Eagle Ditch segment (P-24-001960), Hollow Tree Drain segment (P-24-001959), Gun Club Road Ditch segment (P-24-001961), Walter Ditch segment, and a segment of the Santa Fe Railroad Grade (P-24-000083). We do not anticipate having any effects on these features.

Are there any known archeological sites in the proposed project area?

The Grasslands Water District contracted AECOM to conduct a cultural resources inventory (*North Grasslands Water Conservation/Water Quality Control and Level 2 Refuge Water Exchange Project: Final Environmental Assessment 16-23-MP, US Department of the Interior Bureau of Reclamation. April 2017.* https://www.usbr.gov/mp/nepa/includes/documentShow.php?Doc_ID=28381). No prehistoric cultural resources were identified.

Will the proposed project have a disproportionately high and adverse effect on low income or minority populations?

No.

Will the proposed project limit access to and ceremonial use of Indian sacred sites or result in other impacts on tribal lands?

No. As per a previous question, no prehistoric cultural resources were identified. Even if there were ceremonial sites, our project would not limit access to them.

Will the proposed project contribute to the introduction, continued existence, or spread of noxious weeds or non-native invasive species known to occur in the area?

Our limited ground-truthing of our remotely sensed modeling efforts has the potential to introduce non-native species, however, we will employ stringent best practices for not spreading noxious weeds (e.g. USFS Guide to Noxious Weed Prevention Practices: https://www.fs.fed.us/invasivespecies/documents/FS_WeedBMP_2001.pdf).

REQUIRED PERMITS AND APPROVALS

We do not require any permits.

LETTERS OF SUPPORT

One letter from our Category A partner is attached at the end of the application package.

[redacted]