SB-88 Measurement Method for Measuring and Reporting on the Diversion of Water in the Sacramento-San Joaquin Delta

December 21, 2018 Version 2.0

Prepared by The Freshwater Trust

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EXECUTIVE SUMMARY & PROGRESS REPORT

The Freshwater Trust (TFT) has developed this Remote Sensing-Based Measurement Method (MM) and its Implementation Plan (the Plan) pursuant to regulations implementing Senate Bill 88 (SB-88) surface water diversion reporting requirements. Some landowners and managers in the Sacramento-San Joaquin Delta (Delta) have significant technologic and hydrologic barriers to the application of conventional measuring devices, data collection equipment, and telemetry specified in SB-88. The Plan described in this report fulfills reporting requirements through the development and validation of a new measurement method for determining water diversion in the Delta. This method employs participant-supplied crop, irrigation, and management data; local weather data; and remotely-sensed spatial data, and applies multiple analyses for the calculation of water diversion for each program participant. The Plan advances the science of consumptive use estimations through automation, refinement, and comparison of existing methodologies. In case that the measurement method is determined inconsistent with the statue, the program would default to an Alternative Compliance Plan (ACP), described later.

TFT has taken major steps forward with the implementation of the Plan in 2018, the most significant of which are listed below (2018 Plan Actions). The approach to water diversion and use calculations has been iterative, and is currently being refined to increase accuracy. The majority of effort in developing the MM thus far has been focused on automating and refining the entire workflow, from data collection through water use modeling and allocation to water rights, to fulfill reporting requirements in a way that meets the accuracy requirements of SB-88 and can be repeated annually at scale. Comparisons of MMs to refine and improve the MM began in 2018, including a comparison between the volume of diverted Delta surface water measured using TFT's MM and point of diversion flow meters (Attachment G, Technical Appendix 2). This initial comparison of MMs is preliminary; however, a robust comparison of multiple MMs to validate the MM TFT uses for SB-88 reporting will be completed in 2019. Anticipated next steps in the Plan are also listed below (2019 Plan Actions), and include: testing alternative remotely sensed data sources and evapotranspiration models against those that are currently part of the MM; using additional metered data for more robust statistical MM comparisons; and using metered data and additional models to calculate water budgets to further calibrate water use models. *The primary objectives of (1) advancement in understanding of remote water use calculation methodologies and (2) water use reporting and are currently on track.* By the end of 2019, TFT will fully quantify the accuracy of its MM using the methods described below, as well have completed detailed documentation of both its methodology for the MM and the statistical analyses used for refinement and quantification of accuracy.

2018 Plan Actions

Recruitment

Recruitment of water right holders began in late 2016, and by the end of 2018 TFT had contracted with 79 landowners for their participation in the Plan, for a total of 160 water right permit, license, or statement numbers enrolled. See Attachment A, provided as a PDF, for water right and participant information. Attachment B and the GIS shapefile submitted with this Plan include the locations associated with the water right license or statement numbers according to the California Electronic

Water Right Information Management System (eWRIMS). The shapefile also contains associated tax lots/parcels representing the area served by the Plan.

Consumptive Use Analysis and Automation

The focus of TFT's analytical efforts in 2018 were:

(1) database design, construction, and population to facilitate water use modeling and aggregation to water rights for reporting;
(2) automation of the Consumptive Use Program Plus (CUP+) model for monthly, field-based calculation of consumptive use; and,
(3) development of an additional model to allocate and/or aggregate the estimated water used at the agricultural field level to the appropriate water right for SB-88 reporting.

The full MM process is described in detail in Technical Appendix 1 (Attachment G), and more broadly here and throughout this the Plan. TFT was fortunate to be able to work with the model's developer at the California Department of Water Resources (DWR), Dr. Orang, to fully understand the model's data requirements and the equations and procedures occurring behind the Microsoft Excel interface. The R and SQL programming languages were used to replicate the model, and a work flow for the automation of this model has been completed using the algorithm approach developed by DWR, so that modeled water use data at the field level can be obtained from cropping, weather, and other data stored in the SB-88 database. CUP+ in the Excel spreadsheet form has some additional capabilities that TFT is exploring for advanced analyses.

In summary, evapotranspiration (ET) or consumptive use calculations occur at the field-level using daily, location-specific reference evapotranspiration (ET_0) that is provided by CIMIS on a spatial grid. When reference ET data is missing from the appropriate grid, it is extrapolated from surrounding data through procedures in the automated version of the model. The analysis then uses plant water use factors most representative of the crop type and crop stage to calculate ET_C of the crop in milliliters (which are converted to acre-feet for reporting). ET of applied water (ET_{aw}), which considers reduced irrigation needs due to precipitation, is then calculated based on the time since the last rain event using CIMIS precipitation data interpolated from the three CIMIS stations nearest to the field. Additional factors, including soil water holding capacity and ET of bare soil, will be included in the model in future versions.

As described above, TFT is still in the process of ensuring that ET calculations using these automated methods precisely align with the CUP+ spreadsheet tool's output. Also, automated quality assurance / quality control measures and data and model validation procedures are in development in collaboration with the State Water Resources Control Board (SWRCB) "testbed" process. The 2017 water diversion values reported on behalf of Plan participants to fulfill SB-88 requirements (described below) reflect the current status of TFT's analyses.

The field-level, monthly water use values that result from consumptive use modeling are then used as inputs to another model developed by TFT, called Water Rights Integrator. This second model allocates and aggregates water use to Delta water rights for SB-88 reporting. This is done based on the association between water rights, their points of use (irrigation) reported by participants, and the temporal and spatial restrictions listed in eWRIMS. This model was developed by TFT late in 2018, after understanding the water use allocation workflow based on the 2017 reporting. It will be utilized for 2018 reporting (which occurs in April and June of 2019) and is described further in Technical Appendix 1.

Reporting

On behalf of the Plan participants, TFT submitted the required monthly 2017 water diversion and use data and water right information to the SWRCB for the appropriate water rights by April 1 and July 1, 2018, respectively, for permits and licenses (numbers beginning with A0) and statements (numbers beginning with S0). As the refinement of methods to estimate water diversion and use is iterative, and the Plan was in its first year, 2017 data that was reported reflected TFT's current version of consumptive use calculation via CUP+ methods. This process includes the modeling of monthly ET of applied water calculated at the field level, multiplied by an irrigation efficiency factor, and then aggregated by water right used to irrigate groups of fields. At the time of these first reporting benchmarks, TFT was automating this model and validating outputs through quality assurance (QA) measures. Initial MM QA efforts comparisons were based on comparisons with previously reported water use for each water right, and with published agronomic water application rates for the region[1]. More robust MM validation will occur in 2019 (described below).

2019 Plan Actions

Measurement Method Comparison and Refinement

The MM currently being used to fulfil SB-88 reporting requirements under the ACP is based on the CUP+ model for estimating water use. The design of the "SB88_Db" database, the automation of CUP+, and the development of a model to allocate water used among water rights were the focused tasks of TFT's 2018 analytical effort. These elements created the entire workflow to enable SB-88 reporting through a draft MM. The refinement of this MM and the comparison to other MMs is the focus of TFT's efforts in 2019, to improve the workflow and increase reporting accuracy, as stated in the goals of this ACP. The 2019 MM refinement and validation will involve the four primary analytical tasks listed below, and the results of these efforts have been documented in the Technical Appendices (Attachment G). At the conclusion of 2019, the development and refinement of the MM will be complete and the accuracy of the MM will be quantified and compared with the requirements of SB-88.

(1) The collection of metered water use data is a high priority in 2019, so that modeled consumptive use outputs can be compared between methods. These data will be aggregated through ongoing programs by The Nature Conservancy (TNC), DWR, and other members of the Office of the Delta Watermaster's Consortium, and informed by the Office of Delta Watermaster's Comparative Study for Estimating Crop Evapotranspiration in the Delta.
(2) The scripted version of CUP+, which enables the batch estimation of consumptive water use over many agricultural fields, needs further improvement to parallel DWR's version more precisely. Some factors that are part of the Microsoft Excel version of the model created by DWR are not

[1] Irrigation Training & Research Center. 2003. California Crop and Soil Evapotranspiration. Irrigation Training & Research Center, California Polytechnic State University, San Luis Obispo, California, USA. ITRC Report No. R 03-001. 65 pp

incorporated into TFT's analyses, including soil saturation and root depth factors. TFT plans to meet with the CUP+ developer, Dr. Orang, to better align methods.

(3) In addition to facilitating direct comparisons between metered and modeled data, this additional data will allow TFT to develop water budgets for Delta islands where the majority of water inputs, outputs, and flows are understood. This will reveal the importance of such factors as seepage, infiltration, and conveyance losses to further improve the MM.

(4) The CUP+-based MM is a field-level assessment of consumptive water use. Landscape-level models exist that use remotely sensed data, weather data, and other spatial data to estimate consumptive use over large areas, or to measure actual evapotranspiration via energy budgets. Such models, including METRIC (ITRC) and CalSIMETAW (DWR), will be used to compare, verify, and refine the TFT's MM in 2019.

Field-level data on crop and irrigation practices acquired from analyses of satellite imagery and additional remotely sensed data are also being acquired by TFT in 2019 through its program partners. The feasibility of using this data to reduce the administrative burden of collecting participant data will be tested, to assess applicability of TFT's MM being adopted by the state for SB-88 compliance. The accuracy of these remotely sensed data sets will be quantified via comparisons with participant-supplied crop type, irrigation method, and irrigation frequency data. When the remotely sensed data misclassifies cropping or irrigation practices (e.g., identifying a pasture as an alfalfa field), the resulting model sensitivity will be tested at the field and landscape level to quantify the significance of using remotely sensed data given inherent inaccuracies.

Furthermore, the development of methods for data QA/QC and data validation will take place in 2018, including but not limited to the following steps: (1) metrics to quantify the accuracy of seasonal crop type and other field-level data (by automated comparison of remotely sensed data to participant-supplied or publicly available data), (2) metrics to quantify confidence in TFT's understanding of the relationship between water right, diversion, and irrigated fields, and (3) error or warning reports for consumptive use calculation steps when, for example, interpolated CIMIS data was used because raster data was missing or default planting dates were used instead of participant-supplied data. Outputs of these steps will be included in future water use data reports for SB-88 compliance.

Reporting

TFT will continue submitting water diversion and use data and other information required under SB-88 on behalf of Plan participants. The form and methods of submission of data for future SB-88 reporting under the Plan will continue to be discussed with SWRCB Water Rights staff and modified as needed. For future reporting periods, it is TFT's intent to provide an electronic submittal in collaboration with the SWRCB.

OVERVIEW

Senate Bill 88 (SB-88), Sections 15 through 18, signed June 24, 2015, added measurement and reporting requirements for certain Sacramento-San Joaquin Delta (Delta) surface water diverters.[2] Essentially all water right holders diverting 10 acre-feet of surface water (or more) per year are subject to volumetric metering and monthly reporting requirements starting on January 1, 2017. Delta surface water diverters (diverters), however, have a series of practical impediments to the use of conventional water meters, which were identified after the initial extension of monthly water reporting to all users under SB X7-7.[3] The 2015 legislation (SB-88) has different and more expansive requirements than SB X7-7 that must now be met. The State Water Resources Control Board (SWRCB) has adopted "Regulations for Measuring and Reporting the Diversion and Use of Water" to provide the specific regulatory requirements for water reporting.[4]

Some diverters in the Delta still have significant technologic, hydrologic, and logistic barriers to the use of electronic water meters, data loggers, and telemetry as needed to meet the requirements in SB-88. The regulations recognize these issues and provide for other means of achieving consistency with the requirements. The Freshwater Trust (TFT) is proposing the development of a new measurement method, described here. However, in case that the measurement method is determined inconsistent with the statue, the program would default to an Alternative Compliance Plan (ACP), described later.

This integrated program, titled the Delta SB-88 Measurement Method (method or MM) or its Implementation Plan (the Plan), is intended to research the application and phase in the implementation of alternative remote-sensing water measurement methods starting in 2017 and possibly through 2021. This Plan will allow for a direct statistical comparison of the results of different water measurement and estimation methods under similar environmental conditions. Ideally the program will validate the method more rapidly than expected; however, the Plan period is intended to ensure that the MM is fully supported by the Office of the Delta Watermaster. This approach integrates current scientific understanding from peer-reviewed sources and the recent Office of the Delta Watermaster's Comparative Study for Estimating Crop Evapotranspiration in the Delta.[5]

The use of the Plan's scientific and technical approach will quantify the relative strengths and weaknesses of each of these MMs, and ultimately be used to refine and optimize one or more MMs within the Delta. It is expected that this Plan document will be updated with the latest refinements annually, but not in such a manner that disrupts the fundamental scientific elements of comparing methods and refining one or more MMs.

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[2] CAL. WATER CODE §§ 1840, 1841 & 5100–07 (West 2017); CAL. CODE REGS. tit. 23, §§ 907–38 (2016).

[3] CAL. WATER CODE §§ 10608, 108000 (West 2016). *See also* CAL. DEP'T OF WATER RES., A PROPOSED METHODOLOGY FOR QUANTIFYING THE EFFICIENCY OF AGRICULTURAL WATER USE: A REPORT TO THE LEGISLATURE (May 2012), www.water.ca.gov/wateruseefficiency/sb7/docs/AgWaterUseReport-FINAL.pdf.

[4] State Water Res. Control Bd., Measurement Regulation: Information on SB-88 and Emergency Regulation (Aug. 2017), www.waterboards.ca.gov/waterrights/water_issues/programs/measurement_regulation/.

[5] https://www.waterboards.ca.gov/water_issues/programs/delta_watermaster/crop_c_u_study.html

TFT is the sponsoring organization and coordinating the Plan. TFT will act as the agent of subscribing in-Delta diverters in the Plan's implementation. As such, TFT will be the administrative point of contact for the SWRCB and the Delta Watermaster. However, as noted on the TFT Extension Opt-In Form, each water right claimant is required to provide accurate information in support of the development and implementation of the Plan. Further, each water rights claimant remains individually and independently responsible to report their water diversions and uses to the SWRCB in a timely manner. TFT will support developing, implementing, and administering the Plan and completing such reports. TFT assumes no responsibility for the accuracy, completeness, or timeliness of such reports, which remain the legal responsibility of the individual water right holders. To continue their effective stewardship of the water used for agricultural beneficial uses, the Delta water right holders identified in Attachment A propose to develop and implement this Plan.

DISCUSSION

In-Delta islands have essentially inverted topography, with adjacent channel water surface elevation above the land surface elevation. This hydraulic gradient saturates the soils and necessitates pumping to render the fields suitable for farming. This hydrology also allows for siphons that can draw irrigation water into the islands without power. These agricultural water intakes around the rims of the islands take surface water from the surrounding channels. This water flows by gravity throughout the island, typically reused several times until it gets to the lowest part of the island. Drains collect the water and pumps return the water to the adjacent channel. The water is circulated internally within the island using low-head ditches and small siphons. The low hydraulic head reduces the ability to use flumes to accurately measure these flows, and the siphons (both onto the island and between ditches) are unpowered in many cases. Intakes and any measurement equipment are often situated in remote locations, making them subject to chronic theft and vandalism. Traditional impeller-based meters require hydraulically complex and clog-prone screening, or are subject to internal clogging, cavitation, accuracy errors, and outages. This list of technical impediments is by no means exhaustive, but these technical challenges place disproportional burdens on Delta diverters trying to comply with SB-88.[6]

Notwithstanding these challenges, Delta diverters support the State's attempt to better understand and document diverse water users. On behalf of the subscribing in-Delta diverters, TFT proposes a Plan by which the SWRCB will receive the most accurate and reliable data available in light of their circumstances. A collaborative model will provide water use calculations using state-of-the-science data collection and analysis methods, the MM, through the integration of field-level evapotranspiration (ET) models, spatial CIMIS weather analysis, and the use of satellite imagery and other remote sensing tools.

The Plan's ET and consumptive use estimates will be based on the following methods, subject to calibration and refinement: (1) the Consumptive Use Program PLUS (CUP+) developed by the University of California Davis (UCD), and the California Department of Water Resources (DWR); and (2) the Irrigation Training and Research Center (ITRC) methods developed by California Polytechnic State University

[6] *See, e.g.*, Letter from BSK Associates, Inc., to S.F. Heringer, President, Reclamation District 999 (Sept. 6, 2011), www.waterboards.ca.gov/waterrights/water_issues/programs/diversion_use/docs/bsk_cmmnts.pdf.

(METRIC[7,8,9]). A peer-reviewed algorithm has been extracted from the historic CUP+ method and is being applied here as the basis of a MM. TFT is further assessing additional data inputs for water use estimation that go beyond those required for ET calculations, such as information about water conveyance and remotely sensed irrigation type and intensity. The refinement of these MMs will be documented in annual reports. The Plan provides for comparisons to demonstrate the similarities and differences among MMs and provides additional validation of the methods.

Regardless of the diversion quantification methods, Delta farms are already incentivized to and experienced with optimizing water distribution and application systems. For example, in the Northern Delta, fruit trees are typically planted on the highest ground on the periphery of the island and annual crops are often grown in the lower, central locations, to optimize water use and efficiency from the rim of the islands with well-drained soils to the center of the islands, where seepage and return flows are collected and recirculated or retuned to the channel. The Plan's analysis of these factors can allow a better understanding of local water use and the strength of the modeling assumptions. Surface water management within the Delta is often tightly geographically and topographically controlled, and thus can be readily extrapolated.[10]

For example, this diversion, flow, and return system is typically subject to high water tables due to the inverse topography, disincentivizing excessive irrigation. That is to say, there is little or no storage available if a farmer applied excess irrigation water and significant costs if they do overapply. Since the islands are below sea level, any surplus water simply fills up the space and saturates the roots, reducing yields. In order to avoid that effect from flood or rainwater, water table elevations are often controlled across an entire island through the same surface water diversion canal network, and are interoperated to maintain a suitable root zone moisture content.

BASIS FOR ALTERNATIVE COMPLIANCE

Given the physical conditions, technological limitations, and other Delta-specific challenges of farm gate diversion information collection, management, and potentially telemetry, strict compliance with Chapter 2.8 Measuring and Monitoring is generally not feasible, and where feasible, is not reliable, as demonstrated by recent experience identified by the Delta Measurement Experimentation Consortium.

The Delta has a complex network of channels and sloughs that rely on mechanical pumping and siphons to divert from adjacent tidal sloughs and channels to support beneficial uses, including irrigated agriculture, wetland maintenance, and habitat management for resident and migratory wildlife. This network includes inverse topography, very low hydraulic head, and field elevations at or below sea level.

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[7] *See, e.g.*, CAL. POLYTECHNIC STATE UNIV., IRRIGATION TRAINING & RESEARCH INST., CALIFORNIA EVAPOTRANSPIRATION DATA (2017), *available at* www.itrc.org/etdata/index.html.

[8] J. MEDELLIN-AZUARA & R.E. HOWITT, COMPARING CONSUMPTIVE AGRICULTURAL WATER USE IN THE SACRAMENTO-SAN JOAQUIN DELTA (Sept. 2013), https://watershed.ucdavis.edu/files/biblio/DPC_ComparativeStudy_ET_Final_Report_UCD.pdf.

[9] DELTA PROT. COMM'N., PUBLIC NOTICE & MEETING AGENDA, ITEM 7(B): COMPARING CROP WATER CONSUMPTIVE USE IN THE SACRAMENTO SAN JOAQUIN DELTA: PROOF OF CONCEPT (Nov. 20, 2013), delta.ca.gov/commission/meetings/meeting_archives/meetings_11-20-13/.

[10] Dr. Charles M. Burt, Irrigation Water Conservation—Benefits & Tradeoffs, U.S. Comm. On Irrigation & Drainage Seminar, 51-58 (1995) http://www.itrc.org/papers/pdf/irrwaterconservation.pdf.

Many of the diversion sites are in remote locations where electronic measurement, storage, and transmission challenges are compounded by sparse or nonexistent cell tower coverage and unstable power at the end of transmission lines. The inverted topography further complicates the use of conventional line-of-sight radio frequencies. Monthly, daily, and hourly tidal changes cause periods of low flow that can be below the operational limits of traditional meters. Most water diversion structures are multi-purpose stormwater, flood, and drain structures. At high tide, water may be diverted onto a field with a siphon or into the managed wetland through a gate, but at low tide water can also flow in the opposite direction out of the same water control structure if it is not well-sealed. Moreover, the Delta pumps and their ancillary infrastructure vary in size and age, and are subject to a range of hydraulic inefficiencies from cavitation, bubbles, and debris.

As demonstrated by recent experience of DWR and The Nature Conservancy (TNC) in the Delta, meters are subject to significant variation or even failure under the conditions common in the region. In many cases there is not appropriate pipe length to meet the manufacturer's requirements for permanent mounting. In many locations, equipment would be subject to significant corrosion and fouling, requiring custom installation and specialized construction. Access for refurbishment or replacement can be precluded by State and Federal Endangered Species Act restrictions concerning the distance to Valley elderberry shrubs or for salmonid seasonal timing. Even with refurbishment, aquatic weeds and invasive species can readily impede accuracy, restrict flows, and damage installations.

Because of these technological difficulties of accurately metering water use at the scale and complexity of the Delta, DWR uses its Delta Island Consumptive Use (DICU) model for determining its compliance with SWRCB Decision-1641.[11] The DICU model and other traditional estimation models have also undergone recent analyses to improve their efficiencies.[12, 13, 14, 15, 16, 17, 18]

PARTICIPATION

Participation in the Plan by in-Delta surface water diverters (water right holders) is discretionary, but Plan subscribers are contractually bound to ensure data quality and consistency between sub-areas or

[11] DEPT. OF WATER RES., DELTA ISLAND CONSUMPTIVE USE (2017), *available at* http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dicu/dicu.cfm.

[12] WILLIAM FLEENOR, ET AL., DELTA STEWARDSHIP COUNCIL, AN INDEPENDENT PEER REVIEW REPORT ON THE DWR REPORT ON ESTIMATING NET DELTA OUTFLOW (NDO): APPROACHES TO ESTIMATING NDO IN THE SACRAMENTO-SAN JOAQUIN DELTA (Sept. 2016), *available at* deltacouncil.ca.gov/sites/default/files/2016/10/Independent%20Peer%20Review%20Report%20on%20Estimating%20NDO.pdf.

[13] DEPT. OF WATER RES., ON ESTIMATING NET DELTA OUTFLOW: APPROACHES TO ESTIMATING NDO IN THE SACRAMENTO-SAN JOAQUIN DELTA (Mar. 2016), www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/ndo_report_march2016.pdf.

[14] L.J. Siegfried, Thesis, Physically Based Modeling of Delta Island Consumptive Use: A Case Study of Fabian Tract and Staten Island (2012), *available at* https://watershed.ucdavis.edu/shed/lund/students/LucasSiegfriedMS2012.pdf.

[15] DEPT. OF WATER RES., DIV. OF PLANNING, ESTIMATION OF DELTA ISLAND DIVERSIONS AND RETURN FLOW, C-032892 (Feb. 1995), *available at* http://www.calwater.ca.gov/Admin_Record/C-032892.pdf.

[16] DEPT. OF WATER RES., METHODOLOGY FOR FLOW AND SALINITY ESTIMATES IN THE SACRAMENTO-SAN JOAQUIN DELTA AND SUISUN MARSH: 36TH ANNUAL PROGRESS REPORT IN ACCORDANCE WITH WATER RIGHT DECISIONS 1485 & 1641 (June 2015), http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/AR2015/AR-2015-all.pdf.

[17] Davids Engineering, Inc., Remote Sensing Consumptive Use Analysis (2012), http://davidsengineering.com/projects/remote-sensing/california-department-water-resources-analysis/.

[18] Tariq Kadir, *Estimates for Consumptive Water Demands in the Delta using DETAW, in* METHODOLOGY FOR FLOW AND SALINITY ESTIMATES IN THE SACRAMENTO-SAN JOAQUIN DELTA AND SUISUN MARSH (Oct. 2006), *available at* http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/delta/reports/annrpt/2006/2006Ch7.pdf.

groups. Diverters may also participate through coalitions, including Water Agencies, Reclamation Districts, or groups using joint diversion facilities. Agreement to share in the costs of the program is required. The overall Plan budget and sample participant contract are supplied in Attachments E and F, respectively.

SCALE

The Plan consists of a program of developing, refining through documented studies, and implementing the alternate measurement method, focused on the subscribing diverters within the Northern "legal Delta," currently totaling 160 water rights held by 78 landowners.

TIMING

The Plan will be developed, tested, and rolled out in a step-wise manner to ensure consistent and accurate reporting, and to adjust adaptively based on the latest information and technologies. Coordination with each of the Water Agencies and/or Reclamation Districts to enroll interested farmers in this Plan, as well as direct outreach to individual land owners and managers, began in 2016 and will continue through 2019, as either meter installation, limited time extension, or participation in a Plan that involves a MM or an ACP.

The current list of Plan participants and their associated water right, contact, and other information are provided in Attachment A. The locations associated with the updated participant water right application and statement numbers (according to eWRIMS) are shown in Attachment B and included in the GIS shapefile submitted with each revision of the MM. The Plan's timeline and implementation schedule is provided in Attachment D. As stated earlier, the MM is intended to meet the regulatory requirements for a Monitoring Method; however, it could take up to five years to document that compliance. Achieving that compliance is one of the key reasons for maintaining consistent participation in the technical working groups on this matter, participation in the Delta Consortium, and frequent engagement with the Office of the Delta Watermaster.

PLAN OUTLINE

The MM program is intended to be consistent with the SB-88 statutory requirements and is currently subject to a §916 Request for Additional Time to develop a §934 Measurement Method. In order to ensure that there are no reporting compliance gaps in case the SWRCB's deputy director determines that this MM program is not consistent with §916, the Plan is consistent with §935 Alternative Compliance for a Measuring Device or Measurement Method Requirement (a) Alternative Compliance. As described above, circumstances exist where "strict compliance with sections 933 or 934 of this title is not feasible, would fail to meet the accuracy requirements, would unreasonably affect public trust uses, or would result in the waste or unreasonable use of water."

The Plan is subject to the following requirements in the Statutes (A–F, and b–e):

(A) Name and contact information of all participants, including designation of an agent to serve as the primary contact person.

See Attachment A for participants.

Agent to serve as the primary contact person:

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(B) Topographic or aerial map(s) showing location of participants and covered lands (including all assessor's parcel numbers). The map shall conform to the mapping requirements of article 7 of chapter 2 of division 3 of this title.

See Attachment B (Figure 1), as well as the GIS shapefile submitted with this Plan by TFT.

(C) Description of how the measurement method is implemented to meet the requirements of this chapter.

Provided in Attachments C and D.

(D) Documentation required under subdivision (f) of this section verifying the accuracy of the measurement method.

The Plan will be certified by a licensed California Professional Engineer, Dr. Stephen McCord, PE, supported by analyses provided in Attachment G.

(E) Description of the permits, licenses, registrations, certificates and water right claims covered by the measurement method including for each individual right: file number, owner name, water right type, priority of diversion, monthly and annual diversion amounts, place of use, purpose of use, and alternative sources of water.

Provided in Attachments A and B.

(F) Description of how the measurement method will account for each priority of right during periods of insufficient supply.

The measurement method distinguishes rights by priority, in this case Riparian, Pre-1914 (date) and License; and, within license, North Delta Water Contract holders. In the case of curtailment, the method reflects the degree or extent of water use subject to those rights to supply.

In the case that the Measurement Method is found incomplete, does not meet a specified standard or subject to an adverse determination by the deputy director, an association of Delta Diverters, in partnership with the Freshwater Trust (TFT), propose to submit an alternative compliance plan (ACP) consistent with §935 (and in the relevant text substituting "MM" with alternate method or "AM")[(a) noted above]:

(b) Minimum Standards—an alternative compliance plan under subdivision (a) shall meet the following minimum standards:

(1) The plan shall include the following information:

(A) The name and contact information for all diverters covered by the plan; provided in the form of an Excel spreadsheet;

See Attachment A.

(B) The name and contact information for the person designated to represent all diverters covered by the plan in matters before the board;

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(C) Identification of each individual water right type and priority covered by the plan; provided in the form of an Excel spreadsheet.

See Attachment A.

(D) A detailed description of the area served by the plan, including all points of diversion whether used or not used, all methods of diversion, any conveyance systems, all beneficial uses of water, and all acreage served; provided in the form of an Excel spreadsheet.

See Attachments A and B (Figure 1), as well as the GIS shapefile submitted with this Plan by TFT.

(E) The assessor's parcel numbers and ownership within the area covered by the plan; provided in the form of an Excel spreadsheet, associated figures and a GIS reference;

See Attachments A and B, as well as the GIS shapefile submitted with this Plan by TFT.

(F) Identification of the proposed measurement frequency;

Provided in Attachment C.

(G) Identification of the proposed measurement methodology;

Provided in Attachment C.

(H) Topographic map(s) or aerial photograph(s) of the area covered by the plan that show the separate places of use authorized to be served by claimed water rights covered by the plan and showing the acreage served;

See Attachment B, as well as the GIS shapefile submitted with this Plan by TFT.

(I) An implementation schedule, including date-specific, objective milestones of plan implementation from date of filing through final implementation, including the estimated milestones for acquiring permits required for plan implementation and the estimated milestones for compliance with the California Environmental Quality Act, if required;

Provided in Attachment D.

CEQA: *No impacts to the physical environment will occur nor any known direct or indirect environmental impacts, (e.g., new diversions will be installed, as the MM is applied scientific research for the purpose of understanding water use and diversion, and all permanent physical infrastructure is already emplaced, or will be placed by operators in their normal course of operation.) Therefore, no California Environmental Quality Act (CEQA) analysis or review is required, as there are no known direct or indirect environmental impacts, and there are no discretionary permits required.*

(J) Budget for implementation of the plan and the source(s) of financing for the plan;

Provided in Attachment E.

(K) A list of any permits required for plan implementation, the agencies that will issue the permits, and expected dates for issuance;

None are identified at this time.

(L) An affirmation, signed by all diverters covered by the plan, that the plan will be implemented in accordance with the schedule contained therein and that all claimed water rights covered by the plan will not be exercised outside the scope of the plan;

Provided in Attachment F.

(2) The plan shall include an explanation and substantiating documentation of alternative compliance for each of the requirements of sections 933 and 934 of this title. Absent substantiation of the specific basis for reduced performance standards, the plan shall state how compliance with sections 933 and 934 of this title will be achieved.

The program will use a mix of standard approaches described in §933 & 934, as well as modified standards. As described above, this Plan will specifically quantify water use through the approaches used to demonstrate compliance. Those approaches will be developed by subregion, crop, and measurement or assessment method. Provided in Attachment C and discussed in the Basis for Alternative Compliance.

(3) The plan shall provide detailed documentation establishing and supporting the specific basis for claiming that strict compliance with §933 and 934 of this title is not feasible, would be unreasonably expensive, would unreasonably affect public trust uses, or would result in the waste or unreasonable use of water. Any claim that strict compliance is unreasonably expensive shall be accompanied by a cost analysis.

The program will identify each of the appropriate bases for this determination on the same master spreadsheet so that the Board can assess all of the specifics of diversion (location [lat/lon-APN], applicable right), by diverter, diversion method, measurement or calculation method, measurement frequency, instrument calibration, and any/each claims for compliance basis.

(4) The plan shall include a certification by a qualified individual that the plan is in compliance with this chapter.

The Plan will be certified by a licensed California Professional Engineer, Dr. Stephen McCord, PE.

(c) Filing of Alternative Compliance Plan

(1) The alternative compliance plan shall be filed no later than the compliance deadline applicable to the diverter(s)' claim(s) of right under subdivisions (b) and (c) of §932 of this title.

The Plan will track the strictest of the compliance schedules for the applicable claims. All schedules will be provided in Attachment D.

(2) The alternative compliance plan shall be filed electronically on a form available on the board's website.

The Plan will be submitted electronically once approved by the SWRCB.

(3) The alternative compliance plan shall be filed under penalty of perjury.

The Plan will be filed under penalty of perjury.

(d) Diverters under an alternative compliance plan shall report on plan implementation. Documentation of compliance with the timelines and other elements of the alternative compliance plan shall be filed with the applicable annual report under chapter 2.7 of this title.

The Diverters will report on the appropriate timeline as a contractual obligation of their participation with TFT's Plan, as well as under their particular legal obligations.

(e) All plans submitted in accordance with the provisions of this section shall be timely implemented in accordance with the schedule contained therein.

See above.

ATTACHMENT A: PARTICIPANTS

Spreadsheet following Watermaster's direction. Includes the name and contact information for all diverters, each individual water right type and priority, all points of diversion whether used or not used, all methods of diversion, any conveyance systems, all beneficial uses of water, all acreage served, and assessor's parcel numbers and ownership.

Provided as a PDF with each updated version of this Plan. Current file version is titled: *AttachmentA_WaterRights_December2018.pdf*

ATTACHMENT B: MAPS AND FIGURES

Diversion locations associated with Plan participants (according to the California Electronic Water Rights Information Management System). The assessor's parcel numbers (APN) covered by the Plan. (APNs—as well as which Points of Diversion [PODs] are control points—can be viewed on the interactive version of this map, https://freshwatertrust.maps.arcgis.com/apps/webappviewer/index.html?id=bc3618492b1d450aa9ff7df5dc11729c.)

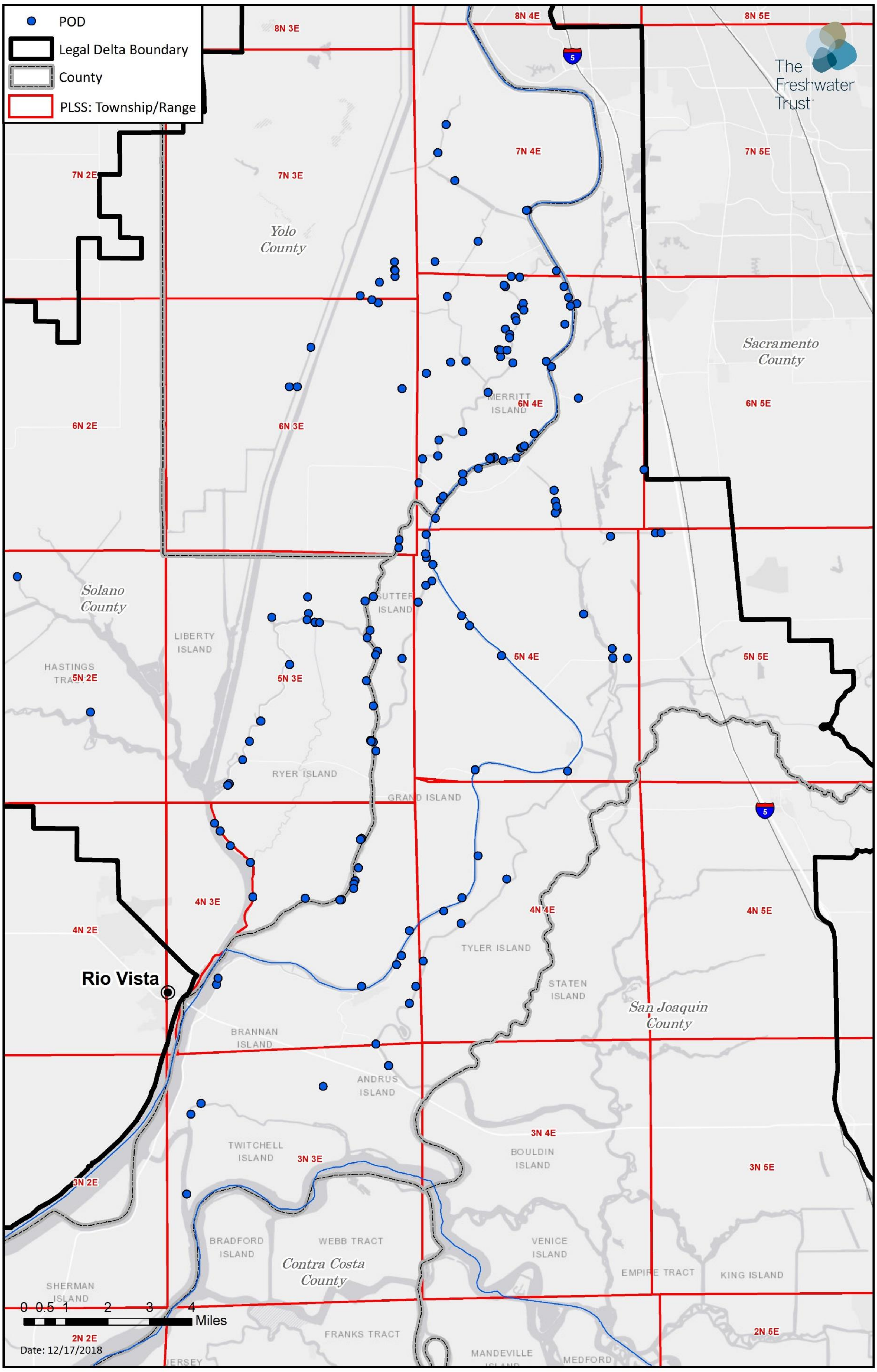

Figure 1. Points of diversion (POD) associated with the Plan

ATTACHMENT C: PROPOSED MEASUREMENT FREQUENCY AND METHOD

The Plan consists of the application of measurement methods (MMs), which requires remote data collection at the agricultural field level, estimation of consumptive water use, and submittal of monthly surface water diversion estimates for each of the participating diversions to the SWRCB annually (as required by SB-88). In order to assess and effectively refine the MMs, a series of scientific studies will be designed and executed by TFT during the Plan development period. Progress will be reported to the SWRCB through an annual summary of findings, as well as a final report. The Plan consists of the four parts described broadly below. Technical reports of the detailed methods and validation of the models are included as Attachment G.

(1) Collect, aggregate, and process data to facilitate the automation, refinement, and comparison of water use estimates. Consumptive use calculations require spatially explicit (field-level) data for crop types, planting and harvesting dates, agricultural plant growth curves, and local daily precipitation and reference ET values. Summing field-level consumptive use estimates to water right application or statement-level estimates for SB-88 reporting necessitates fine scale understanding of the relationships between each water right, point of diversion, and point of use. Measured water use data, as well as additional data describing field-specific water conveyance features, irrigation practices, and other farm operation and environmental factors, contribute to the refinement of water use estimates beyond consumptive use calculations. A large-scale effort is required to collect, process, and ensure the accuracy of these data sets from MM participants, project partners, and government agencies. To produce annual reports of monthly water use by water right, the frequency of data collection varies among daily weather data downloads, annual participant crop and irrigation surveys, and remotely sensed data updates.

(2) Automate consumptive use calculations (Irrigation Training and Research Center [ITRC] R 03-001, or equivalent newer methods, and the primary method, Consumptive Use Program [CUP+] Metric Version 6.5). For daily, field-level ET calculations to be automated for each participant field, and then aggregated to the water right application or statement level for reporting, a complex database structure is needed to securely store the data described above, and facilitate the scripted modeling and reporting of consumptive use. The ITRC and CUP+ models are currently in web or Microsoft Excel forms, but TFT has extracted the equations and dependencies from these models in their current form. Scripts were written that communicate with the database and run the same procedures as these models to calculate daily, field-level ET automatically, aggregating these estimations by month and application/statement number as an output. As the method is developed further, data validation and data quality assurance results will be reported in outputs and indicated in the database as QA codes. Examples of this include: flags when weather data is not available and data from an alternative station must be used; a crop correctness code characterizing the degree of similarity between participant-reported crops and remotely sensed crop data; and a QA code describing TFT's confidence in the relationship between points of diversion and points of use.

(3) Refine water use model estimates using additional factors. Machine learning and neural networks applied to frequently collected satellite imagery and other remotely sensed data are enabling highly accurate, field-level predictions of conveyance networks, irrigation methods, irrigation intensity, soil saturation, field flooding intensity and frequency, and inter- and intra-annual cropping practices. These field operations, infrastructure, and practices data are being acquired by TFT for the area covered by the Plan both directly from Plan participants and through project partners. These data are not required as inputs to consumptive use models; however, through statistical analyses, they can be used to account for differences, where they exist, between the consumptive use model results and measured water use. For example, the distance between a surface water diversion and its point of use may be related to carriage loss factors, or flood irrigation may result in more water use than sprinklers irrigating the same crop over the same area. These variables can be included in models to refine and calibrate estimations of water use. Once all data sets are aggregated and ET estimates have been automated, TFT will conduct analyses between MMs. These analyses will result in accuracy metrics that will be included in summary reports (e.g., model chi-squared values for goodness-of-fit).

(4) Compare a sub-sample of field and modeled water use data for the same irrigated field or crop type class using tabular estimation methods, consumptive use models, and findings from other similar studies in the Delta. The data collection, data storage, and automated modeling employed under this Plan will allow for robust comparison among consumptive use estimates. The Office of the Delta Watermaster has been facilitating advanced consumptive use analyses, including the Comparative Study for Estimating Crop Evapotranspiration in the Delta, which will support improvements to the crop water use estimation, irrigation application technology, and conveyance information to the Plan.[19] This approach provides an additional comparisons among methods, provides additional validation and calibration of the methods used, allows for finer scale calibration, and provides the statistical support for the CUP+ and METRIC models.[20, 21]

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[19] https://www.waterboards.ca.gov/water_issues/programs/delta_watermaster/crop_c_u_study.html

[20] J. MEDELLIN-AZUARA & R.E. HOWITT, COMPARING CONSUMPTIVE AGRICULTURAL WATER USE IN THE SACRAMENTO-SAN JOAQUIN DELTA (Sept. 2013), https://watershed.ucdavis.edu/files/biblio/DPC_ComparativeStudy_ET_Final_Report_UCD.pdf.

[21] DELTA PROT. COMM'N., PUBLIC NOTICE & MEETING AGENDA, ITEM 7(B): COMPARING CROP WATER CONSUMPTIVE USE IN THE SACRAMENTO SAN JOAQUIN DELTA: PROOF OF CONCEPT (Nov. 20, 2013), delta.ca.gov/commission/meetings/meeting_archives/meetings_11-20-13/.

Measurement Methodology

Goal: Develop an accurate picture of agricultural water diversion and use in the Delta using a statistical comparison of the previously described MMs, refining the method's accuracy iteratively based on improved understanding of water use and conveyance, emerging data sets, and scientific experimentation. Demonstrate that the MM meets or improves upon the accuracy criteria for diversion measurements established by the State Water Resources Control Board in the regulations implementing Senate Bill 88.

MM Approach: The Plan will use remotely sensed data, Plan participant-supplied farm management data, and ET modeling to estimate water diversion volumes and timing for each Plan participant.

The following steps constitute the Measurement Method to be used under this Plan. Technical reports of the detailed methods and validation of the models are included as Attachment G.

1. Secure control sites

   The control sites are locations within the Delta that have available remote sensing data, such as satellite, drone, and other data, characteristic of the crops, cropping patterns, and irrigation practices that will be assessed with multiple MMs. The locations are identified on Attachment B, Figure 1.

   - Multiple control sites are necessary in order to capture and validate remote sensed variability in crops grown and irrigation methods employed throughout the area covered by the Plan.
   - The control sites do not necessarily need to be participating in the Plan.
   - Purposes of the control sites:
     - The Plan relies on remote sensing and modeling to estimate water use for each participating surface water diversion.
     - To provide comparative information regarding the volume and timing of diverted surface water.
   - Field data requirements:
     - Cropping practices, including crop type, age, planting date, harvest date, irrigation method, irrigation frequency, irrigation start date, irrigation end date, acreage, and yield, collected on a monthly basis.
     - Weather and soils data from publicly available sources, such as Spatial CIMIS and USGS, respectively.
2. Analyze geospatial data
   - Using available LiDAR data, delineate drainage patterns within the Plan area to determine the portion of the field where runoff is likely to leave the field (typically the lowest elevation point on the field).
   - If available, review photography (orthoimagery), LiDAR drainage patterns, and additional infrastructure data to delineate the irrigation systems within the Plan area. Delineating the irrigation systems will allow TFT to understand the delivery and movement of water from each surface water diversion.

3. Calculate consumptive use
    - For each field served by a surface water diversion, reported agricultural practices (including crop type, planting date, harvest date, irrigation frequency, irrigation start date, irrigation end date, acreage, cover cropping, and soils data) will be used to complete the estimation for each field.
    - Using the reported agricultural information, meteorological data, and the available ET models, the agricultural consumptive use for each field will be calculated. Calculation results will be available by month.
    - In the event that insufficient or incomplete information regarding the agricultural practices on a field is available, remotely sensed crop data and county agronomic data will be used to complete the modeling.
    - ET calculations will be completed to determine the consumptive water use for each agricultural field for each month in the calendar year.
    - These analyses will support and be informed by the Delta Watermaster's ongoing Comparative Study for Estimating Crop Evapotranspiration in the Delta.
4. Estimate diverted water volumes
    - To facilitate reporting, the modeled consumptive use for each field served by a water right will be summed to determine the total estimated consumptive use for the aggregate sum of the fields receiving the diverted surface water. Following the Delta Watermaster's approach, consolidation of reporting will be used where applicable with the consent of the reporters.
    - Based on the analysis of water use in areas served by the control sites, carriage water or the additional water necessary to facilitate the delivery of irrigation water[22], as well as the varying efficiencies in the irrigation systems and irrigation practices, will be calculated for each diversion. This additional water is not captured through the ET modeling.
    - For each Plan participant, the total monthly diversion calculation will be reported.
5. Compare ET model results
    - Run two ET models (CUP+ and METRIC) for each agricultural field. Compare the consumptive use results for each field and across all fields in the area covered by the Plan to determine whether there are consistent trends that results from each model.
    - Compare results of the ET models. The comparison of models provides additional information regarding the precision of the models.

[22] Carriage water is needed for the transit of water from the diversion to the field, or from the drainage from one field to another. This water is typically consumptively lost to shallow groundwater, evaporation, or to weeds along the ditches (if not piped). That approach is typical to convey water from the diversion to the field, and in the case or sprinklers and drip irrigation are the main losses. However, carriage water serves to provide field drainage for flood irrigation to ensure the entire field is covered and that sufficient water exists to support the next field(s) downgradient in the irrigation system.

ATTACHMENT D: IMPLEMENTATION SCHEDULE

The implementation schedule—including date-specific, objective milestones of Plan implementation from date of filing through final implementation, as well as the estimated milestones for acquiring permits required for Plan implementation.

The start date of the Plan is January 1, 2017. The MMs will be developed, tested, and rolled out iteratively to ensure consistent and accurate reporting and to adapt using the latest information and technologies.

2017-2019: Coordinate with each of the Water Agencies and/or Reclamation Districts (RD) to enroll water rights claimants in this Plan. The specific water users participating in the Plan are identified by their Statement of Diversion and Use or License number and location.

2017 (Year 1): Collect agricultural field-level data from participants, project partners, and publicly available sources for inputs into consumptive use models (e.g., CUP+) and additional water use calculation refinement. Research calculations and procedures employed by these models to inform automation and database design. Design and build database to store collected data and facilitate automated ET calculations and reporting. Understand SB-88 water use reporting needs and methods through discussions with SWRCB and the Delta Watermaster; establish method control locations; establish partnerships or agreements with Consortium participants.

2018-2019 (Years 2-3): Automate consumptive use models, including data validation and quality assurance calculations. Collect and aggregate control-site water use data. Regionally within the Delta, compare model outputs to control site data and among the multiple consumptive use models. Refine water use estimates beyond consumptive use with participant-supplied or remotely sensed data on field-specific irrigation, cropping, and conveyance practices. Annually report monthly water use and other required data to SWRCB.

EOY 2019 (Year 3): Summary and synthesis of results from years 1-3 will be provided in a white paper submitted to the Delta Watermaster.

2020-21 (Years 4-5): Reporting will continue and an assessment will be made of next steps of the program, including submittal formally as a MM in coordination with Delta Watermaster staff as appropriate.

ATTACHMENT E: BUDGET

Budget for implementation of the Plan and the source(s) of financing for the Plan.

<u>Estimated Program Costs</u>

Program Development and Administration

$15,000 (ongoing, annual)

Plan Development

$20,000 (ongoing, annual)

Annual Analysis and Reporting

$90,000 (ongoing, until 2020)

Final Program Analysis Report

$20,000 (in 2021)

<u>Estimated Annual Revenue</u>

Estimated Annual Participation Fee

160 water rights at $775/year fee* = $124,000

*tiered discounted fees provided to participants enrolling more than five diversions and no fee charged for enrolled control points.

The program is funded through the participant contributions. The program budget is based on the estimated costs to develop and implement a program that uses an intensive geospatial analytical framework and a complex database structure.

ATTACHMENT F: AFFIRMATION

An affirmation, signed by all diverters covered by the Plan, that the Plan will be implemented in accordance with the schedule contained therein, and that all claimed water rights covered by the Plan will not be exercised outside the scope of the Plan.

See below contract for participation in the Plan.

California Water Code § 1840 – Senate Bill 88
Alternative Measurement Method and Alternative Compliance Plan

Landowner Participation Agreement (2018 Version)

THIS AGREEMENT ("Agreement") is made this ______ day of ____________________ 2018, between ____________________________ ("Landowner") and The Freshwater Trust ("TFT"), a non-profit corporation.

1. Measurement Method & Alternative Compliance Plan.

Landowner is the owner of real property with a place of water diversion(s) at the following location. Landowner wishes to participate in the development of TFT's Measurement Method and Alternative Compliance Plan ("Plan"), attached as Exhibit A, in lieu of Landowner's obligation to measure annual individual water rights water use that meets or exceeds 10 acre-feet per year. Each covered diversion will be reflected in a statement and or license number provided below.

Statement Number 1: _______________________________

Associated Point of Use
Assessor Parcel Number(s): _______________________________

Password/Reporting Identifier: _______________________________

Statement Number 2: _______________________________

Associated Point of Use
Assessor Parcel Number(s): _______________________________

Password/Reporting Identifier: _______________________________

For additional statement numbers, please include attachments at the end of this Agreement.

License Number (if applicable): _______________________________

2. Term and Termination.

2.1. This Agreement is effective as of the date last signed by the parties ("Effective Date"), and unless mutually earlier terminated by the parties in writing, shall expire on December 31, 2021.

2.2. This Agreement may be terminated by either party without cause upon thirty (30) days' prior written notice to the other party. In the event of termination by Landowner, Landowner will pay TFT for the portion of the Annual Per-Diversion Fee (as defined in Section 3) earned up and until the date of termination.

3. Annual Per-Diversion Fee.

3.1. Landowner agrees to pay TFT an annual payment of $775.00 per diversion ("Annual Per-Diversion Fee"). In exchange for this Annual Per-Diversion Fee, TFT will provide the Landowner's required annual surface water diversion reporting to the State Water Resources Control Board as required by California Water Code § 1840.

3.2. Landowner will pay the Annual Per-Diversion Fee to TFT within thirty (30) days of execution of this Agreement via online payment or check. Pay online at https://www.thefreshwatertrust.org/getinvolved/process-payment-sb88/. Check shall be sent to: The Freshwater Trust, Attn: Heather Jones, 700 SW Taylor Street, Suite 200, Portland, OR 97205. TFT shall have no obligation to provide reporting for Landowner under this Agreement until payment is received. Each year thereafter, the Annual Per-Diversion Fee shall be due to TFT on or before the first of the year.

4. Diversion Information.

4.1. Landowner must provide TFT with the information required in the attached Exhibit B. Using the submitted information, TFT will use remotely sensed data and modeling to characterize water use within the Delta in order to report calculated water diversion at each participating surface water diversion on Landowner's behalf. At Landowner's option, TFT will also submit Landowner's annual Statement of Water Diversion and Use. If applicable, Landowner shall complete, sign, and scan or fax a copy of the applicable Initial Statement or Supplemental Statement form to TFT for inclusion in annual reporting. Exhibit B and other forms can be emailed to TFT at sb88@thefreshwatertrust.org.

4.2. In the event that the Measurement Methodology and a subsequent Alternative Compliance Plan is rejected by the relevant staff of the State Water Resources Control Board, or is otherwise determined to be inadequate to satisfy the applicable legal requirements at any time during the term of this Agreement, TFT will notify Landowner within five (5) business days.

4.3. Landowner represents and warrants to TFT that the information provided to TFT at all times during this Agreement will be true and correct to the best of Landowner's knowledge. Landowner acknowledges and agrees that should s/he misrepresent or otherwise provides inaccurate information to TFT, that TFT assumes no responsibility or liability for Landowner's inaccurate information. Landowner agrees to indemnify TFT, without limitation, against any and all claims, costs, or damages resulting from such inaccurate misrepresentations.

4.4. Landowner will provide monthly water use, method and period of irrigation, crop type, acres per crop, and associated information in the attached Exhibit C to the following TFT website: http://www.thefreshwatertrust.org/sb-88-monthly-reporting.

4.5. Landowner must provide all of the information identified in this Agreement. Failure to provide complete information will result in additional TFT staff research time that is otherwise not included within the cost of the Annual Per-Diversion Fee. TFT will notify Landowner of incomplete information and provide Landowner with an opportunity to respond with the omitted information. In the event that Landowner fails to supply complete information within seven (7) business days of TFT's notice, Landowner acknowledges and agrees that TFT will invoice Landowner on an hourly basis at a rate of $80.00 per hour for staff time and resources spent pursuing incomplete information. Landowner shall pay any such additional costs within 30 days of receiving TFT's invoice.

5. Miscellaneous.

5.1. This Agreement constitutes the entire agreement between the parties and supersedes all oral or written prior or contemporaneous communications and proposals of every kind on the subject. No course of dealing between the parties and no usage of trade shall be relevant to supplement any term used in this Agreement. This Agreement shall be binding upon the parties and their respective heirs, successors, and assigns.

5.2. This Agreement may be executed by facsimile and in multiple counterparts, each of which shall constitute an original and all of which together shall constitute one Agreement. The terms of this Agreement may not be waived, altered, modified, supplemented or amended in any manner except by mutual written agreement by the parties.

5.3. If any provisions contained in this Agreement are held illegal, invalid or unenforceable, the remaining provisions are to survive and remain in full force and effect.

5.4. All notices related to this Agreement shall be sent either electronically via email or physically via registered or certified mail, postage pre-paid, to the addresses provided below:

Landowner Mailing Address:

____

____

____

The Freshwater Trust:

Attn: SB88 Alternative Compliance Plan

700 SW Taylor St., Ste. 200

Portland, OR 97205

Landowner or Authorized Representative Contact Information:

Primary Phone: _____________________________

Secondary Phone: ___________________________

Email: _____________________________________

6. Signatures.

Landowner (or Authorized Representative):

____

Name

____

Title

____

Date

The Freshwater Trust, an Oregon non-profit corporation

____

Name

____

Title

____

Date

Additional statement numbers, if applicable:

Statement Number 3: ___________________________________

Associated Point of Use APN(s): ___________________________________

Password/Reporting Identifier: ___________________________________

Statement Number 4: ___________________________________

Associated Point of Use APN(s): ___________________________________

Password/Reporting Identifier: ___________________________________

Statement Number 5: ___________________________________

Associated Point of Use APN(s): ___________________________________

Password/Reporting Identifier: ___________________________________

Statement Number 6: ___________________________________

Associated Point of Use APN(s): ___________________________________

Password/Reporting Identifier: ___________________________________

Statement Number 7: ___________________________________

Associated Point of Use APN(s): ___________________________________

Password/Reporting Identifier: ___________________________________

Statement Number 8: ___________________________________

Associated Point of Use APN(s): ___________________________________

Password/Reporting Identifier: ___________________________________

Statement Number 9: ___________________________________

Associated Point of Use APN(s): ___________________________________

Password/Reporting Identifier: ___________________________________

Exhibit A – SB-88 Measurement Method for Measuring and Reporting on the Diversion of Water in the Sacramento-San Joaquin Delta

See Plan at https://www.thefreshwatertrust.org/sb-88-alternative-compliance-plan/.

Exhibit B – Annual Reporting Information: One per Diversion (2018 Version)

Email to sb88@thefreshwatertrust.org. Please provide information about the surface water diversion(s) the water right claim is associated with here.

SWRCB Statement Number(s) for this water right claim:____________________________________

SWRCB License Number for claim(s) (if applicable): _______________________________________

Located in Reclamation District No.: ____

Type(s) of Water Right claimed (check all that apply):

☐ Riparian ☐ License ☐ Pre- 1914 ☐ Other (explain): ______________________________

Method of Diversion and measurement:

☐ Staff gauge ☐ Ditch gate

☐ Metered siphon ☐ Unmetered siphon

☐ Metered pump ☐ Unmetered pump

☐ Other (describe): ____

Is there a meter at the point of diversion? ☐ Yes ☐ No

Model type: ____

Can it log data digitally or does it have a counter? ____

If no meter is used, how are volume and rate estimated?

____

Is power available at the point of diversion? ☐ Yes ☐ No

Type: _____________________________ Volts: ____

Is the point of diversion shared with other users? ☐ Yes ☐ No

If yes, please list other user name(s) and S0 number (if known) below:

Name: ____

SWRCB Statement Number: ________________________

Exhibit C – Point of Use Crop and Irrigation Information (2018 Version)

Submit online at http://www.thefreshwatertrust.org/sb-88-monthly-reporting/ or email to sb88@thefreshwatertrust.org.

SWRCB Statement/License Number for this water right claim:

____

Alternative name or nickname used for the diversion, if applicable:

____

Contact Name: ____

Email: _________________________________ Phone: _______________________

Beginning with the start of the most recent calendar year (January), use the table(s) below to indicate the crop rotation and schedule for each field irrigated using the above water right claim, including cover crops. Estimate irrigation start and end dates as best as possible.

FIELD 1

Assessor's Parcel Number (if known):					
Orchard? ☐ Yes ☐ No			Vineyard? ☐ Yes ☐ No		
Describe crops, including cover crops, below:					
Crop 1	Acres	Irrigation Method *(drip, furrow, sprinkler)*	Irrigation Frequency	Irrigation Start Date	Irrigation End Date
Crop 2	Acres	Irrigation Method *(drip, furrow, sprinkler)*	Irrigation Frequency	Irrigation Start Date	Irrigation End Date
Crop 3	Acres	Irrigation Method *(drip, furrow, sprinkler)*	Irrigation Frequency	Irrigation Start Date	Irrigation End Date
Crop 4	Acres	Irrigation Method *(drip, furrow, sprinkler)*	Irrigation Frequency	Irrigation Start Date	Irrigation End Date
Notes:					

(continued)

FIELD 2

Assessor's Parcel Number (if known):					
Orchard? ☐ Yes ☐ No			Vineyard? ☐ Yes ☐ No		
Describe crops, including cover crops, below:					
Crop 1	Acres	Irrigation Method *(drip, furrow, sprinkler)*	Irrigation Frequency	Irrigation Start Date	Irrigation End Date
Crop 2	Acres	Irrigation Method *(drip, furrow, sprinkler)*	Irrigation Frequency	Irrigation Start Date	Irrigation End Date
Crop 3	Acres	Irrigation Method *(drip, furrow, sprinkler)*	Irrigation Frequency	Irrigation Start Date	Irrigation End Date
Crop 4	Acres	Irrigation Method *(drip, furrow, sprinkler)*	Irrigation Frequency	Irrigation Start Date	Irrigation End Date
Notes:					

FIELD 3

Assessor's Parcel Number (if known):					
Orchard? ☐ Yes ☐ No			Vineyard? ☐ Yes ☐ No		
Describe crops, including cover crops, below:					
Crop 1	Acres	Irrigation Method *(drip, furrow, sprinkler)*	Irrigation Frequency	Irrigation Start Date	Irrigation End Date
Crop 2	Acres	Irrigation Method *(drip, furrow, sprinkler)*	Irrigation Frequency	Irrigation Start Date	Irrigation End Date
Crop 3	Acres	Irrigation Method *(drip, furrow, sprinkler)*	Irrigation Frequency	Irrigation Start Date	Irrigation End Date
Crop 4	Acres	Irrigation Method *(drip, furrow, sprinkler)*	Irrigation Frequency	Irrigation Start Date	Irrigation End Date
Notes:					

(continued)

FIELD 4

<table>
<tr><td colspan="6">Assessor’s Parcel Number (if known):</td></tr>
<tr><td colspan="3">Orchard? ☐ Yes ☐ No</td><td colspan="3">Vineyard? ☐ Yes ☐ No</td></tr>
<tr><td colspan="6">Describe crops, including cover crops, below:</td></tr>
<tr><td>Crop 1</td><td>Acres</td><td>Irrigation Method
(drip, furrow, sprinkler)</td><td>Irrigation Frequency</td><td>Irrigation Start Date</td><td>Irrigation End Date</td></tr>
<tr><td>Crop 2</td><td>Acres</td><td>Irrigation Method
(drip, furrow, sprinkler)</td><td>Irrigation Frequency</td><td>Irrigation Start Date</td><td>Irrigation End Date</td></tr>
<tr><td>Crop 3</td><td>Acres</td><td>Irrigation Method
(drip, furrow, sprinkler)</td><td>Irrigation Frequency</td><td>Irrigation Start Date</td><td>Irrigation End Date</td></tr>
<tr><td>Crop 4</td><td>Acres</td><td>Irrigation Method
(drip, furrow, sprinkler)</td><td>Irrigation Frequency</td><td>Irrigation Start Date</td><td>Irrigation End Date</td></tr>
<tr><td colspan="6">Notes:</td></tr>
</table>

Please attach an aerial map/photograph (e.g., USDA crop map, Google Earth image, or drawn) of the area served by the claimed water right, showing the diversion location. Please indicate on the map your fields and crops so we can further understand your farming operations.

ATTACHMENT G: TECHNICAL APPENDICES 1 & 2

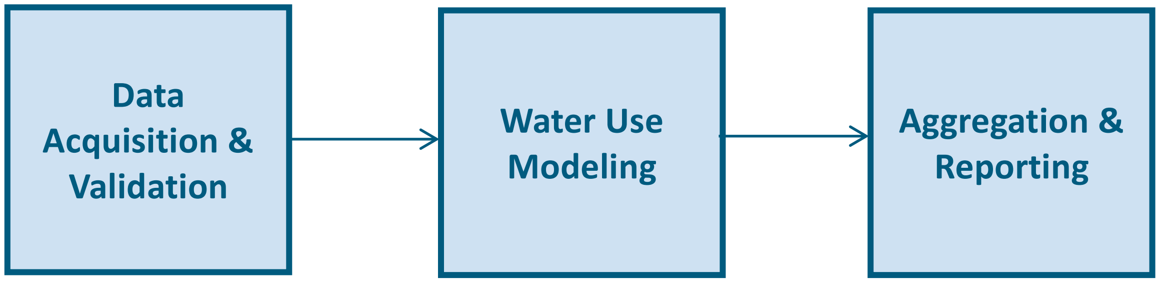
TECHNICAL APPENDIX 1: MEASUREMENT AND REPORTING METHODOLOGY

INTRODUCTION

The Freshwater Trust (TFT) has developed a proposed method for the remote measurement and subsequent reporting of surface water diverted in the Delta for agricultural and other beneficial uses. This proposed measurement method (MM), developed through TFT's SB-88 Measurement Method and Alternative Compliance Plan (ACP), uses remotely sensed data, consumptive water use modeling, and additional analytics to fulfill SB-88 reporting requirements for the California State Water Resources Control Board (SWRCB). The validation of the measurement and reporting methods are documented in Technical Appendix 2: Measurement Method Comparison and Validation. This document describes the analytic approach for the MM, including the three primary workflow steps (Figure 1) of:

(1) acquiring, processing, and validating the data needed for water use estimation;
(2) estimating water use at the agricultural field level, through consumptive use modeling and additional water use calculations; and,
(3) aggregating and/or allocating field-level water use estimations to individual diversions.

The purpose of this document is to give an overview of the data flow, data sources, scientific methods, and assumptions made throughout this process. This technical appendix will be updated annually to reflect the current state of the MM that TFT is using in order to fulfill SB-88 reporting requirements for the program participants. The MM will be updated as improvements are made through automation, quality assurance, and improvement of model accuracy through comparison of MMs. The MM-ACP development process began in 2017 and will be completed no later than the end of 2021. Adding significant detail of the MM below (including figures) is planned for 2019; this first draft provides an overview of the process developed throughout 2017 and 2018.



- GIS field delineation
- Field characteristics: size, soils, location (to identify appropriate CIMIS data), etc.
- Participant reported crops, POD-POU associations, etc.
- CIMIS station (precip.) and Spatial CIMIS (ET_o) data

- Run CUP+ model for each field to get crop evapotranspiration (ET_c) and evapotranspiration of applied water (ET_{aw})
- Incorporate irrigation efficiency and additional water use factors

- ET_{aw} aggregated from field to APN
- ET_{aw} allocated to water rights, with time and quantity restrictions where applicable
- Reports generated

Figure 1. Overview of the workflow, data inputs, and data outputs for TFT's measurement and reporting method.

DATA ACQUISITION & VALIDATION

To facilitate the subsequent steps of water use modeling and allocation of modeled water among water diversions and associated rights for reporting, data are acquired and processed as described below. These data are stored in TFT's "SB88_Db"and "CimisWx", MySql compliant relational databases intended to support the data collection, quality assurance, storage, and analysis for the MM.

CIMIS Weather Data

The California Irrigation Management Information System (CIMIS)[23] is a program within the California Department of Water Resources (DWR). CIMIS is an integrated network of over 145 automated weather stations throughout California. The MM requires daily precipitation and reference crop evapotranspiration data (ET_O), each of which is provided in a different format by CIMIS, described below. CIMIS data are updated by DWR daily, and new data automatically populate the TFT CimisWx database each day.

Hourly precipitation (in inches) is provided for each weather station location. TFT interpolates rainfall for each agricultural field using an inverse distance weighted average of data from the three nearest reporting stations to each field for the total precipitation each day. The spatial centroid of each field is used to determine the three nearest stations and the distance to them. Using an inverse weighted average is a scientifically accepted approach that avoids extreme values that may otherwise be observed by simply taking data from a single nearby station, yet preserves the influence of distance-from-measure overall. The equation is as follows:

[23] https://cimis.water.ca.gov

Equation 1. Inverse distance weighted average used to extrapolate field specific precipitation from weather station data.

$$\hat{P} = \sum \frac{\frac{1}{d_i}}{\sum 1/d_i} * p_i$$

P-hat is the estimated precipitation at the location.
d_i is the distance from the location to reporting station ***i***.
p_i is the observed precipitation at station ***i***.

ET_o is the rate of evapotranspiration from a reference surface, usually a hypothetical grass, that is used to calculate estimated crop evapotranspiration (ET_c) as a function of the growth-stage specific crop coefficient (K_c). Daily ET_o (in mm) is provided through Spatial CIMIS, a raster grid of two-kilometer resolution for which ET_o is calculated through interpolation of temperature, humidity, and other data from nearby CIMIS stations using the American Society of Civil Engineers version of the Penman-Monteith equation (ASCE-PM). Solar radiation data required for the ASCE-PM is acquired by CIMIS through NOAA's Heliosat-II model. The two-kilometer raster that a field's centroid falls within is the raster used for ET_o for that field.

Participant-Reported Water Right and Agricultural Management Data

Participants enrolled in TFT's SB-88 MM-ACP are required to provide TFT with contact information, as well as detailed information about their water rights and the cropping, planting, harvest, irrigation, and other management practices on each of their agricultural fields. The following information is required prior to being entered in the program, and any changes are required to be reported annually.

Contact Information

- First Name
- Last (or Corporate) Name
- Address1
- Email1
- Phone Number1
- Customer Relationship Management ID number
- Stakeholder Type: Up to four different values can be stored

Water Right and/or Diversion Information

- Water right ID (WRID)
- Water right type
- Assessor's Parcel Number(s) (APN)
- Reclamation district
- Diversion method
- Meter model
- Log or counter type
- Power availability and type

Agricultural Management Information

- Crop Season (Primary, secondary, tertiary)
- Crop type or rotation
- Irrigation method/type (e.g., flood, sprinkler, or drip)
- Acreage (acreage of each field associated with each crop type)
- Irrigation start and end dates
- Planting and/or harvest dates

Water Rights

SWRCB's Electronic Water Rights Information Management System (eWRIMS) is a database that stores information on water rights permits and licenses, registrations, certificates, and other records. Quality control checks for each diversion were performed by cross-checking eWRIMs location with County APN info: Sacramento County, San Joaquin County, and Yolo County. If the locations did not match or the APN did not exist, TFT staff used available resources to match the appropriate APN with the water right. eWRIMS supplies the water right temporal and spatial restrictions used in the allocation of modeled water use to the appropriate diversion and associated water right(s).

Data Backstops

If the participant did not provide the voluntary field, crop, irrigation, or other information, the following default information is used. This method was also used to provide QA/QC information to assess the quality of reported data.

TFT created a spatial dataset of individual agricultural field polygons (henceforth referred to as fields) by analyzing aerial imagery (National Agriculture Imagery Program, 2016) and digitizing field boundaries in ArcGIS. Field boundaries were delineated based on contiguous crop areas; roads, ditches, canals, and spatially dis-continuity of perceived crop type typically guided digitization. Areas that appeared to have non-agronomic land uses were excluded from field polygons. Resulting fields contain a single crop type (at the time imagery was acquired) and are not intersected by, or inclusive of, any other features, such as houses, irrigation and fertilization structures, barns, roads, canals, etc.

If crop information is not provided, the crop type according to the United States Department of Agriculture's Cropland data layer[24] is used. The majority crop type is used for the field if the dataset shows multiple crops within a field polygon. This spatial data set is updated annually; therefore, the data set for the reporting year is used when needed. The Consumptive Use Program Plus, described below, stores lookup tables for the planting and harvest dates for California crops. These are used in place of participant-supplied planting and harvest dates when necessary. Similarly, irrigation type is assumed based on the crop type when not specified. Lastly, the field acreage associated with the field polygon is used for the field size if it is not specified by the participant.

[24] USDA National Agricultural Statistics Service Cropland Data Layer. Published crop-specific data layer. Available at https://nassgeodata.gmu.edu/CropScape/ USDA-NASS, Washington, DC.

As part of its MM, TFT is researching the relative variance using these datasets, and additional remotely-sensed model inputs, in place of participant-supplied data. If it does not statistically vary significantly, the systematic use of remotely-sensed data could increase automation and reduce reporting burden to water right holders in the future, and allow scaling throughout the State.

Data Validation & Quality Assurance

Quality assurance checks are currently performed manually throughout the MM workflow to ensure model inputs and outputs meet data quality objectives. For example, outliers for field size, crop type, planting and harvest dates, etc. are detected and researched further. Modeled water use values are checked for reasonableness and compared to previous years reporting for each water right before reporting.

In 2019, TFT will be auditing the current MM workflow and any changes to it to find places to automate QA/QC, such as comparisons between remotely-sensed data values and those reported by participants, and database automated flags for modeled values outside of reasonable ranges. However, validation of the overall model to ensure accuracy of water use estimation through TFT's MM is a separate process from QA/QC of specific, routine model inputs and outputs; that process will be documented in Technical Appendix 2.

WATER USE MODELING

"Water use," or the amount of surface water diverted, is currently estimated for each ACP participant's field or fields by modeling ET_{aw} and then applying an irrigation application efficiency factor (IEF) based on the existing irrigation infrastructure. This process is outlined below and will be improved iteratively throughout the program based on data availability and MM validation analyses. Water use is modeled for each field as described by the participants annually, based on the participant-reported field acreages, crops, planting and harvest dates, irrigation methods, and other farm management information.

Consumptive Use Model

TFT has implemented a limited version of the Consumptive Use Program Plus (CUP+ version 6.1), developed by DWR[25, 26]. The original CUP+ model was developed as a Microsoft Excel spreadsheet to "help growers and water agencies determine reference evapotranspiration (ET_o), crop coefficient (K_c) values, and evapotranspiration of applied water (ET_{aw}), which provides an estimate of the net irrigation water diversion needed to produce a crop." TFT continues to refine its implementation of the model through consultation with CUP+ developer Dr. Orang. Future refinement and consultation is planned to better account for soil moisture and other factors. The general order of operations for TFT's current implementation of the model is as follows:

1. A crop coefficient (K_c) curve is constructed for each field to determine the daily K_c. Functions defining the default curves for each crop type or crop series were sourced from CUP+ and are

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[25] Orang, M.N, Snyder, R.L., and J.S. Matyac. 2005. CUP (Consumptive Use Program) Model. DWR and UC Davis. California Water Plan Update 2005.

[26] Orang, M.N, Matyac, J.S., and R. L. Snyder. 2011. CUP+ (Daily Soil Water Balance Program). ICID 21st International Congress on Irrigation and Drainage. 15-23 October 2011. Tehran, Iran.

stored in the SB88_Db. K_c curves are adjusted to incorporate the planting and harvest dates supplied by the participants, using the methods described by Orang et al. (2011).

2. Daily reference ET values (ET_o) are taken from the CimisWx database which holds the information downloaded from the CIMIS 2km spatial data model. The correct ET_o value is determined by a lookup table which associates field centroids with the correct spatial grid. Multiplying the daily ET_o by the daily K_c value provides a daily estimate of the crop demand for water (ET_c).

3. ET_{aw} (evaporation of applied water) is the net amount of applied irrigation water that contributes to ET_c throughout a growing season. ET_{aw} is calculated using a moderating "bare soil" K_c curve to take into account the effective seepage, bare soil evapotranspiration, and rainfall contributions to ET_c. The bare soil K_c curve provides a floor value for overall crop-related evapotranspiration that primarily affects estimated ET_{aw} during the period when annual crops are in early growth stages (germination included). TFT's MM currently uses daily precipitation data to estimate daily bare soil K_c according to the methods specified by Orang et al. (2011) and through consultation with Dr. Orang. This adjustment reflects reduced demand for additional irrigation immediately following significant rain events. The effects of bare soil K_c become less impactful as the crop grows and ET_c increases over the course of the irrigation season. ET_{aw} is otherwise calculated by subtracting the amount of estimated rainfall from the biological crop demand for water (ET_c).

Orang et al. (2011) detail multiple methods for estimating the gross effects of rainfall and/or seepage on the final ET_{aw} value, depending in part on what data is available. In communications between TFT and Dr. Orang, he has advised that in cases where actual rainfall data is available, as it is in the program area of interest, CIMIS precipitation data should be used in preference to other approaches.

TFT's implementation follows the CUP+ model as described in the paper presented at the ICID 21st Congress, in Tehran Iran in October of 2011. The major difference between the TFT implementation and the original CUP+ Excel-based model is based in a lack of soil moisture data. Since TFT does not have any soil moisture data available, it is not currently incorporated into water use modeling. It is assumed that farmers will neither apply so much nor so little water to their fields that plant growth is adversely affected. TFT also assumes that on or about the crop planting date (or alternatively the crop growing season for tree and vine crops), farmers will initiate irrigation if necessary for crop germination or leaf out. TFT is working with Dr. Orang in 2019 to better incorporate field specific soil texture, plant rooting depth, and other factors into its implementation of the model so that soil moisture and seepage are better addressed.

Irrigation Efficiency Factors

Irrigation application efficiency factors (IEFs) were applied based on the identified irrigation systems used on each field, and allow TFT to account for total sum of applied water. Irrigation application efficiency estimates vary between fields, irrigation systems, management decisions, and other factors. Given the lack of data on most factors, estimates are initially based on the identified class of irrigation system. TFT classifies systems as flood/furrow[27], sprinkler, and drip/micro. The ranges of the specific efficiencies for the

[27] Flood/furrow systems are also commonly referred to as surface irrigation, however because we classify field based on water source (surface or ground), flood/furrow prevents us from having two classifications of surface.

systems within these classes are well-documented[28], and are used along with local expertise to make general assumptions of application efficiency based on the classification of a field's irrigation system. For this analysis we assumed irrigation application efficiencies for flood/furrow, sprinkler, and drip/micro irrigation as 65%, 75%, and 90%, respectively. Equation 2 is used to estimate the total applied water for a given field.

Equation 2. Total Applied Water

$$TAW_i = \frac{(ET_{aw})_j}{\theta_k} * Acres_i$$

Where:
TAWi represent the total applied water to field i
(ETaw)j is the crop water demand, met through irrigation for field j
ϑk is the estimated irrigation application efficiency of irrigation system k
Acresi is the size of field i, in acres

These efficiency values currently used as part of the MM are the result of literature review and take multiple sources into account. TFT seeks to develop additional and improved IEFs through the MM validation process.

Additional Model Parameters

Additional model refinements are being developed through the comparison of modeled and metered data, as well as through the development of Delta island water budgets and calculations of landscape-level actual (METRIC) and estimated (CalSIMETAW) evapotranspiration. Trends found in differences between modeled, metered, and landscape data may be attributable to factors such as conveyance loss, crop age (for multi-season crops such as alfalfa and orchards), location on an island, seepage, etc. These will be discovered through statistical analyses during the MM comparison and verification process. If these analyses result in additional model parameters that can account for variations in water use due to such factors, they will be included in the MM iteratively. The same analyses may also result in IEFs specific to this MM. Analyses to identify additional factors will be described in Technical Appendix 2.

WATER USE ALLOCATION FOR REPORTING

SB-88 reporting fulfilled through TFT's ACP and this MM requires the submittal of annual reports of monthly water use data to SWRCB, for each diversion and associated water right(s), identified by its permit or license number (beginning with A0) or statement number (beginning with S0). The processes described

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[28] Evans, R. G. (n.d.). *Irrigation Technologies*. Sidney, MT. Retrieved from https://www.ars.usda.gov/ARSUserFiles/30320500/IrrigationInfo/general irrigation systems-mondak.pdf
Martin, D. L., & Gilley, J. R. (1993). Irrigation Water Requirements. *Part 623 National Engineering Handbook*, (September 1993).
Neibling, H. (1994). Irrigation Systems for Idaho Agriculture. University of Idaho, College of Agriculture.
Rogers, D. H., Lamm, F. R., Alam, M., Trooien, T. P., Clark, G. A., Barnes, P. L., & Mankin, K. (1997). *Efficiencies and Water Losses of Irrigation Systems*. Retrieved from https://www.bookstore.ksre.ksu.edu/pubs/MF2243.pdf

below allocate the monthly, field-specific modeled water use to water rights for reporting. Reporting for each diversion is currently fulfilled manually through the SWRCB reporting portal.

Water use is modeled at the agricultural field level using the data sources and methods described in the previous sections of this Technical Appendix. Field-level water usage is aggregated to the APN-level as a first step in the reporting process. A single APN may be associated with multiple water rights and a single or multiple water rights can be associated with multiple APNs. Another complicating factor in assigning modeled water use to water rights is the restrictions put on “appropriative” water rights (numbers beginning with A0), often proscribing and limiting water use by month or groups of months. TFT has developed a model to automatically divide water used on fields to water rights despite these complicating factors.

Via TFT’s allocation model, monthly modeled water use at the field scale is aggregated to the overlying APN (or APNs in the case of a single field spanning more than one parcel). The association between a field and the parcel is primarily determined by participant reporting. If this reporting is insufficient or too ambiguous to define the correct APN, TFT outreach staff take maps to the participant and attempt to reconcile the information with the directly. However, where there is still uncertainty, a fallback association can be made by using the GIS-determined field centroid/APN combination to determine the place of use (POU).

Once the POU is known, an APN can be associated with water rights as reported by the participants. All participants are required to identify all water rights that are used for each APN. Thus, modeled water usage is aggregated from field, to APN, and then to water rights. These are not limited to one-to-one associations. As noted earlier, any field may have one or more water rights that it draws upon, and water rights may be used on one or more parcels.

A large three dimensional matrix was built to represent all possible associations among APNs, water rights, and time of water use, with each of these factors along one axis of the matrix. Boolean values (0 or 1) are placed in each cell to indicate whether the APN is associated with the diversion and it water right(s). The “time of use” dimension has an accounting function for both allowable time of use and for quantity limits associated with each water right. The modeled water use is attached to this matrix creating a three-dimensional array that has all the information necessary for model allocation.

Modeled water for each APN is then efficiently allocated to each associated water right (“efficient” in this case adopting the economic meaning of “without waste or loss”). All appropriative rights have time and quantity restrictions that are taken into account during the allocation process by allocating water to the restricted water right first. The remaining water is split among the applicable non-restricted water rights. The function built to allocate water takes into account the multiple scenario possibilities of linking APNs to the applicable water right and water usage in every possible combination. The construction of this array ensures that water usage is allocated efficiently to the correct water rights and that a comprehensive system of water accounting is rigorously enforced.

TECHNICAL APPENDIX 2: MEASUREMENT METHOD COMPARISON AND VALIDATION

INTRODUCTION

The Freshwater Trust (TFT) has developed a proposed method for the remote measurement and subsequent reporting of surface water diverted in the Delta for agricultural and other irrigation uses. This proposed measurement method (MM), developed through TFT's SB-88 Alternative Compliance Plan (ACP), uses remotely sensed data, consumptive water use modeling, and additional analytics to fulfill SB-88 reporting requirements for the California State Water Resources Control Board (SWRCB).

This document describes the analyses and results used to determine the accuracy of the MM, described in detail in Technical Appendix 1: Measurement and Reporting Methodology. The analyses described here will guide the iterative improvement of the MM, as they will help to incorporate additional water use factors beyond evapotranspiration (ET), consumptive water use, and irrigation efficiency. This technical appendix will be updated annually throughout the ACP to reflect the current state of the MM validation process. The MM-ACP began in 2017 and will be completed no later than the end of 2021.

The MM currently being used to fulfil SB-88 reporting requirements under the ACP is based on the California Department of Water Resources' (DWR) Consumptive Use Program Plus (CUP+) model for estimating water use. The design of the "SB88_Db" database, the automation of CUP+, and the development of a model to allocate water used among water rights were the focus tasks of TFT's 2017 and 2018 analytical effort. These elements created the entire workflow to enable SB-88 reporting through a draft MM that can be implemented at a large scale. The refinement of this MM and the comparison to other MMs is the focus of TFT's efforts for the remainder of the MM-ACP development process, to improve the workflow and increase reporting accuracy, as are stated in the goals of this ACP. The 2019 MM refinement and validation will involve the four primary analysis tasks listed below.

(1) The scripted version of CUP+, which enables the batch estimation of consumptive water use over many agricultural fields, needs further improvement to parallel DWR's version more precisely. Some factors that are part of the Microsoft Excel version of the model created by DWR are not incorporated into TFT's analyses, including soil saturation and root depth factors.
(2) The collection and exchange of Collaborative Partner use data is a high priority in 2019, so that modeled consumptive use outputs can be compared between various methods. These data will be aggregated through ongoing programs by The Nature Conservancy (TNC), DWR, and other members of the Office of the Delta Watermaster's Consortium, and informed by the Office of Delta Watermaster's Comparative Study for Estimating Crop Evapotranspiration in the Delta.
(3) In addition to facilitating direct comparisons between methods, this additional data will allow TFT to develop water budgets for Delta islands where the majority of water inputs, outputs, and flows are understood. This will reveal the importance of such factors as seepage, infiltration, and conveyance losses to further improve the MM.
(4) The CUP+-based MM is a field-level assessment of consumptive water use. Landscape-level models exist that use remotely sensed data, weather data, and other spatial data to estimate consumptive use over large areas, or to measure actual evapotranspiration via energy budgets.

Such models, including METRIC (ITRC) and CalSIMETAW (DWR), will be used to compare, verify, and refine TFT's MM in 2019.

Field-level data on crop and irrigation practices acquired from analyses of satellite imagery and additional remotely sensed data are also being acquired by TFT in 2019 through its program partners. The feasibility of using this data to reduce the administrative burden of collecting participant data will be tested, to assess applicability of TFT's MM being adopted by the state for SB-88 compliance. The accuracy of these remotely sensed data sets will be quantified via comparisons with participant-supplied crop type, irrigation method, and irrigation frequency data. When the remotely sensed data misclassifies cropping or irrigation practices (e.g., identifying a pasture as an alfalfa field), the resulting model sensitivity will be tested at the field and landscape level to quantify the significance of using remotely sensed data given inherent inaccuracies.

PRELIMINARY ANALYSIS

To demonstrate to the Delta Watermaster the state of validation of TFT's MM, the results of the first comparison between very high-precision metered water use data (one type of MM) and water use data modeled using TFT's MM is presented below. TNC has provided TFT with some of the first data in the Delta where the accuracy of the equipment has been independently and rigorously tested and the management practices of the lands irrigated with the metered diversions are well understood. The metered data used for comparison is from surface water diverted during the 2018 irrigation season to irrigate crops on Staten Island. This Delta island is managed by TNC for wildlife species habitat, but it has also been the test location for a research effort by TNC to determine the feasibility of use and the accuracy of various flow meter models for SB-88 compliance. TFT compared MM modeled data to data from four metered siphons where TNC had a comprehensive understanding of which agricultural fields and crops they were being used to irrigate. The same flow meter model, Sierra Instruments InnovaSonic, was attached to each siphon to acquire the metered data at 5 to 15 minute intervals, with +/- 10% accuracy. Flow data was converted to total acre-feet (AF) per siphon per month (or over the entire irrigation season) for comparison with TFT's MM outputs.

At the time of this report, TNC was not able to confirm when and if meters were ever inoperative during the irrigation season (as opposed to reading zero flow); therefore, it is unknown whether the meters were capturing all surface water diverted. This preliminary analysis is meant to guide future metered data collection efforts (e.g., sample size, variability in sample set) and help TFT understand what additional farm management data are needed to fully contextualize metered data for future comparisons (e.g., details about irrigation infrastructure and schedules).

Each of the four metered siphons was used to divert surface water to irrigate a different combination of crop fields of varying acreages. Table 1 shows the total water diverted according to the meter over the course of the irrigation season (May through September), as well as the total water use modeled via TFT's MM. The ET of applied water and the "modeled diverted water" are both shown and reflect the output of TFT's MM before and after an irrigation application efficiency factor (IEF) was applied, respectively.

Table 1. Preliminary seasonal totals of water use, measured through metering and modeled via TFT's MM, for multiple metered siphons in 2018. The ET_{aw} and Modeled Diverted Water represent TFT's MM results with and without the IEF applied, respectively.

Siphon	Crop Type	Irrigated Acres	ET of Applied Water (AF)	Modeled Diverted Water (AF)	Metered Siphon (AF)
Siphon 11	Corn, Triticale	358	436	581	512
Siphon 15	Corn	228	428	570	425
Siphon 30	Corn, Potatoes	254	602	802	986
Siphon 7	Potatoes	165	411	548	273

Note: Draft Data supplied by TNC, not validated. Following validation, this analysis will be updated.

The sprinkler IEF was applied for all fields, according to the irrigation methods provided to TFT by TNC. Potatoes on Staten Island are sprinkler irrigated, while corn is irrigated through a sub-surface ditch method (presumed to be similar to furrow irrigation). Because this method of irrigating corn does not seem as inefficient as flood irrigation, the sprinkler IEF was chosen. Finally, the irrigation method of triticale was not provided, and the sprinkler efficiency factor was used as a default efficiency value, for consistency. Obviously, lack of certainty in irrigation methods and the lack of diversity of efficiency factors to represent all irrigation methods are problems being addressed in the MM.

The totals for siphons 11 and 15, which primarily irrigated corn, were similar between MMs. For siphon 15, the ET_{aw} almost exactly equaled the metered water use over the season (meaning the IEF was not needed or correct). For siphon 11, the metered value fell between the TFT MM values with and without the IEF applied, but the seasonal timing of water use varied significantly between MMs (Figure 1, top right).

The TFT modeled water used to irrigate potatoes via siphon 7 greatly over-estimated the metered water diverted (Table 1); further information about how sprinklers were turned on so infrequently and at relatively low flows (Figure 1, bottom right) is needed from TNC farm managers to better understand the discrepancy between water used according to the MMs. It seems that crop water demand could not have been met with the metered water diverted, but this may be attributable to high water tables on Staten Island leading to sub-irrigation. This would be key information for TFT to improve its MM. Conversely, the water use modeled via TFT's MM underestimated the water diverted via siphon 30, which was used to irrigate corn and potatoes. This discrepancy is mainly the result of high metered water use in August and September that was not predicted through the MM. See Figure 1 for the seasonal variability and trends in water measured among the MMs. TFT believes this is an error in metering (because it is unlikely water was continuously diverted for a month), or that this water was being used for a wildlife management practice, which cannot be quantified through TFT's MM currently. In June, on the other hand, TFT's modeled water use (with IEF applied) was equal to that of water use measured via the meter (229AF and 230AF, respectively).

TNC has not yet reviewed these results or provided comments. At the time of this report, TNC itself has not had time to fully QA or validate its metered data. TFT will continue to work with TNC to address irrigation method uncertainties, meter operation uncertainties, and other potential issues and update this analysis. In 2019, TFT will gather additional data for more robust statistical comparisons between MMs for the refinement of the TFT MM used to fulfill SB-88 reporting requirements through its ACP.

This preliminary analysis has pointed to the importance of understanding the actual general irrigation schedules and methods of participants, and improving irrigation efficiency factors. It has also highlighted the potential practical importance of reduced irrigation demand due to the high water table in the Delta (in the case of siphon 7).

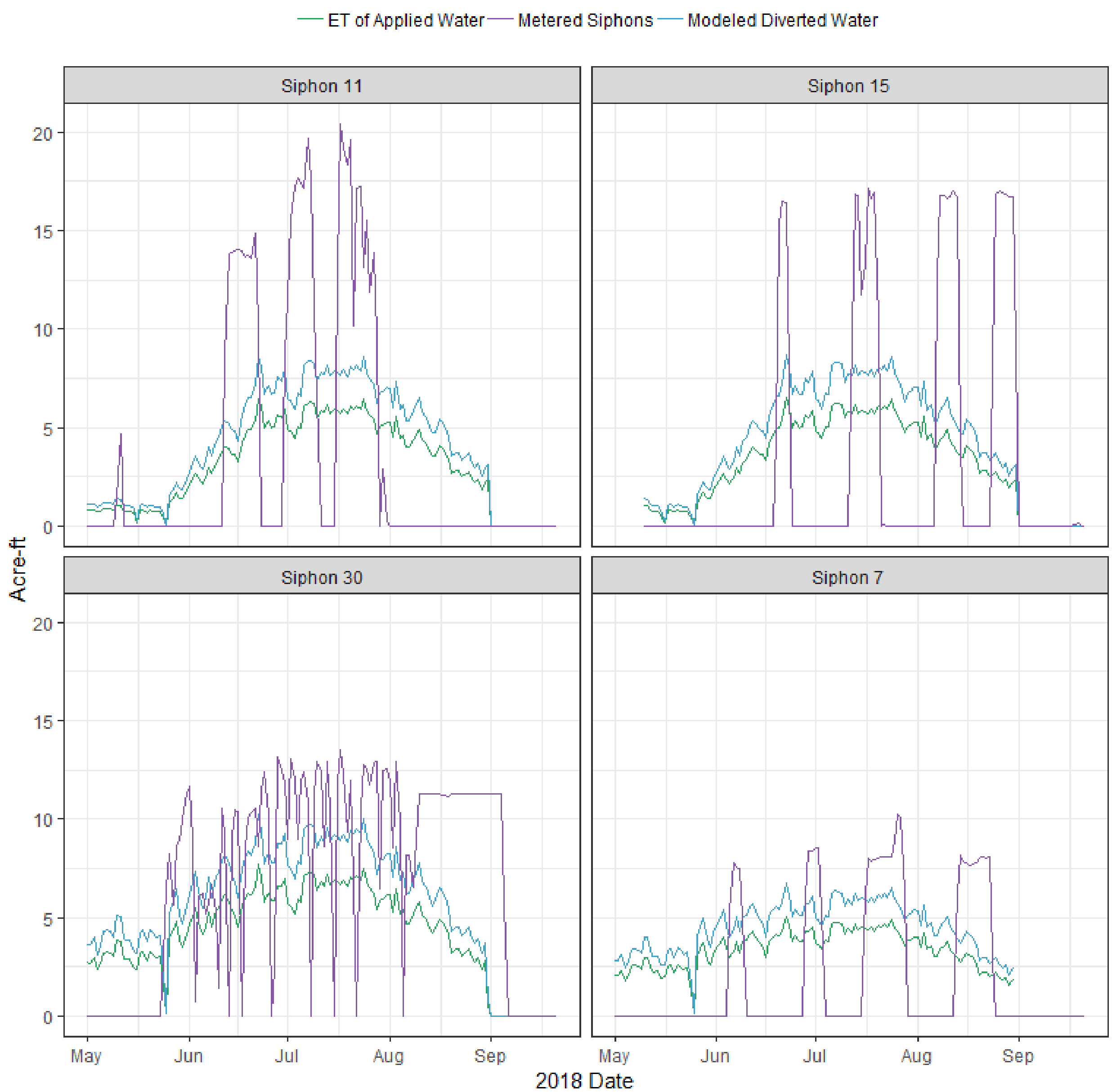

Figure 1. Seasonal variability of water use, measured through metering and modeled via TFT's MM, for multiple metered siphons in 2018. The ET_{aw} and Modeled Diverted Water represent TFT's MM results with and without the IEF applied, respectively.