Appendix V

LandIQ Scope of Work for ET Data Analysis

LAND IQ DATA DRIVEN ET METHOD (LDDM) FOR EVAPOTRANSPIRATION, PRECIPITATION, CROP TYPE, AND PERMANENT CROP TYPE AGE AT THE FIELD LEVEL – KERN SUBBASIN GSAS

TO: Kern Subbasin Groundwater Sustainability Agencies
Kern Groundwater Authority Groundwater Sustainability Agency
Kern River Groundwater Sustainability Agency
Olcese Groundwater Sustainability Agency
Buena Vista Groundwater Sustainability Agency
Henry Miller Groundwater Sustainability Agency

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DATE: February 16, 2022

INTRODUCTION, PROJECT BACKGROUND, AND JUSTIFICATION

The Kern Subbasin is a critically over-drafted groundwater basin in the southern end of the San Joaquin Valley. A wide range of agricultural crops are grown in this region. The water use of these crops can be estimated via empirical methods (e.g. Kc approaches), however these estimates are not unique to individual fields, irrigation management, soil type, changing environmental conditions, etc. The work proposed here is to implement a proven (in Kern County) method to remotely sense evapotranspiration on a field-by-field basis, unique to the aforementioned variables. The Land IQ approach to estimating field-by-field ET incorporates heavy ground truthing (32 eddy covariance and surface renewal climatic stations) to calibrate and validate the data-driven models. ET is the greatest "outflow" of water from the water balance of these systems and needs to be estimated as accurately as possible. Under-estimation of ET can result in over-pumping of groundwater. Over-estimation reduces the opportunity for optimization of farmed and irrigated ground. Incorporation of ground truthing significantly aids in reducing the variability of field-by-field ET estimates. Also, field-by-field crop type, precipitation, and permanent crop age are also provided. The accuracy of the four deliverables are expected to be:

- Field-by-field ET (+/- 5-7%)
- Field-by-field precipitation (+/- 5-10 mm)

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- Field-by-field crop mapping (97.5% prediction accuracy and +/- 6 feet spatial boundary accuracy)
- Field-by-field permanent crop age (+/- 1-2 years)

All of these spatial results significantly enhance the ability to better understand the overall water balance within the subbasin and comply with necessary regulatory requirements. Because the results will be landscape-wide for the Kern Subbasin, they will serve all communities within the subbasin.

The work proposed here are critical input parameters needed to monitor and evaluate the measurable objectives and minimum thresholds outlined in the GSPs for the Kern Subbasin.

Calculation of ET can be performed accurately using weighing lysimeters and eddy correlation monitoring techniques. These methods are limited, however, because they provide point values of ET for a specific location and fail to provide the ET on a regional scale. This limitation has motivated the development of using remotely sensed (RS) data from satellites to evaluate ET over large areas. Satellite data are well suited for deriving spatially continuous ET surfaces that can be pared down to the field scale because of their temporal and spatial characteristics. However, the most accurate use of RS models require calibration to actual surface measurements and roll up from the field level originally. The approach proposed for the tasks in this scope of work includes a combination of high-density, specific ground measurements and remotely sensed modeling, calibrated with those field measurements.

The work defined below will be performed for the entire area of the Kern Subbasin. Results will be consistent across the entire landscape including both irrigated and non-irrigated systems. In addition, this same approach is being used in the Tulare Lake Subbasin and the Tule Subbasin – both of which border the Kern Subbasin to the north. The smaller, White Wolf Subbasin to the south is in conversation for implementation of the Land IQ method as well.

This scope of work proposal was developed at the request of the Kern Subbasin Groundwater Sustainability Agencies (GSAs) for the purpose of developing a monthly field by field estimate of actual evapotranspiration (ET) occurring within the GSAs. Included in the quantifiable deliverables will be:

- Field by field ET (monthly)
- Field by field precipitation (monthly)
- Field by field crop mapping (2x-3x per year depending on area)
- Field by field permanent crop age (2x per year at +/- 1-2 years, excluding vineyards)

A web tool will be used to relay the results each month. This scope of work does not currently include the White Wolf Subbasin, but can be modified accordingly as requested.

STAFFING RESOURCES AND PROJECT COOPERATORS

Staff expected to work on this project from Land IQ have been involved in various aspects of evapotranspiration modeling, agricultural remote sensing, and regulatory support for the last 4 to 26 years, and are listed below. Other appropriately qualified staff may also participate to facilitate completion of any tasks approved by the GSAS as a part of this proposed scope of work.

- Principal In Charge and Principal Agricultural Scientist – Joel Kimmelshue, PhD
- Principal Remote Sensing Analyst – Zhongwu Wang, PhD
- Biometeorologist – Frank Anderson, MS
- Agricultural Scientist – Seth Mulder, MS
- Agricultural Scientist – Chris Stall, MS
- Remote Sensing Analyst – Juan Geng, MS

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- Project Manager/Client Relations – Casey Gudel, MS
- GIS Analyst – Justin Sitton, BS
- Agricultural Field Technician – JB Buller, BS
- Support Staff – Various as needed

Land IQ also welcomes input and collaboration with GSAS and/or associated District/GSA staff and intends on integrating staff into continued instrumentation efforts, data collection, and monitoring programs as the on-the-ground, local component of the team, if desired and feasible for GSAS and/or associated District/GSA staff. This is not a requirement of the work efforts, however.

Implementation of these tasks may also include coordination efforts with other technical providers (costs included) that Land IQ will manage as a part of this overall effort. Land IQ intends on working openly with these parties to help facilitate, to the extent possible, understanding and acceptance of the work approaches and data management used for analysis and ultimate results.

TASKS

This scope of work has been developed based on individual task discussions and requests from GSAS. These tasks include:

- **Task 1** – Monthly Field by Field ET, Precipitation, 2x-3x Crop Mapping, and Permanent Crop Age
- **Task 2** – Monthly Reporting Via A Web-Based Tool
- **Task 3** – Station Management and Maintenance
- **Task 4** – Outreach

Each of these tasks is discussed in detail below and includes schedule and deliverables. A cost summary for all work is provided.

TASK 1. MONTHLY FIELD BY FIELD ET, PRECIPITATION, 2X-3X CROP MAPPING, AND PERMANENT CROP AGE

Scope of Work: It is proposed that the Land IQ Data Driven ET Method (LDDM) already developed and implemented for 8 irrigation districts/GSAs within Kern County (beginning in 2016) and an additional 13 irrigation districts/GSA in Kings and Tulare Counties be used for the entire Kern Subbasin (Figure 1). The LDDM is used to interpret image data and leverages robust and repeated ground station data (now approaching 100 total stations) to be implemented within the GSAS as well as a more direct image analysis. The approach yields more accurate results when repeated and representative ground calibration data are available as compared to remote sensing ET estimates without site-specific ground truthing.

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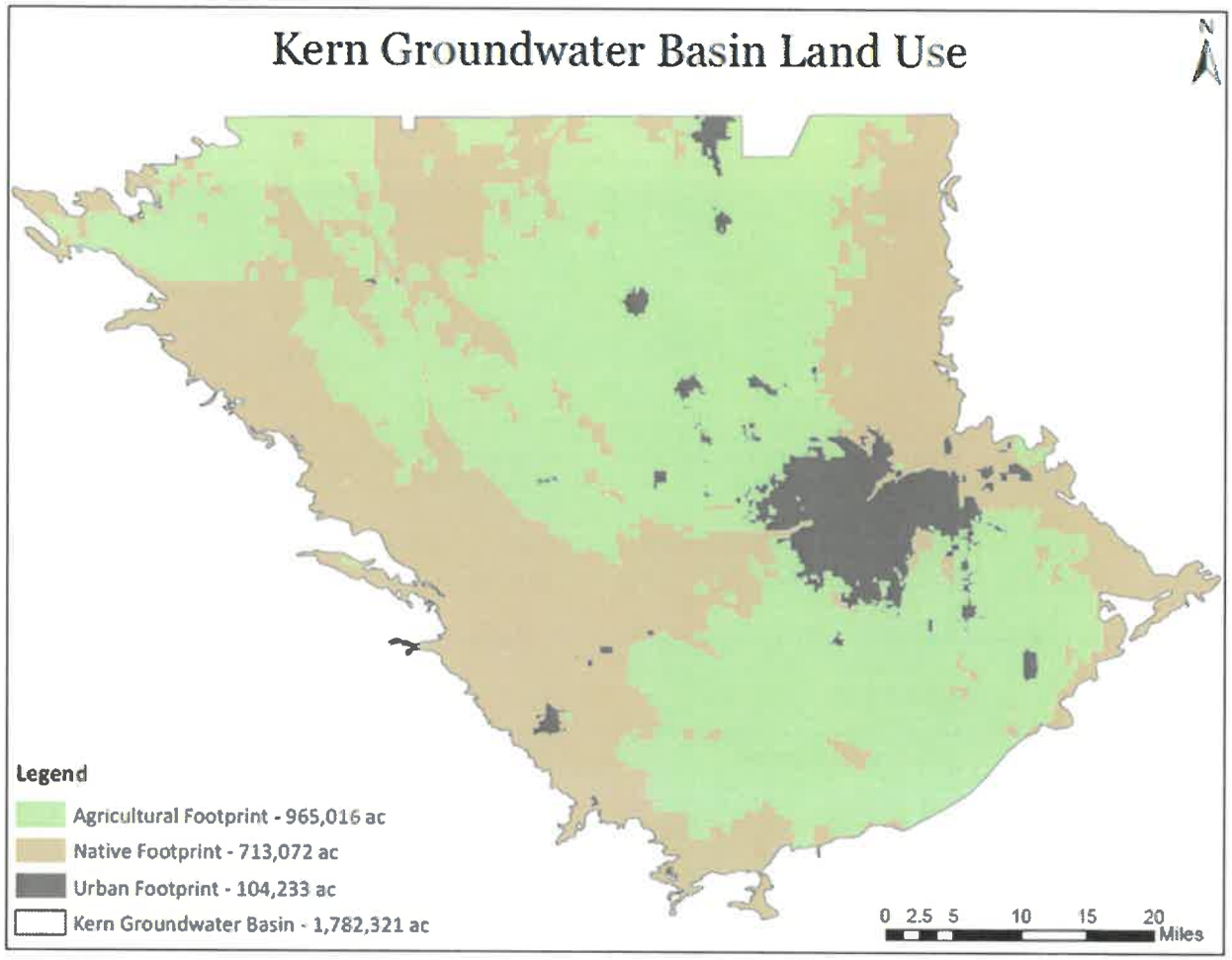

Figure 2. Kern groundwater basin land use and acreage.

Because the LDDM establishes calibration and validation data at the field level and also analyzes at the field level, the result is field-level ET which can then be rolled up to any regional area desired. This is unique to the LDDM RS method as compared to other RS approaches and models.

This method does, however, require robust ground truthing data, which is required as part of this work effort for GSAS. This effort will employ Landsat 8, Landsat 9, Sentinel 2, and purchased high resolution satellite imagery (contracted by Land IQ and included in the overall cost). Satellite data will be screened for cloud cover and terrain corrected. It is important that the images used contain a clear sky. Ground measurements from monitored eddy covariance (EC), surface renewal (SR), Land IQ stations, and cooperator stations will be used to generate hourly ET data correlated to the satellite image overpasses and then used as a dependent variable in the modeling process.

Included in the analysis will be:

- Field by field ETa (monthly)
- Field by field precipitation (monthly)
- Field by field crop mapping (2x-3x per year depending on area)
- Field by field permanent crop age (2x per year at +/- 1-2 years, excluding vineyards)

A web tool will be used to relay the results each month. This scope of work does not currently include the White Wolf Subbasin to the south, but can be modify accordingly as requested. It should be noted

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that Land IQ is providing similar results for all GSAs in the Tule Subbasin, and 5 of 6 GSAs in the Tulare Lake Subbasin, both of which border the Kern Subbasin to the north.

It should be noted that Land IQ has hired retired UC Cooperative Extension Agents for complete independent review of our monthly results including the following individuals:

- Blake Sanden, M.S., UCCE Irrigation & Agronomy Farm Advisor Emeritus, Kern County
- Allan Fulton, M.S., UC Irrigation and Water Resources Advisor, Emeritus, Kings and Tehama Counties

In additional to Blake Sanden and Allan Fulton, Land IQ has developed an independent advisory group that meets 2-3x per year for independent review and includes the following individuals:

- Dan Howes, PhD, Cal Poly, San Luis Obispo
- Daniele Zaccaria, PhD – UC Davis
- Rick Snyder, PhD – UC Davis, Emeritus
- Khaled Bali, PhD – UC ANR
- Pasquale Steduto, PhD – UN-FAO

Deliverables: None

Schedule: Individual analyses will be completed monthly, and results delivered (Task 2) to the GSAS within approximately 25-30 days from the end of the previous month via the web application tool (Figure 2).

Figure 2. Example of field-by-field ET results for a 76.81-acre almond orchard in Kern County.

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TASK 2. MONTHLY REPORTING VIA A WEB-BASED TOOL

Scope of Work: Monthly reports will be developed. The first of the 12 monthly reports will begin on the 1st of the month following completion of recording of 30 days of climatic data and will be delivered within approximately 25-30 days of the end of the previous month. Results will be delivered in both report and web-based format. The web tool will contain all fields, field boundaries, current crop mapping, permanent crop age, coverages of field-by-field ET and precipitation as well as a download link for all results and reports. The web-based tool is designed to be used at the GSA level. The tool is not currently designed for individual grower access, however, can be developed at additional cost not included in this scope of work.

Deliverables: Monthly results will be delivered in both shape file and report formats.

In addition to ET, Land IQ will provide field by field crop type mapping for GSAS in electronic and summary form at least 2 times per year. These data will be the same crop mapping detail that are provided to the State of California, Department of Water Resources as Land IQ is the contractor for that dataset. The delivery of the crop mapping will be approximately July 15 and October 15 of each year and may be modified based on crop rotations and timing. Field by field precipitation will also be delivered as spatially interpolated from rain gauges on Land IQ climatic stations and other publicly available and reliable gauges (e.g. CIMIS stations, airports, municipalities, etc).

The multiple deliverables include:

- Monthly field-by-field ET
- Monthly field-by-field precipitation
- Field-by-field crop mapping (2-3 times per year)
- Permanent crop age (not including vineyards)

All electronic vector and raster GIS files are available.

Schedule: Individual analyses and reporting will be completed monthly, and results delivered within approximately 25-30 days of the end of the previous month being analyzed. Crop mapping data will be delivered on or about July 15 and October 15 of each year.

TASK 3. STATION MANAGEMENT AND MAINTENANCE

Scope of Work: This effort installs, manages and continuously maintains dozens of ground truthing climatic stations of eddy covariance and/or surface renewal approaches to collect instantaneous ET ground data at select locations representing crop production within GSAS. At times, and depending on crop type/location shift, it should be expected that some stations may need to be moved. However, with some permanent crops within GSAS, some stations will stay within those permanent crops and are not expected to be moved. Regardless, all costs are included in the overall cost. Participating grower cooperation is required for station siting.

The data collected by these stations will be used to calibrate the LDDM RS models for ET and create ET estimates across all fields within GSAS to get a complete estimate of GSAS-wide ET and ET by crop type by field. Data stations are fully telemetered by cellular communication systems to Land IQ servers. The system incorporates data flagging protocols to identify any inconsistencies in collection or outages. Land IQ will conduct approximately bi-month site visits in coordination with GSAS personnel (if desired) to verify proper functionality and perform any necessary or seasonal adjustments.

Deliverables: None

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Schedule: Continuous

TASK 4. OUTREACH AND PRESENTATIONS

Scope of Work: Land IQ will work with each of the multiple interested party stakeholder groups that include:

- Groundwater sustainability agencies
- Irrigation and water districts
- Water managers
- Underrepresented communities and SDACs
- Growers
- Other interested parties (e.g. NGOs, residents, political leaders)

This task accounts for up to six public meetings per year to assist with or participate in outreach meetings with interested party stakeholders.

Deliverables: Presentation materials

Schedule: As directed by GSAS.

TIMELINE

Beginning in 2016, Land IQ has been providing field-by-field ET, precipitation, crop type, and most recently permanent crop age to approximately 30% of the area of the Kern Subbasin. The objective of this proposal is to integrate the remaining areas of the Kern Subbasin into this monthly delivery analysis schedule. Analysis is expected to begin for the entire Subbasin (while continuing the subset area) at the start of the 2023 water year (Oct 1, 2022). The duration of the monthly deliverables is intended to be through June, 2025.

Beginning Date: October 1, 2022

End Date: April 30, 2025

TOTAL COST AND PAYMENT TERMS

According to DWR records developed through Land IQ land use mapping there are approximately 1,782,321 gross acres within GSAS (Figure 1). Land IQ has mapped 104,233 acres of urban areas within GSAS. Therefore, the net analysis area is 1,678,088. Of that analysis acreage, 965,016 acres are cropped or fallow and 712,072 acres are native areas that have not been cropped or fallowed in multiple years, if ever.

If the entire Kern Subbasin is analyzed, the per acre cost will be:

Cropped Areas: 965,016 acres x $0.63/acre/water year = $607,960/year or $50,663/month

Non-cropped or Native Areas: 713,072 acres x $0.38/acre/water year = 270,967/year or $22,581/month

Total = $878,927/water year.

Of this total, $28,800/water year will be dedicated to outreach to GSAs, growers, and other interested stakeholders.

For perspective, and depending on the size of individual irrigation districts/GSAs, the cost can range from approximately $10,000/year to $130,000/year, however, is dependent on the amounts of cropped

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and non-cropped lands. This coincides and compliments with the basin study which will be completed by 2025.

The Kern GSAs have already committed to and purchased the necessary ground truthing calibration and validation climatic stations.

Land IQ will issue monthly invoices and has agreed to receive quarterly payment of this invoices upon receipt of the grant funds from DWR.

Acceptance:

Dan Waterhouse
Chair
Kern Groundwater Authority

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