ATTACHMENT 5: WORK PLAN

The Deer Creek and Tule River Authority (Authority) is proposing to prepare a Remote Sensing and Water Balance Analysis Model (Project) to better understand the DCTRA Basin and meet some of the Basin Management Objectives of the Groundwater Management Plan (GWMP).

As part of reporting requirements to the State, the Authority is interested in improving estimates of net extraction of groundwater within its member districts. Net extraction consists of total groundwater pumping for irrigation, minus deep percolation of groundwater applied for irrigation purposes. Challenges to existing methods to estimate net extraction include quantifying the effects of changes in irrigated acreage, cropping, and crop timing over time.

Following is a detailed Scope of Work to complete the Project, summary of how the proposed Project will implement the objectives of the existing GWMP, the Project Performance and Deliverables, and the Environmental Compliance for Project.

Proposed Methodology

This proposal describes a methodology combining remote sensing of crop transpiration with application of a daily root zone water balance model to simulate evaporation and irrigation processes at the individual field scale. Results of the analysis can then be aggregated to various scales (e.g., section, township, irrigation district, groundwater model cell, subbasin) to estimate fluxes and changes in root zone storage and groundwater storage over time, including:

- Crop Evapotranspiration (ET)
    - ET from applied irrigation water
    - ET from precipitation
- Applied Irrigation Water (AW)
- Precipitation
- Runoff
    - Runoff of precipitation
    - Tailwater runoff from irrigation
- Deep Percolation
    - Deep percolation of applied water
    - Deep percolation of precipitation
- Change in Soil Moisture Storage
    - Storage of Applied Water
    - Storage of Precipitation

The basis of the approach is to use Landsat satellite imagery, available every 8 to 16 days, to quantify the amount of green vegetation present by calculating the Normalized Difference Vegetation Index (NDVI)[1]. NDVI values are then converted to crop transpiration coefficients, which when multiplied by reference ET from a nearby weather station (e.g., the Porterville CIMIS station) yield an estimate of total transpiration by the crop, which typically accounts for 80 to 90% of total crop ET on an annual basis. The conversion of NDVI to a transpiration coefficient is relatively insensitive to crop type, avoiding the need for annual crop maps to develop reliable ET

[1] For additional information, see the following website: earthobservatory.nasa.gov/Features/MeasuringVegetation/measuring_vegetation_2.php.

estimates. Additionally, the tracking of NDVI on a monthly or more frequent basis inherently accounts for changes in crop timing and intensity over time.

The relationship to estimate the transpiration coefficient based on NDVI is locally calibrated using available remotely sensed ET data developed using the Surface Energy Balance Algorithm for Land (SEBAL). SEBAL is an energy balance model that accounts for all incoming and outgoing energy sources and solves for latent heating, or ET, for individual satellite image dates (Figure 2). These results, when extrapolated over a growing season, have been consistently shown to agree within 5% of reliable ground based ET estimation techniques[2]. In contrast, estimates of seasonal ET based on traditional approaches with good cropping data have an estimated uncertainty of approximately 15%, even when calculated by an experienced analyst.

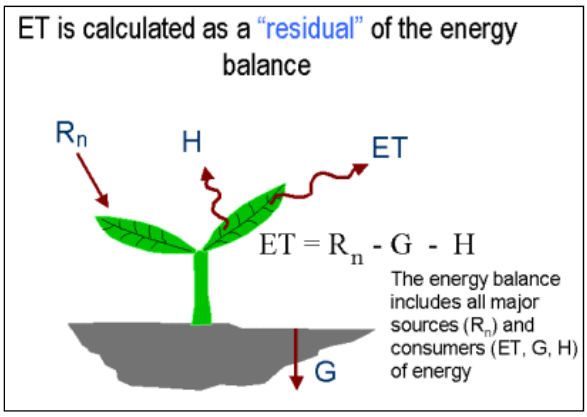

Figure 2. Conceptual Schematic of Surface Energy Balance.

A sample of SEBAL ET data for southern San Joaquin Valley highlighting the Kaweah Delta Water Conservation District (KDWCD, immediately North of the DCTRA) for 2007 is shown in Figure 3. Application of SEBAL every year would likely not be practical due to the significant cost of the SEBAL analysis; the proposed approach leverages already available SEBAL data by using relatively inexpensive NDVI information. This approach has been demonstrated to work with a high degree of accuracy for KDWCD.

The results of the remote sensing analysis are input to a field scale daily root zone water balance model developed based on the dual crop coefficient irrigation scheduling model described in FAO Irrigation and Drainage Paper 56[3]. The model will be parameterized based on local soils, cropping, and irrigation practices and applied to estimate the fluxes and storage parameters listed previously. As part of validation, total ET results from the root zone water balance model will be compared to independent estimates of ET from SEBAL not used as part of the calibration process. The model will be built as a Microsoft SQL Server database application.

[2] For additional information describing SEBAL, see www.sebal.us or Bastiaanssen, W.G.M., Noordman, E.J.M., Pelgrum H., Davids, G., Thoreson, B.P., Allen,R.G., (2005). SEBAL Model with Remotely Sensed Data to Improve Water Resources Management under Actual Field Conditions. J. Irrig. Drain. Eng., 131(1), 85-93 (available at www.kimberly.uidaho.edu/water/papers/remote/ASCE_JIDE_2005_Bastiaanssen%20et%20al_p85.pdf).

[3] For additional information, see Allen, R.G., Pereira, L.S., Raes, D., and Smith, M. (1998). "Crop evapotranspiration, guidelines for computing crop water requirements." FAO Irrigation and Drainage Paper 56, Food and Agriculture Organization of the United Nations (FAO), Rome. Available at: www.kimberly.uidaho.edu/water/fao56/index.html.

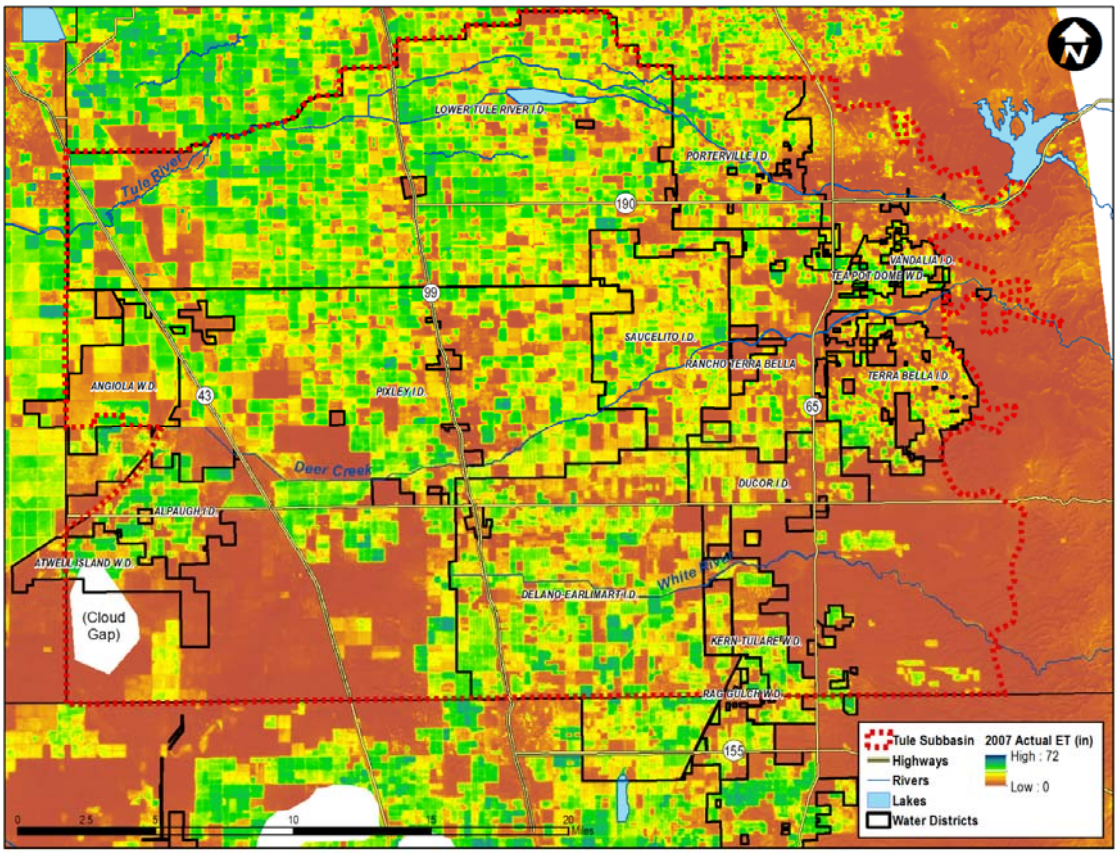

Figure 3. Tule Subbasin SEBAL Actual ET for 2007[4].

Proposed Scope of Work

The ultimate goals of this effort are the following:

- Develop a calibrated model combining remote sensing with daily root zone water balance simulation at the field scale to provide estimates of crop ET of applied water for the period 2007 to 2011.
- Provide the model to DCTRA to allow for future application on an annual basis by Authority staff to support ongoing reporting.

It is recommended that the work be conducted in two phases. In the first phase, the model will be developed, applied, and calibrated for 2007 through 2011. In the second phase, the model will be delivered to DCTRA, and training and support will be provided for Authority staff to apply the model for 2012.

Phase I Scope

The following tasks describe the proposed work during Phase I. As part of the first phase, time series estimates of the various fluxes and storage parameters discussed previously will be developed for the

[4] This figure is excerpted from a report documenting a SEBAL analysis conducted for the Kaweah Delta Water Conservation District for the 2007 Calendar Year.

period from January 1, 2007 to December 31, 2011 (5 years). Wherever practical, data developed as part of prior projects will be utilized to reduce project costs. Available data include NDVI imagery from 2007 through 2010, quality-controlled weather data through 2010 for the Porterville CIMIS station, and SEBAL data encompassing the DCTRA service area for 2007, 2008, and 2009.

Task 1. Development of Field Boundaries and Initial Crop-Method Groups

1.1 Assemble available field boundary datasets. Combine to provide complete coverage of analysis area.
1.2 Assign general crop-irrigation method classification to fields based on 2007 DWR land use survey for Tulare County.
1.3 Assign representative soil texture to each field based on NRCS SSURGO soils data.

Task 2. NDVI Imagery Review, Selection, and Analysis

2.1 Review available Landsat imagery for 2007 through 2010. Identify gaps and acquire additional imagery, as needed. Calculate NDVI values for additional images.
2.2 Select Landsat imagery for 2011. Calculate NDVI. Procure additional, substitute imagery from MODIS (coarser resolution), if needed to fill cloud gaps and adjust NDVI values for consistency with Landsat.
2.3 Extract average NDVI values for each image date by field. Interpolate between image dates to provide daily time series of NDVI by field for 2007 to 2011 analysis period.

ASSUMPTIONS:

A. An existing relationship to estimate transpiration based on NDVI developed for KDWCD will be used, rather than developing a relationship specific to DCTRA. It is assumed that the relationships do not differ significantly between the two study areas
B. Up to three additional NDVI images will be needed for the 2007 to 2010 period.
C. Up to 15 NDVI images will be prepared for 2011 based on a combination of Landsat and MODIS satellite imagery. No more than 3, coarser resolution MODIS images will be used.[5]

Task 3. Develop Local Root Zone Model Parameters

3.1 Evaluate soils characteristics for each representative soil texture based on NRCS SSURGO soils data, and estimate model parameters including total porosity, permanent wilting point, soil hydrologic group, and saturated hydraulic conductivity.
3.2 Estimate crop-irrigation method group parameters related to general crop types and irrigation methods including rooting depth, management allowable depletion, fraction of soil surface wetted during irrigation, irrigation event application efficiency, and annual crop consumptive use fraction.

Task 4. Configure and Run Root Zone Water Balance Model

4.1 Prepare input datasets for root zone water balance model and load to database. Verify that all data is correctly and completely loaded.
4.2 Perform initial model run and check all calculations. Summarize results by crop-irrigation method group, by irrigation district or other area of interest, and by general soil type.

[5] MODIS imagery is used a substitute for Landsat when cloud-free Landsat imagery is not available for a period of approximately 45 days or more. Landsat is preferred to MODIS, due to its pixel size of 30 meters (0.2 acres) as compared to 250 meters (15 acres).

Task 5. Model Calibration and Validation

5.1 Compare total ET results to independent SEBAL results from 2007, 2008, and 2009. Adjust NDVI relationships and other parameters as appropriate. Rerun model and validate total ET results.
5.2 Following calibration of ET, compare total applied water from model results to target amounts based on estimates of annual crop consumptive use fraction (ratio of ET of applied water to total applied water) by crop-irrigation method group. Adjust irrigation parameters as appropriate. Rerun model and validate total applied water results.

ASSUMPTIONS:

A. Calibration of total ET will require up to 4 model runs.
B. Calibration of total applied water will require up to 4 model runs.

Task 6. Identify and Prepare Specific Data Deliverables

6.1 In consultation with DCTRA and its consultant, identify specific fluxes and storage volumes of interest, spatial scale at which volumes will be aggregated (e.g., field, section, GW model node, irrigation district), and time scale for deliverables (e.g., weekly, monthly, annual)
6.2 Assemble spreadsheets and or databases containing data deliverables and brief metadata describing data structure and contents.

Task 7. Prepare Detailed Scope, Budget, and Schedule for Phase II

7.1 Refine initial Phase II scope based on outcome of Phase I. Identify number and extent of training sessions. Review and discuss Phase II scope with DCTRA staff and consultants.
7.2 Prepare detailed Phase II budget and schedule based on refined scope.

Task 8. Project Management, Coordination, and Documentation

8.1 Prepare for and conduct initial field visit to observe cropping and irrigation practices on the ground and to meet with project team members to review approach and other pertinent topics.
8.2 Prepare for and conduct workshop prior to finalization of results to review findings and potential refinements. Discuss specific data deliverables.
8.3 Prepare final report documenting Tasks 1 through 6.
8.4 General project management and client coordination.

Phase II Scope

The following tasks describe the proposed work during Phase II. As part of the second phase, an MS Access user interface will be developed to allow operation of the model by DCTRA staff, including the generation of reports to facilitiate review and reporting of model results. Additionally, documentation will be prepared to support application of the model by DCTRA. Finally, taining will be provided to DCTRA staff who will be applying the model. The training will include applying the model and developing results for 2012, including all associated reports.

Task 1. Develop MS Access Front End to Operate SQL Server Database Model

The model is run in SQL Server due to the amount of data and calculations involved, but SQL server does not have the capability to set up a front end for users of the model who do not have database programming skills. Access provides a customizable, user-friendly environment for operating the model, extracting and aggregating results, and creating reports. Specific subtasks would include:

1.1 Develop forms to modify required input tables housed on the server
1.2 Develop methods to import and load data required for annual update
1.3 Develop quality control checks to review loaded data
1.4 Develop a method to run SQL server procedures

Task 2. Develop Standardized Reports for Review of Analysis Output and Extraction of Required Data

The amount of effort required will vary depending on the number and types of reports that are needed to review the model results and meet the authority's reporting requirements to DWR and others. Specific subtasks would include:

2.1 Identify and define specific reports to be generated.
2.2 Set up and test reports in MS Access front end.

Task 3. Prepare User Guide and Programmer Guide

Additional documentation will be developed to support ongoing application of the model by DCTRA. Documents to be prepared include a User Guide and Programmer Guide.

3.1 Prepare user guide containing detailed documentation of how to use the MS Access front end, tables, forms, and reports from a user's perspective.
3.2 Prepare programmer guide including detailed documentation of tables, forms, reports, and procedures used in the SQL Server and MS Access applications from a database programmer's perspective.

Task 4. Perform Remote Sensing Analysis to Develop NDVI Input Data for 2012

4.1 Select and procure satellite imagery for 2012 analysis period.
4.2 Calculate NDVI and extract average NDVI data by field for each image date.
4.3 Develop daily time series of NDVI values by field for 2012 to be imported into database model.

Task 5. Provide Training and Initial Technical Support

5.1 Support the procurement and setup of a computer to house the SQL server application.
5.2 Provide training for DCTRA staff in the update and operation of the model, as well as checking of model results and preparation of reports.
5.3 Provide on-call technical support for application of the model by DCTRA staff for 2012. Review model results.

Project Implementation of Existing GWMP:

The DCTRA Board adopted the latest GWMP Update in May 2012 which includes five (5) Basin Management Objectives (BMO) as follows:

- Groundwater Resource Protection
- Groundwater Sustainability
- Groundwater Resource Understanding
- Groundwater Basin Understanding
- Information Dissemination

Each of these BMO's has a specific purpose and goal to help manage the groundwater within the DCTRA Basin. But, because there has not been a collective collaboration between all the stakeholders, member participants, and communities within the Basin, it is difficult to achieve some of the BMO's. For instance, it is difficult to achieve specific Groundwater Resource Protection Objectives when there is limited information on groundwater quality available on a Basin wide scale. Overall management practices can be implemented, but source identification is not possible without more information and data. Another example is that it is difficult to achieve Groundwater Sustainability without understanding the areas within the Basin that may be overdrafting groundwater.

In summary, the purpose of this proposed Project is to gather existing data and establish a data model to help inform the DCTRA Board and Stakeholder the condition of the Basin. This project focuses on the Groundwater Basin Understanding BMO's.

Project Performance and Deliverables:

Following is a list of the Project performance and deliverables for assessing progress and accomplishments during the duration of the Project and the final Project reports.

Ongoing Progress Reports:

During the duration of the Project, ongoing project update and progress reports will be completed, outlining both the financial progress and workload progress. The purpose of the ongoing progress reports are to ensure the project stays on schedule and within budget. Following is an outline of how the project will be held accountable through the DCTRA Advisory Committee and Board. On a monthly basis, the Project Manager (consultant) will provide the Project Director a memorandum summarizing the project workload status as compared to the schedule and provide an invoice summarizing the expenses and labor from the previous month. The Project Director will provide an update to the Advisory Committee monthly on the status of the Project. Every two months, the DCTRA Board meets and the Advisory Committee will provide the DCTRA Board with updates on the progress of the project as identified in the monthly progress reports to the Project Director. Having constant communication and updates between the DCTRA staff, the consultant, and the DCTRA Board will keep each member accountable and help keep the project on schedule.

On a quarterly basis, a progress report will be provided to the Department of Water Resources (DWR) staff assigned to this Project Grant. The Quarterly Progress Report will include an update on the financial aspects to the Project, as well as an update on the workload as compared to the schedule. DWR Staff can request an updated Progress Report at any time during the duration of the Project, at a minimum the Staff will receive a quarterly report.

Final Project Reports:

Phase I deliverables include the following:

1. Root zone model outputs, formatted to required spatial and temporal scales to support subsequent analysis.
2. Metadata describing data deliverables.
3. Final report documenting Tasks 1 through 6.

4. Workshop materials and notes.

Phase II deliverables include the following:

1. MS Access front end and SQL Server Express database containing input data and results for 2007 through 2011.
2. User Guide and Programmer Guide.
3. Table containing NDVI time series data for 2012.

Environmental Compliance:

The proposed Project will not require any environmental compliance permitting or other permits to complete the Project.