CENTRAL VALLEY REGIONAL WATER QUALITY CONTROL BOARD

DISCLOSURE FORM
EX PARTE COMMUNICATIONS REGARDING PENDING GENERAL ORDERS

Note: This form is intended to assist the public in providing the disclosure required by law. It is designed to document meetings and phone calls. Written communications may be disclosed by providing a complete copy of the written document, with attachments. Unless the board member(s) provided you with a different contact person, please send your materials to: Kiran.Lanfranchi-Rizzardi@waterboards.ca.gov
Use of this form is not mandatory.

1. Pending General Order that the communication concerned:
WDR GO for Growers within the Tulare Lake Basin Area that are Members of the Third-Party Group

2. Name, title and contact information of person completing this form:
Note: Contact information is not mandatory, but will allow the Water Board to assist you if additional information is required. If your contact information includes your personal residence address, personal telephone number or personal email address, please use a separate sheet of paper if you do not want that information posted on our website. However, this information may be provided to members of the public under the Public Records Act.
Kimberly Brown, Resource Manager, Paramount Farming Company, 33141 E Lerdo Highway, Bakersfield, CA 93308

3. Date of meeting, phone call or other communication: Meeting held:Wednesday, February 20, 2013

   Time: 9:30am to 10:20am

   Location: 1215 K Street, Suite 1900, Sacramento, CA 95814

4. Type of communication (written, oral or both): written and oral

5. Names of all participants in the communication, including all board members who participated: Board Member: Jon Costantino, William Phillimore, Kimberly Brown

6. Name of person(s) who initiated the communication: Kimberly Brown

7. Describe the communication and the content of the communication. *Include a brief list or summary of topics discussed at the meeting, any legal or policy positions advocated at the meeting, any factual matters discussed, and any other disclosure you believe relevant. The Office of Chief Counsel recommends that any persons requesting an ex parte meeting prepare an agenda to make it easier to document the discussion properly. Attach additional pages, if necessary.* Please see the attached. Background information was provided to Board Member Costantino via e-mail on Friday, February 15, 2013. The e-mail and all documents provided in the e-mail and discussed during the February 20 meeting are attached.

8. **Attach a copy of handouts, PowerPoint presentations and other materials any person used or distributed at the meeting. If you have electronic copies, please email them to facilitate web posting.**

Please see the attached.

MEETING WITH PARAMOUNT FARMING REPRESENTATIVES WILLIAM PHILLIMORE AND KIMBERLY BROWN AND REGIONAL BOARD MEMBER JON COSTANTINO

FEBRUARY 20, 2013

What is the Goal?

<u>Protect groundwater from further degradation by changing current behavior and irrigation practices.</u>

- (Supposed to be) limited to “lands from which there are discharges of waste that could affect the quality of any waters of the state.”

- Finding 20: “Whether an individual discharge of waste from irrigated lands may affect the quality of the waters of the state depends on the quantity of the discharge, quantity of the waste, the quality of the waste, the extent of treatment, soil characteristics, distance to surface water, depth to groundwater, crop type, management practices and other site-specific factors.”
  - The ESJ Order and draft TLB Order have NOT reflected a unique approach to “site-specific factors.”

- Finding 21: “The burden, including costs, of these reports shall bear a reasonable relationship to the need for the report and the benefits to be obtained from the reports.”

What is the Goal?

Protect groundwater from further degradation by changing current behavior and irrigation practices.

- Kern has demonstrated conditions which substantially differ from other areas and warrant a unique approach to reach the desired goal.
  - The ESJ Order and draft TLB Order have NOT reflected a unique approach to "site-specific factors."

Average Depth to Groundwater	
East San Joaquin Watershed	88ft
Kings Subbasin	87ft
Kaweah Subbasin	102ft
Tulare Lake Subbasin	77ft
Tule Subbasin	159ft
Kern County Subbasin	219ft

- Kern has a longstanding history of local groundwater management and feels it is most knowledgeable to recommend an effective, measurable, implementable and results drive solution.
- To achieve this it MUST:
  - Account for unique characteristics.
  - Understand the extent to which legacy practices will impact current and future water quality degradation.

NHI vs. Well Monitoring & Reporting

Description:

Kern Subwatershed Recommendation	Draft TLB Order
Nitrogen Hazard Index (NHI)	**Well Monitoring & Reporting**
Engaged landowner process to consider and measure the impacts of various site-specific characteristics to gauge potential to discharge	Periodic measurements of water quality from identified areas within the basin and reporting requirements (NMP, MPEP) for all irrigated agriculture
Accounts for multiple, site-specific factors (crop, soil, irrigation method, management practice, depth to groundwater…) and assess relative impacts by site	Does not identify site specific contributors and overly burdensome to those without, or with limited potential to discharge
Relates current conditions to the potential to discharge	Produces data without a causal relationship to current conditions

NHI vs. Well Monitoring & Reporting

Characteristics	NHI	Monitoring & Reporting
Regulatory framework independent of legacy nitrate groundwater levels	Yes	No
Measures current condition/current practice contributions	Yes	Partial
Ability to separate legacy from current practice contributions	Yes	No
Is flexible (can be modified based on research & science)	Yes	No
Accounts for crop type	Yes	Partial
Accounts for soil type	Yes	No
Accounts for depth to groundwater	Yes	No
Accounts for irrigation system type & efficiency	Yes	Partial
Accounts for nutrient management practices	Yes	Yes
Educational	Yes	No
Results driven	Yes	No
Comparable/Measurable	Yes	No
Economically defensible (can gauge level, if any, of regulation)	Yes	No

What is the Goal?

Protect groundwater from further degradation by changing current behavior and irrigation practices.

- A NHI approach:
  - Incentivizes the correct behavior by identifying the conditions that warrant regulation
  - Directs the expense to achieve the goal
  - Avoids expensive and unproductive monitoring

END

Kern River Watershed Coalition Authority

A joint powers authority to serve as coordinator and coalition group under the Irrigated Lands Regulatory Program
in the Kern River watershed portion of Kern and Tulare Counties

Business Address:
c o Rosedale Rio-Bravo Water Storage District
P.O. Box 20820, Bakersfield, CA 93390-0820
661-589-6045

Financial Address:
c o Wheeler Ridge-Maricopa Water Storage District
12109 Highway 166, Bakersfield, CA 93313-9630
661-858-2281

President: Eric Averett
Vice-President: Jason Gianquinto
Treasurer: Robert Kunde
Secretary: Lori Honea

February 13, 2013

Ms. Pamela Creedon, Executive Officer
Central Valley Regional Water Quality Control Board
11020 Sun Center Drive, # 200
Rancho Cordova, CA 95670-6114

RE: Our meeting of February 20th

Dear Ms. Creedon:

Bill Phillimore and I look forward to meeting with you again on February 20th. As you may be aware, the Kern River Watershed Coalition Authority ("KRWCA") has engaged several technical studies to help inform various issues raised in the proposed Southern San Joaquin Order ("SSJ Order").

Based upon the technical work done by the KRWCA, we believe that we have demonstrated conditions which substantially differ from other areas within the Tulare Lake Basin. This investigative work provides the basis for the KRWCA to pursue either 1) acknowledgement within the SSJ Order that the KRWCA is unique and implementation of the SSJ Order will reflect these unique characteristics, consistent with the points below; or 2) a separate Order for the KRWCA area. We would ask that the SSJ Order or a separate KRWCA area Order be customized for our unique conditions

If the Porter Cologne Act ("Act") requires that we be regulated, we want to ensure that the regulations further the intent of the Act. We believe that the current approach, when applied to the unique circumstances within the KRWCA area, is overly burdensome and costly.

In preparation for the meeting on the 20th, we take this opportunity to provide some additional technical information which shall provide the basis for our discussion.

Additional Information on Unique Aspects of the KRWCA or ("Kern Sub-Basin")

Enclosed find the following (three copies of each):

--a final draft report from the Source Group, Inc., by Robert M Gailey, P.G., C.HG. concerning hydrogeologic conditions in the KRWCA area; and

--a final draft report from NewFields Agricultural and Environmental Resources, by Dr. Joel Kimmelshue, concerning potential for nitrate migration in the KRWCA area.

The information in these reports is similar to the power point presentations these two gentlemen made at the workshop in Bakersfield on November 30th, but with additional detail. The key findings of these expert reports can be summarized as follows:

In summary, Mr. Gailey notes:

1. "From a hydrogeologic perspective, the KRWCA area is notably different from the other parts of the Tulare Lake Hydrologic Region (TLHR) and also the East San Joaquin Watershed (ESJW)"(p. 2-1). In particular he points to (a) one-half to one-third the rainfall, (b) much greater groundwater recharge and extractions, (c) significantly greater groundwater depths than to the north, and (d) less pronounced nitrate impacts than to the north (p. 3-3);

2. In part because of significantly deeper groundwater in the KRWCA area, there are significant transit times between surface water application and any changes in groundwater quality (p. 4-1, 4-2);

3. About 85% of the groundwater in the KRWCA area is at depths greater than previous studies cited in the draft Order as the basis for the regulation (p. 4-1, Figure 11);

4. Nitrates residing in the unsaturated zone are a significant ongoing and legacy source for years to come, regardless of current farming practices (p. 4-2, 4-3); and

5. The draft Order would result in significant costs (with KRWCA area costs being significantly higher because of deeper groundwater), and not achieve the objectives of the draft Order (p. 4-5). He concludes, "A trend monitoring program conducted under such conditions cannot meet the monitoring goals of the draft order because there is a temporal disconnect between actions at ground surface and reactions in groundwater located at depth. Changing current irrigation and fertilization practices cannot affect what has occurred in the past" (p. 4-2).

In summary, Dr. Kimmelshue notes:

1. "For a variety of reasons (e.g. water availability, water cost, soil type, crop mix, market conditions, effective rainfall, etc.) the relative water use and nitrogen use in the Kern Sub-Basin is generally more efficient as compared to other areas of the Southern San Joaquin Valley. This is also supported by research conducted by others." (p. 1)

2. "A preliminary NHI [Nitrate Hazard Index] was developed for the Kern Sub-Basin and compared to previous years. The potential for nitrate leaching [in the KRWCA area] has decreased significantly over the past 20 years due to the rapid conversion to highly-efficient irrigated perennial crops from historic surface irrigated row and field crops." (p. 2)

3. "In general, results indicate that perennial crops on high efficiency irrigation systems (common to the Kern sub basin), result in limited return flows to groundwater. Largest return flows occur under corn/wheat, sudan/wheat or alfalfa crop rotations that are commonly associated with feeding operations for dairies. The majority of these systems are currently regulated under the Dairy General Order." (p. 2)

4. The NHI is more reflective of what potential risks are actually posed to groundwater in the KRWCA area. He points out his conclusions are similar to those reached by other researchers (some of which has been funded by the State Board), although his analysis is specific to the KRWCA area. He notes that NHI studies demonstrate that the nitrate risk to groundwater in the KRWCA area is clearly much less than other areas to the North. (p. 31-32)

Additional unique conditions of the KRWCA area include:

1. There are very few cases of drinking water systems with nitrates exceeding the MCL, as reported by Kern County Public Health.

2. Geographic area of over one-million acres which is larger than many "stand alone" coalition areas.

3. Recognized by DWR as a separate and distinct hydrologic sub-region of the Tulare Lake Basin.

Topics We Wish to Discuss on the 20th.

The enclosed reports, taken in conjunction with the testimony provided at the November 30th workshop, demonstrate that the KRWCA area has several unique characteristics when compared to other areas in the Central Valley Region. We appreciate comments by you and the Board indicating unique conditions will be accommodated across the different geographic areas and ask for an accommodation of the following:

1. We believe we would use the NHI (as discussed in Dr. Kimmelshue's report) as the primary tool for classifying areas in the KRWCA area in terms of what risk, if any, irrigation of specific lands pose to groundwater, and in turn what requirements under the Order are appropriate.

2. Recognizing that depth to groundwater in the KRWCA area renders groundwater monitoring of little or no benefit when correlating surface activities (agricultural practices) and groundwater quality, any Order for the KRWCA area needs to be modified with respect to any further monitoring program. However, we are committed to continue

existing monitoring programs carried out by our districts and the Kern County Water Agency through AB 3030 programs and otherwise to monitor existing wells.

3. Certain aspects of the Management Practice Evaluation Program (MPEP) are not appropriate for the KRWCA where monitoring of first encountered groundwater has no correlation to surface activities. Travel time to the first-encountered groundwater is often decades (up to 500 years in some areas) and cannot provide a basis for real-time regulatory actions. We wish to work with the Board staff and have a better understanding of expectations of this program.

4. For areas identified as low risk under the NHI, we see no basis for completing Nutrient Management Plans (NMPs). By meeting the low risk criteria in the NHI, the overlying landowner has already demonstrated the ability to protect groundwater. Any additional requirements are not reasonable and would have no further benefit to protecting groundwater, our common objective.

5. The Westside of our area (generally the lands within Belridge Water Storage District and Berrenda Mesa, Lost Hills and Dudley Ridge Water Districts), with groundwater which does not meet municipal standards and has severe limitations for most agricultural uses, should be exempt from the Order. Those Districts have through separate correspondence with the Regional Board staff, sought an exemption from the groundwater regulation provisions of the ILRP and initiated the longer-term process for a basin plan amendment.

The KRWCA is committed to working with the RWQCB staff to develop a program to ensure that current practices in the KRWCA area do not degrade water quality in a manner that unreasonably affects beneficial uses. Our goal is to assist in the development of an Order that can realistically be implemented in a cost effective manner. We look forward to meeting with you on the 20th to outline an approach going forward that we can all support.

Very Truly Yours,

Eric Averett, Chair

Enclosures: Gailey Draft Report
Kimmelshue Draft Report

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DRAFT

Kern River Watershed Coalition Authority

Assessment of Potential for Nitrate Migration in Kern Sub-Basin

Documentation Submittal for Preliminary Review Only

TO:

Ernest Conant/Young Wooldridge

John Schaap/Provost & Pritchard

Rob Gailey/The Source Group

FROM:

Joel Kimmelshue/NewFields Agricultural & Environmental Resources

Stephanie Tillman/NewFields Agricultural & Environmental Resources

February 14, 2013

Executive Summary

Background

The California Regional Water Quality Control Board – Central Valley Region (CVRWQCB) has issued Order R5-2013-XXXX titled, Waste Discharge Requirements General Order for members of a third-party group within the Tulare Lake Basin, excluding the area of the Westlands Stormwater Coalition. The Kern River Watershed Coalition Authority (KRWCA) has chosen to develop comments to this Draft General Order prior to the deadline imposed by the CVRWQCB.

The purpose of this technical memorandum is to document on-going technical work that addresses the unique nature of the Kern Sub-Basin area as well as provide for a methodology for relatively quantifying, tracking, and managing the potential for nitrate leaching to groundwater.

Approach

The overall approach of the work performed for the KRWCA was to:

- Develop of representative leaching conditions using a Soil Moisture Root Zone Balance (SMB) and understand the inherent variability associated with those estimates.

- Develop a Nitrate Hazard Index (NHI) as a comprehensive tool to use in assessing large landscape areas on a field by field basis in order to estimate relative potential nitrate contributions to groundwater based on surface agricultural activities and conditions.

Results and Conclusions

It should be noted that the results and conclusions listed below are a part of an on-going investigation, however are consistent with the conclusions from various researchers and approaches. NewFields used specific information applicable to the Kern Sub-Basin area.

- Currently, the Draft Order suggests that agriculture in the Kern sub-basin is to be regulated similarly across all cropping systems regardless of irrigation method, N management, soil type, crop type, location, etc. The results of this preliminary evaluation indicate that within the Kern Sub-Basin there are significant differences between crop types and resultant contributions of N to groundwater resources which will require more flexible and perhaps crop- or area-specific considerations in order to develop effective regulations.

- For a variety of reasons (e.g. water availability, water cost, soil type, crop mix, market conditions, effective rainfall, etc.) the relative water use and nitrogen use in the Kern Sub-Basin is generally more efficient as compared to other areas of the Southern San

Joaquin Valley. This is also supported by research conducted by others (Pettygrove, et al, 2012) (Boyle, et al, 2011) as contracted by the State Water Quality Control Board.

- It is imperative to note that estimating nitrate leaching, even under specified conditions, is a highly complex task with many variables. Therefore, the results of any N leaching estimating methods should be interpreted as precisely that – estimates only – and are subject to modification with new information.

- The most significant effort related to broad land-based estimates of nitrate leaching potential to date focused on assessing nitrate contamination in groundwater from agricultural sources in California and resulted in the UC Nitrate Hazard Index. This effort intentionally avoided any attempt to place absolute values on total amounts of nitrate leached, due to the known variability (Wu et al, 1995). This work was developed and reviewed by some of the foremost experts in this multi-disciplinary subject, and should serve as an indication of the caution with which estimates of nitrate leaching must be interpreted and how variable they can be.

- A preliminary NHI was developed for the Kern Sub-Basin and compared to previous years. The potential for nitrate leaching has decreased significantly over the past 20 years due to the rapid conversion to highly-efficient irrigated perennial crops from historic surface irrigated row and field crops. The NHI approach allows for comprehensive assessment for the potential of nitrate leaching on large landscapes at the field level.

- From a hydraulic perspective, for purposes of our investigations, the Kern Sub Basin area was successfully separated into 6 regions that offered like soil, crop, water supply and overall production system similarities and a spatial dataset was developed from recent crop mapping (Kern Co., 2011) as the basis for analysis.

- This spatial dataset coupled with detailed literature resources and local expert knowledge specific to the Kern Sub-Basin was used in creation of inputs used for the analysis performed.

- Major crop type systems were evaluated from both a hydraulic (agronomic water balance focusing on return flows to groundwater) and nutrient use efficiency standpoint.

- In general, results indicate that perennial crops on high efficiency irrigation systems (common to the Kern sub basin), result in limited return flows to groundwater.

- Largest return flows occur under corn/wheat, sudan/wheat or alfalfa crop rotations that are commonly associated with feeding operations for dairies. The majority of these systems are currently regulated under the Dairy General Order (2007-035)

- Other row crops such as cotton/wheat and carrot/potato rotations result in moderate return flow estimates mostly because of the types of irrigation methods and management employed.

- Estimated nitrate leaching ranged from relatively low values of 10-20 pounds N/acre/year in drip-irrigated citrus and grapes to maximum values of 50-100 pounds/acre/year in a surface-irrigated silage corn/winter wheat rotation. This wide range of results verifies that agricultural systems are dissimilar in their potential to contribute to groundwater nitrate pollution.

- The variation in nitrate leaching estimates for diverse cropping scenarios is significant, as irrigation method and soil combinations result in a wide range of nitrate leaching estimates. This finding is substantiated by numerous authors whose work contributes to the scientific literature on N dynamics in cropping scenarios (Viers et al., 2012), and reinforces the point that nitrate leaching from various cropping systems cannot be considered or treated as similar systems.

- As a result of this preliminary evaluation, it is evident that a continued significant contributor to nitrate concentrations in groundwater is forage cropping systems predominantly used for dairy feed sources. The conclusion is supported by work performed by UC Davis (Pettygrove, et al., 2012). Much of this forage crop production is currently regulated under the existing dairy order.

- As a result of our evaluation, drip/micro irrigated perennials have a low NHI due to limited return flow and effective precipitation. These results also agree with work performed by UC Davis (Pettygrove, et al., 2012) that also show that the nitrate risk to groundwater in the Kern Sub-Basin is significantly less than other areas to the North.

General Introduction

The California Regional Water Quality Control Board – Central Valley Region (CVRWQCB) has issued Order R5-2013-XXXX titled, Waste Discharge Requirements General Order for members of a third-party group within the Tulare Lake Basin, excluding the area of the Westlands Stormwater Coalition (January 2013 Draft) is the subject of this review.

NewFields Agricultural & Environmental Resources has been retained by Young Wooldridge, LLP, on behalf of the Kern River Watershed Coalition Authority, to assist in development of some of those comments. Some focus areas will include:

- irrigation and drainage management
- nutrient use efficiencies
- soil/nutrient dynamics
- crop production
- root zone moisture management
- other related scientific approaches

Our project team has focuses efforts on estimated hydraulic and nitrogen components of the varied agricultural systems within the Kern Sub-Basin of the Southern San Joaquin Water Quality Coalition (SSJWQC). A comparison to other directly applicable published work will also be provided.

More specifically, the technical tasks that have been completed include:

- Review of the Draft General Order and Other Appropriate Literature
- Development of Spatial Data Resources
- Development of Representative Scenarios
- Development of Return Flow Estimates through a SMB
- Development of a Preliminary NHI for the entire Kern Sub-Basin

In addition to these tasks, an attempt to compare existing agronomic conditions to past trends has been developed both from a water use efficiency and nitrogen (N) use efficiency standpoint.

Finally, the results of this work were compared to agronomic-focused research in the same area conducted by other researchers (e.g. Pettygrove, et al., 2012 and Boyle, et al, 2011). These researchers and others have developed components of an overall study performed by UC Davis (Harter, et. al. 2012) and support the work performed here.

Development of Spatial Data Resources

Introduction

The first step in assessing a region of this size is to partition "like" or more "manageable" areas that may be similar in soil type, crop type, irrigation supply and management, climate, etc. The information below provides the detailed documentation as to the methods used to separate the Kern sub-basin into six regional components for the purpose of our investigations.

Methods

Determination of Regions

The following descriptions outline the features that were used to determine the boundaries between each region. Names of KRWCA agencies (water districts, irrigation districts and water storage districts) are also included to ensure all KRWCA agencies are accounted for in a region or multiple regions. Final results indicate six distinct areas with similar characteristics (Figure 1).

Clay Rim Region

This region was created in response to two dominant zones of fine-textured clay present within the valley. The region encompasses all of the Buena Vista WSD and Henry Miller WD, portions of the Wheeler Ridge-Maricopa WSD (from the districts northern border to Copus Rd), southwest portions of the Kern Delta WD (from I-5 west and Herring Rd south), the northwestern portion of the Semitropic WSD (from Gun Club Rd. west and CA-46 north) and the northeastern corner of the Lost Hills WD (East of I-5).

Foothills Region

The Foothills region contains portions of the Southern San Joaquin MUD (east of the Famoso-Porterville Hwy), a portion of the Delano-Earlimart ID, Kern-Tulare WD, the Olcese WD, the Cawelo WD and a portion of the Arvin-Edison WSD. The eastern boundary of the region follows the Kern-Tulare WD and the Cawelo WD boundaries. The western boundary was determined based on the distribution of crop types due to the limited difference between soil mapping units found. A noticeable shift in crop types occurs immediately to the east of the city of Delano and the Famoso-Porterville Hwy/Richgrove Dr. from Vestal south to Famoso. This shift along Famoso-Porterville Hwy/Richgrove Dr from predominately annuals, almonds, and grapes to the west and predominately citrus to the east necessitates deviating from coalition agency boundaries to define the western edge of the Foothill region. The eastern and western boundaries head south along Poso Creek until it reaches the eastern border of Cawelo WD. The inclusion of a northern portion of the Arvin-Edison WSD is due to the density of citrus in this area. The northern boundary is formed by the Kern-Tulare WD northern border south of the city of Ducor near Vestal.

Kern Fan Region

The Kern Fan region contains the Rosedale-Rio Bravo WSD and the Kern Delta WD. The boundary was determined using differences in soil texture from the USGS SSURGO soil database and WSD boundaries. The orientation of soil map units (directionality of sediment deposition based on historic water flow characteristics) and the horizontal stratification associated with alluvial fans (coarse textured soils near the mouth of the stream and finer textured soils as distance increases away from the mouth of the stream) clearly shows the extent of the Kern River Fan. The southern boundary is formed along the Clay Rim region and a small section of the Arvin-Edison WSD The northern boundary is found along the Rosedale-Rio Bravo WSD northern border. The eastern edge is found along the Kern Delta WD and Arvin-Edison WSD boundary and extends north along CA-99 to Oildale. The western boundary is found running south from the Clay Rim region at Buttonwillow to the California Aqueduct at the Tule Elk State Reserve and south along the Aqueduct to Ironback Rd.

Westside Region

The Westside region contains the Belridge WSD, Dudley Ridge WD, Lost Hills WD and Berrenda Mesa WD. The boundary extends west to the edge of the Kern Sub-Basin, down to the bottom of Belridge WSD. The Eastern boundary follows the Clay Rim region which closely coincides with the Semitropic WSD and Buena Vista WSD western boundaries. More specifically, the eastern boundary mirrors that of the Clay Rim region to the bottom of Belridge WSD. The northern boundary extends to the northern most portion of the Dudley Ridge WD. The southern boundary of the region is shared by the southern boundary of the Belridge WSD and terminates near Lokern Rd by Missouri Triangle. The southern end of this region neighbors land that is not cropped and was therefore excluded. The interface between all of these coalition agency boundaries also corresponds closely with differences in soil texture distribution with the north end of this region being more heterogeneous in the textures found and the neighboring region (Northern region) being more homogeneous.

Northern Region

The North region contains portions of the Semitropic WSD (with the exception of the northwest corner from approx. CA-46, north and Gun Club Rd, west), the Southern San Joaquin MUD (west of Famoso-Porterville Hwy), Shafter-Wasco ID and the majority of the North Kern WSD (omitting the portion of the North Kern WSD that follows the Kern River). The western boundary respects the border established by the Clay Rim region. The eastern boundary follows the Famoso-Porterville Hwy to near the city of Famoso where it then follows Poso Creek and meets the Cawelo WD. The southern boundary lies along the northern border of the Rosedale-Rio Bravo WSD which happens to follow differences in soil texture found between the Northern region and Kern Fan region. The northern boundary is shared with the northern boundary of the Delano-Earlimart ID. The distinguishing characteristics that merit including this area as a separate region are the widespread presence of almonds and the divergent soil textures when compared to neighboring WSD’s and regions.

Wheeler Ridge/Arvin-Edison Region

The Wheeler Ridge/Arvin–Edison region contains both of these water districts. The boundary follows the Arvin-Edison WSD and Wheeler Ridge-Maricopa WSD borders. Slight modifications to the boundary were made based on differences in soil texture and crop distribution when compared to surrounding areas, specifically coarser textured soils and citrus establishment. As a result, a portion of the northeastern section of Arvin-Edison WSD has been included in the Foothills WSD. Additionally, the dominant crop type in the area differed from other zones and overall crop diversity was increased in this region versus others. Furthermore, because of differences in soil texture and crop type in the northern part of the Wheeler Ridge-Maricopa WSD, the section from Copus Rd north to the district boundary is included in the Clay Rim region.

Approximately 935,000 acres were irrigated within the Kern Sub-basin in 2011 (Table 1).

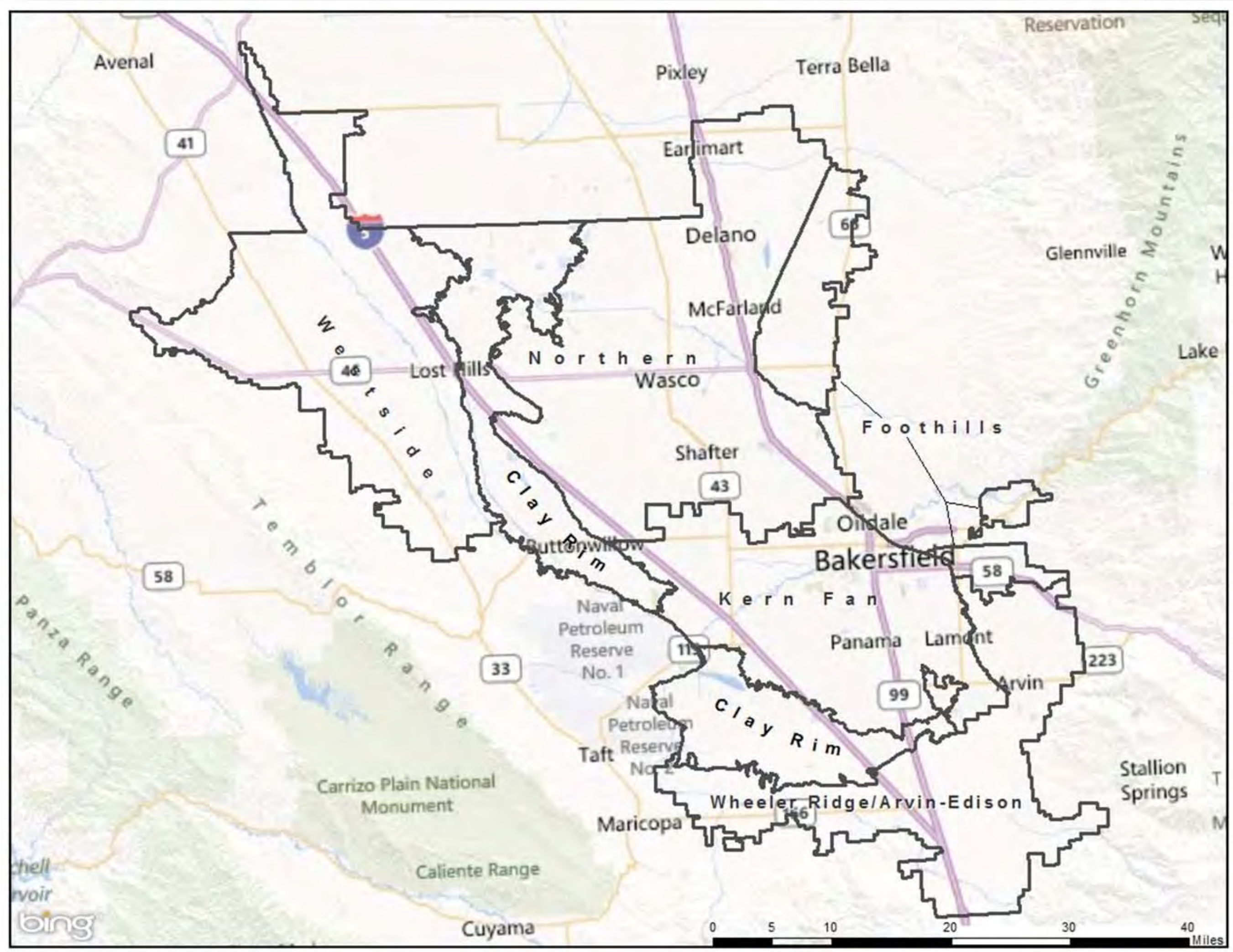


Figure 1. Six distinct regions based on differences in soil type, crop types and management

Table 1. Acreage summary for each region (includes irrigated lands only)

Region (AOI) Name	Acres
Clay Rim	114,809
Foothills	68,861
Kern Fan	106,032
Northern	321,360
Westside	152,013
Wheeler Ridge/Arvin-Edison	172,290
Total	935,365

Determination of Soil Type

The complexity and diversity of soil type over approximately 935,000 irrigated acres in the Kern sub-basin is substantial. The main driving force behind determining soil type was for the purpose of accounting for soil water holding capacities and relationships to crop types and modifications in irrigation management practices. The national SURRGO spatial soils database was initially used to partition the multitude of map unit classifications into three main categories (fine, medium and coarse) based on dominant surface texture within the expected rooting zone of the crops (Figure 2). It should be noted that soil types may also be categorized by drainage classification. Fine textured soils included mostly clays and any sandy clays and silty clays as defined by USDA textural classifications. Coarse textured soils included sands, loamy sands and coarse sandy loams. For the purposes of this evaluation, all other sandy loams (e.g. medium and fine sandy loams) were grouped with the medium classification due to similar water holding capacities and other hydraulic characteristics. Soil type was ultimately used as a variable in the calculation of both SMB and NHI.

Determination of Crop Type

Crop type was determined through the use of the Kern County crop distribution spatial data resources (Figure 3) for 2011 (Kern County, 2011). This annual data resource is detailed by crop type and even within various crop rotations within a single field. It offers a recent summary of existing crop distribution in an area of the state that is rapidly changing from lower water use efficiency annual row crops to higher water use efficiency perennial crops. In some areas, however, annual and forage crops still persist. This is especially true in areas within the Clay Rim and locations associated with dairy operations. The following figures represent all crop distribution within the Kern sub basin (Figure 3) as well as individual major crop types (Figures 4-11).

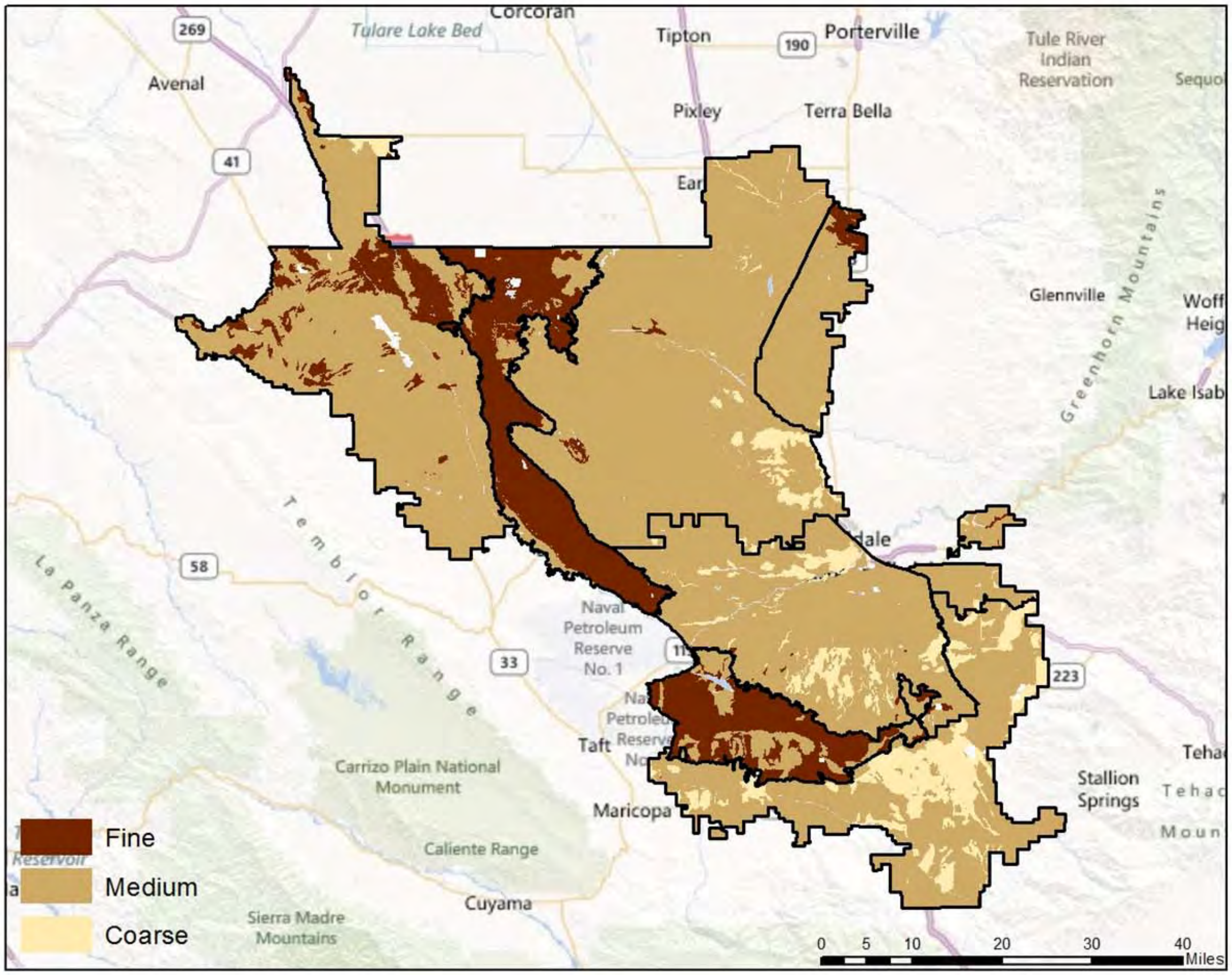

Corcoran
Tulare Lake Bed
Tipton
Porterville
Tule River Indian Reservation
Avenal
Pixley
Terra Bella
Glennville
Greenhorn Mountains
Lake Isab
Tembl or Range
La Panza Range
Naval Petroleum Reserve No. 1
Taft
Carrizo Plain National Monument
Maricopa
Caliente Range
Cuyama
Sierra Madre Mountains
Stallion Springs
Fine
Medium
Coarse
0 5 10 20 30 40
Miles

Figure 2. Generalized soil texture groupings derived from USDA SURRGO spatial soil data.

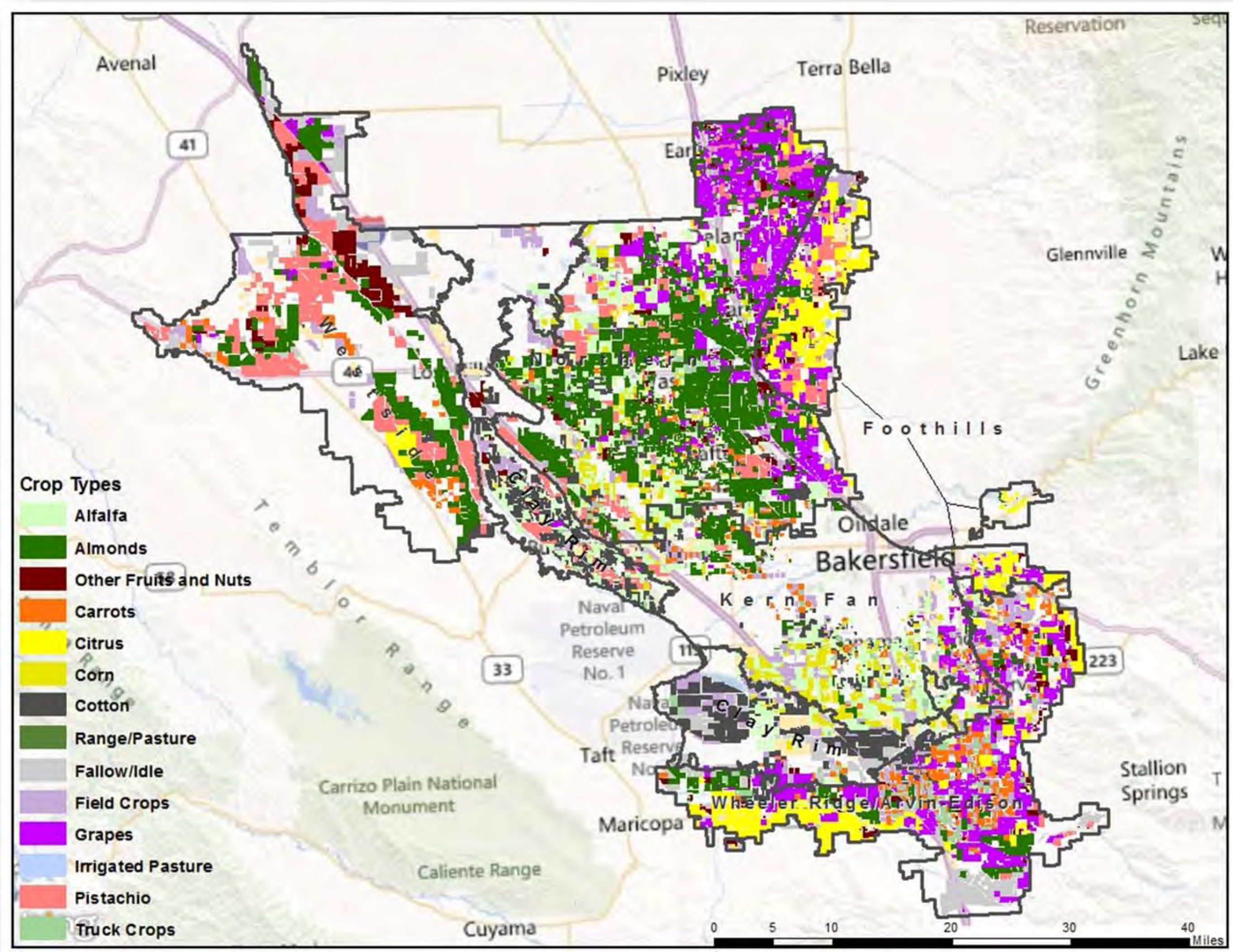


Figure 3. Comprehensive crop types and crop groupings in the KRWCA Sub-Basin.

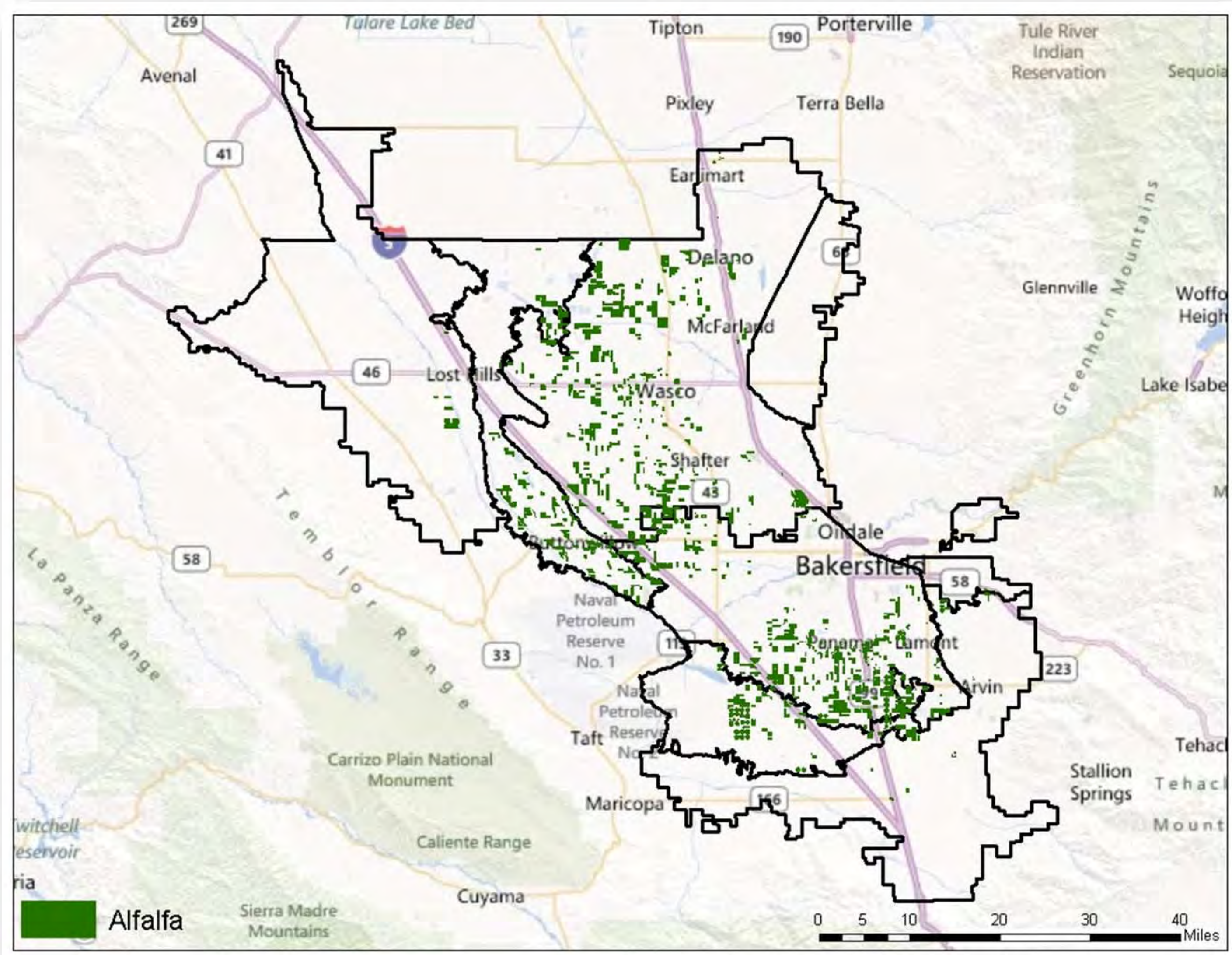


Figure 4. Alfalfa production within the KRWCA Sub-Basin.

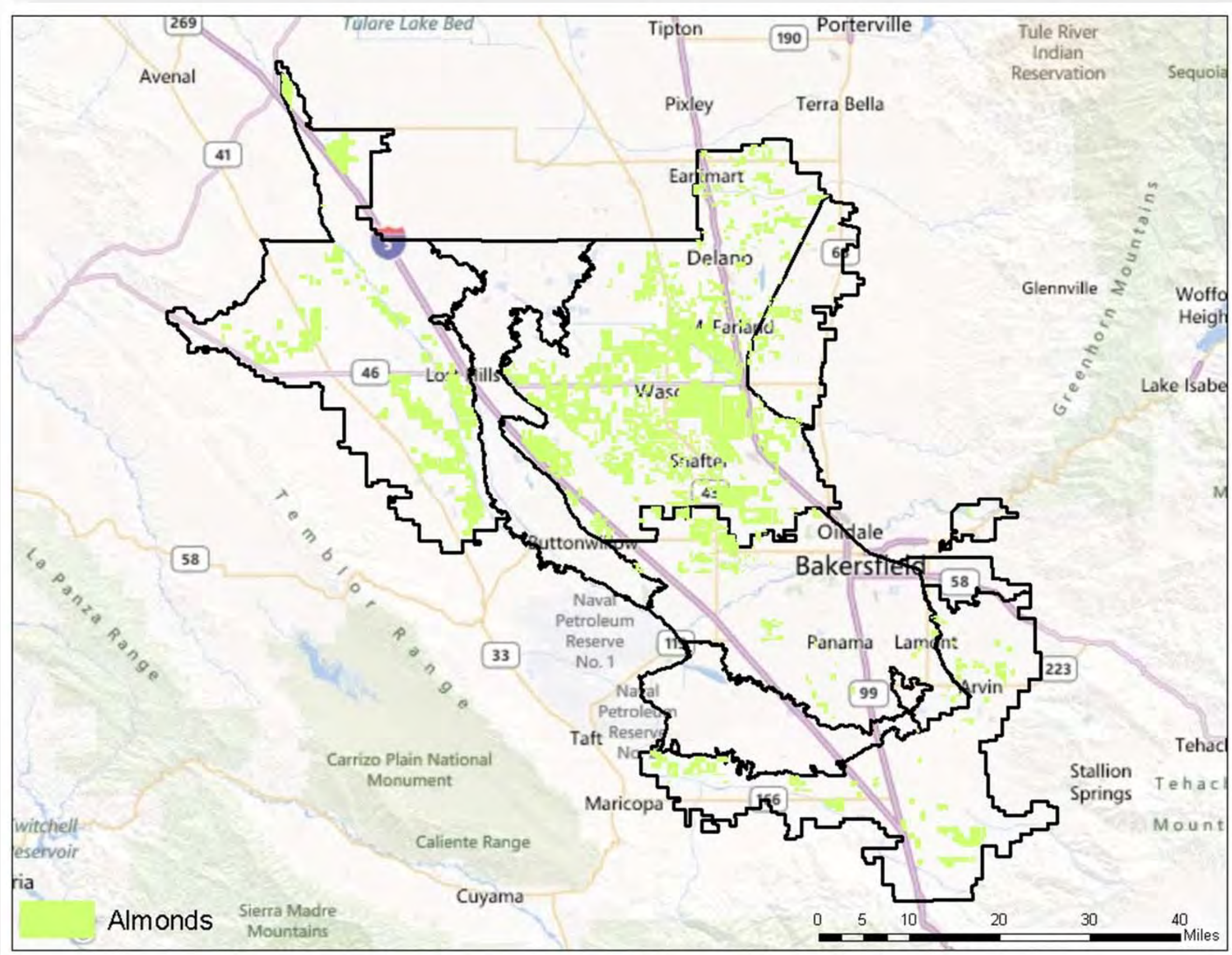


Figure 5. Almond production within the KRWCA Sub-Basin.

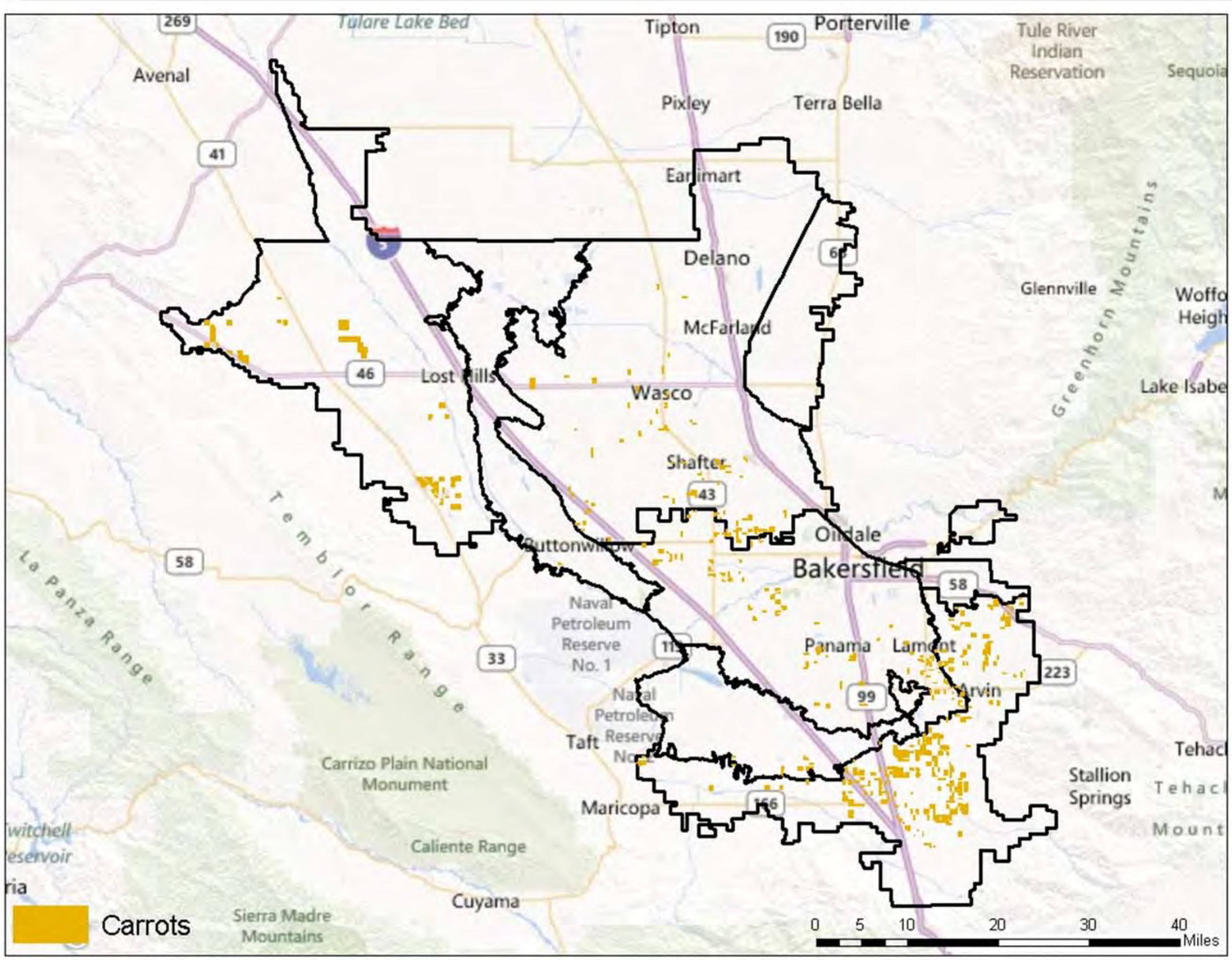


Figure 6. Carrot production within the KRWCA Sub-Basin.

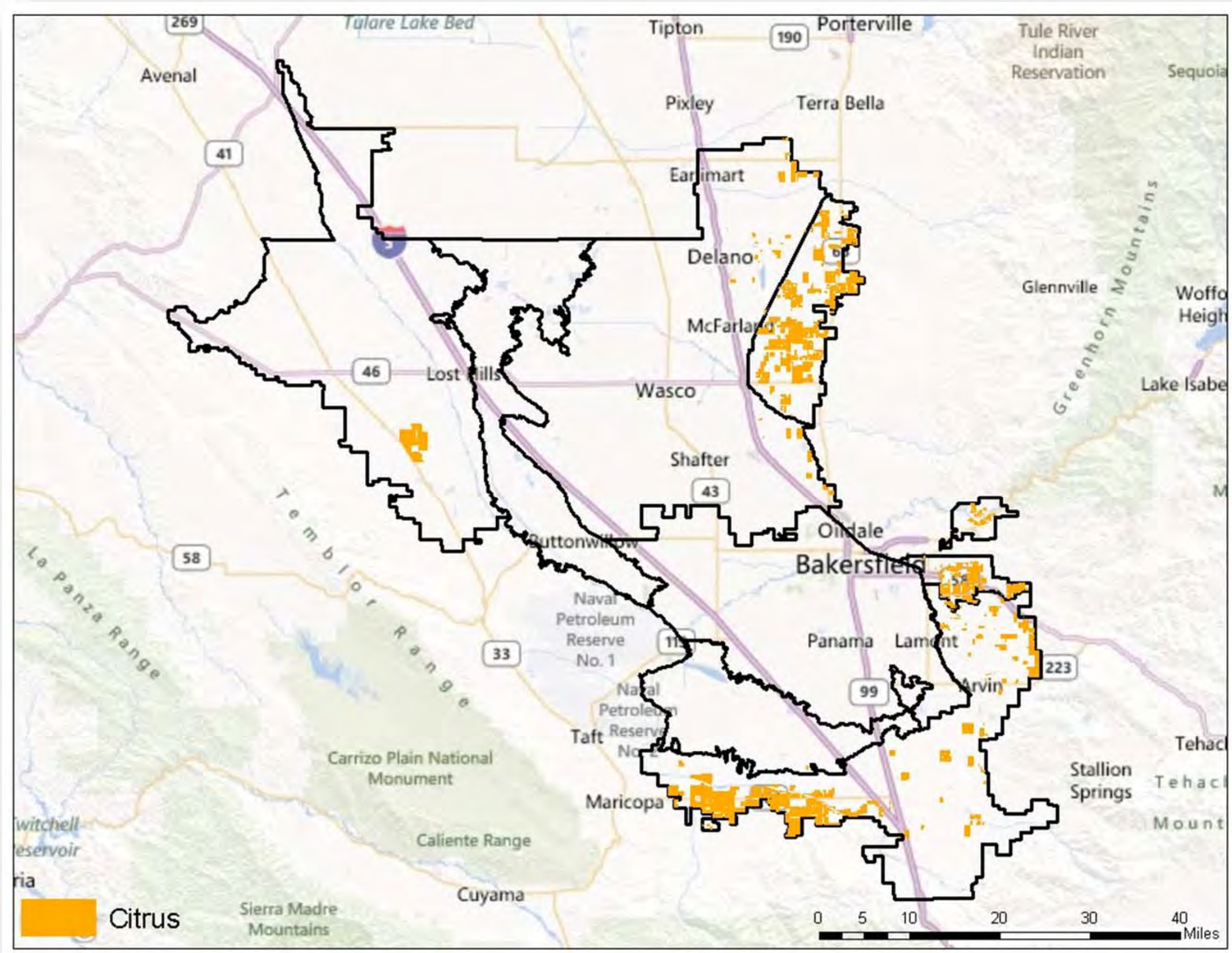


Figure 7. Citrus production within the KRWCA Sub-Basin.

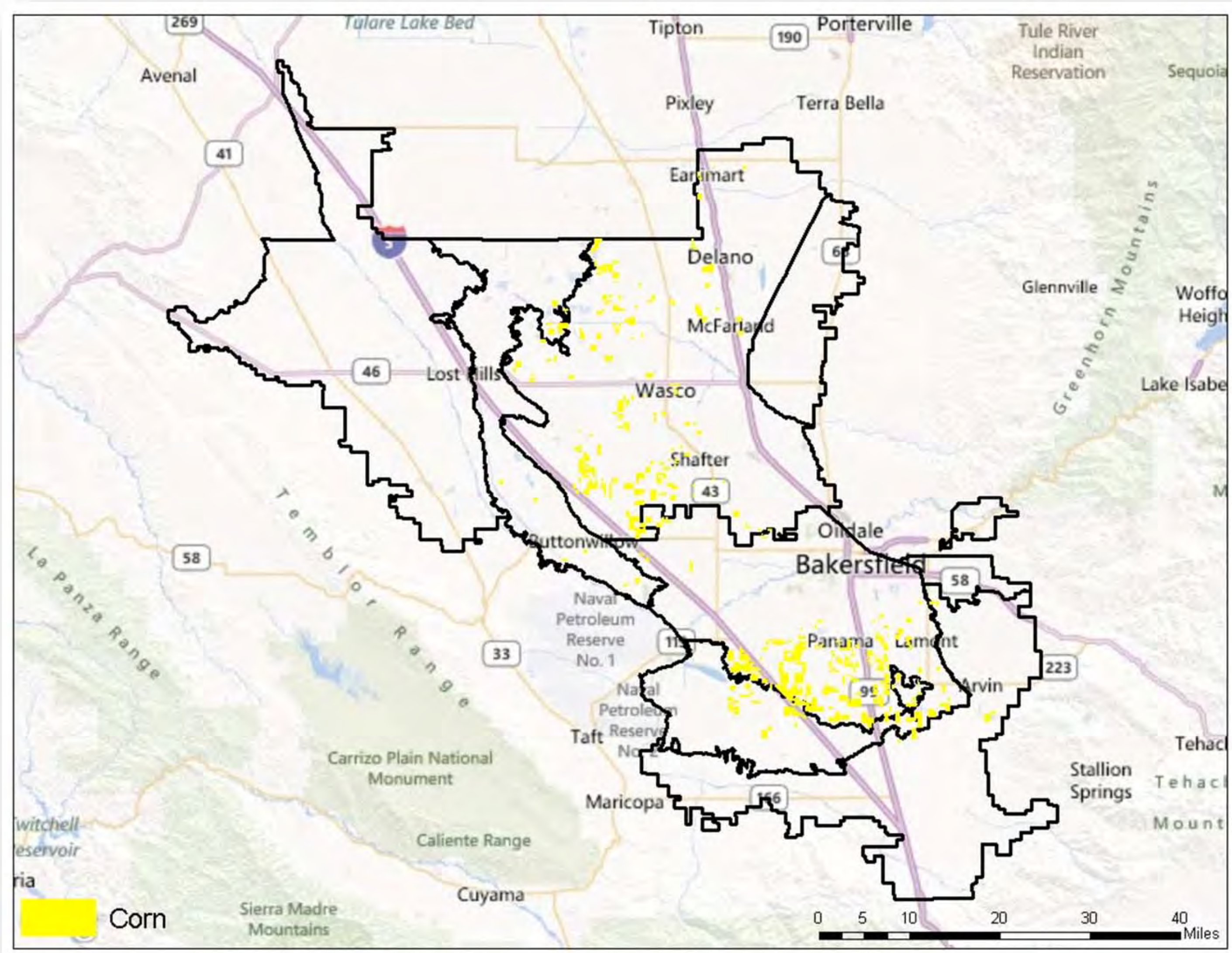


Figure 8. Corn production within the KRWCA Sub-Basin.

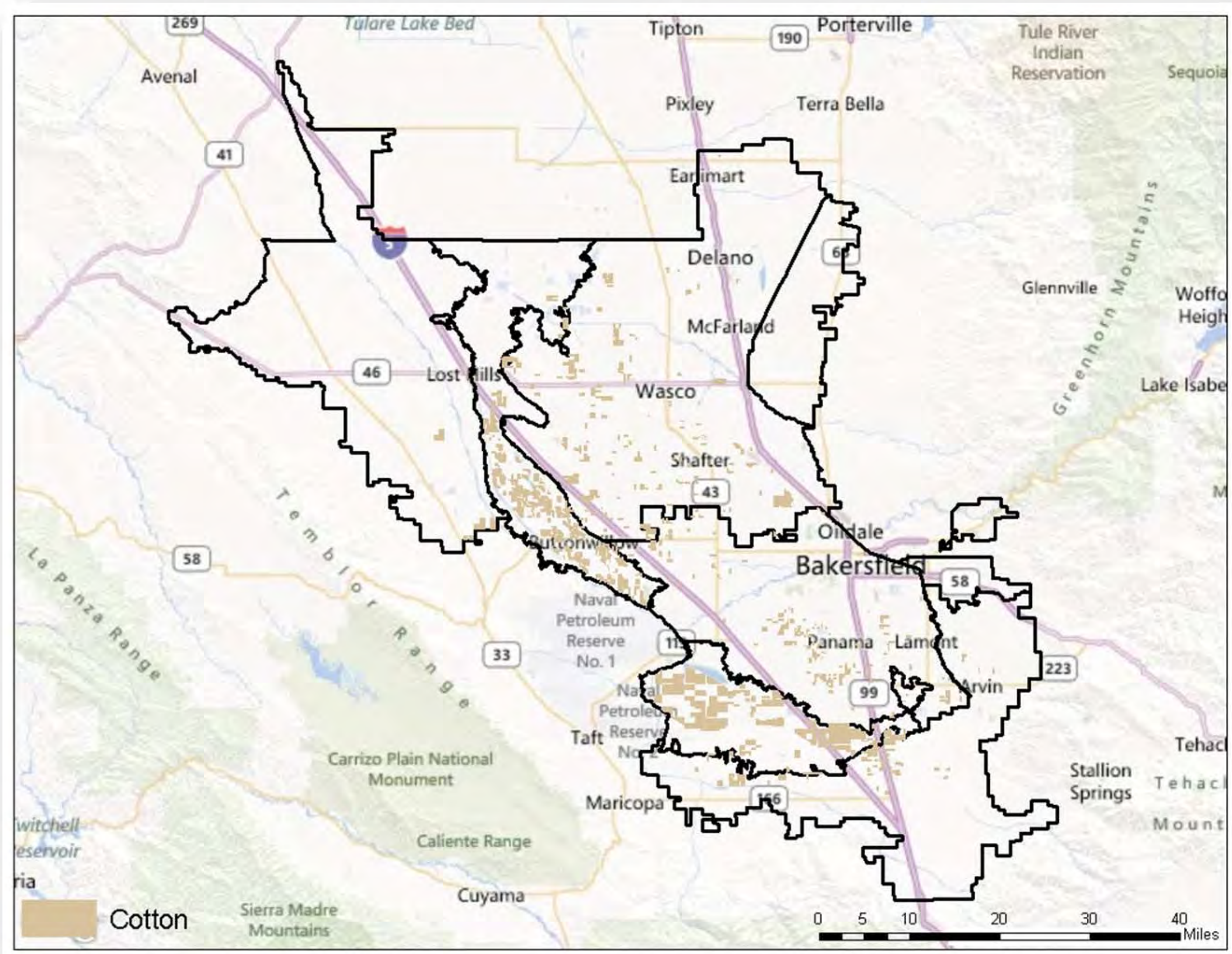


Figure 9. Cotton production within the KRWCA Sub-Basin.

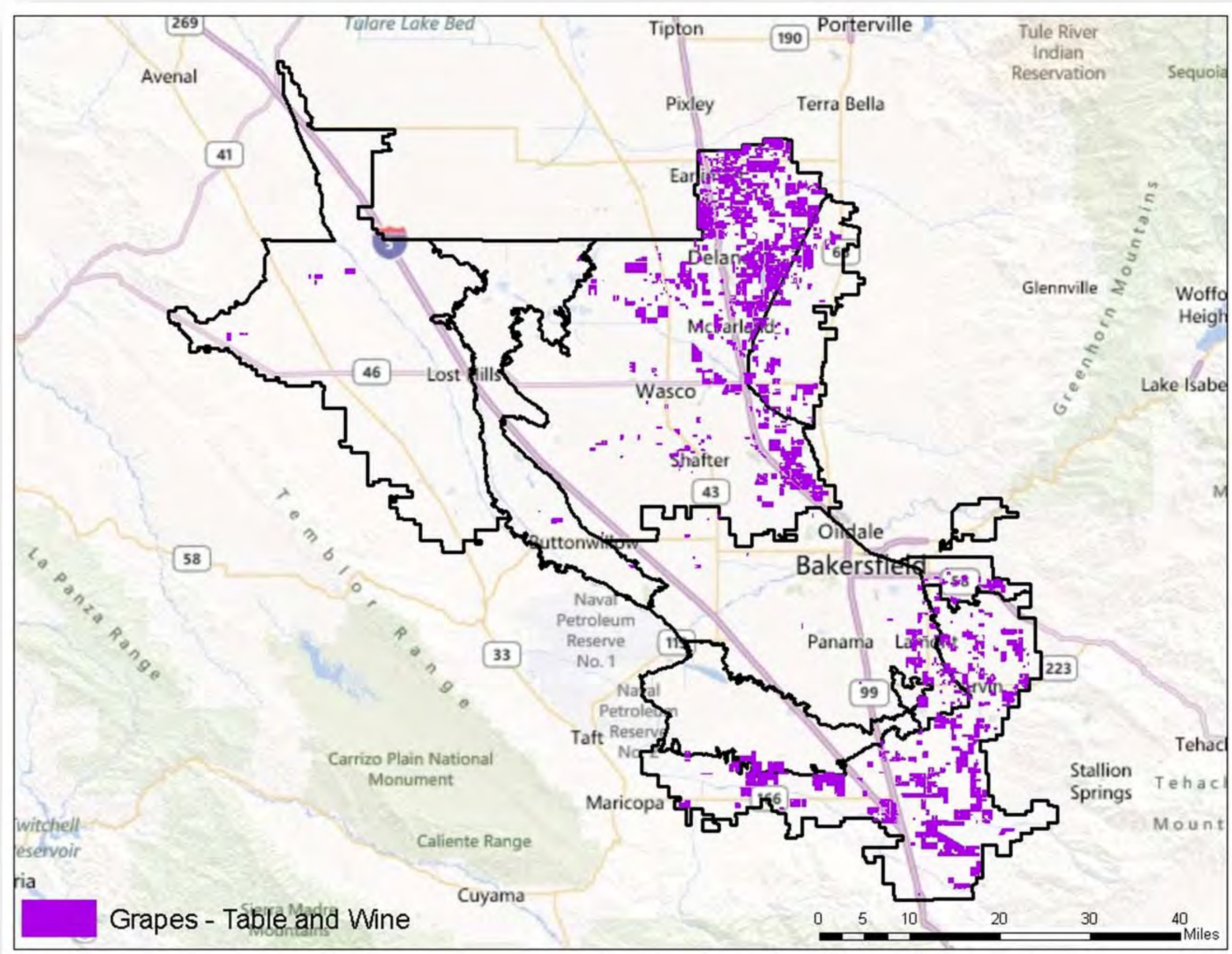


Figure 10. Grape production within the KRWCA Sub-Basin.

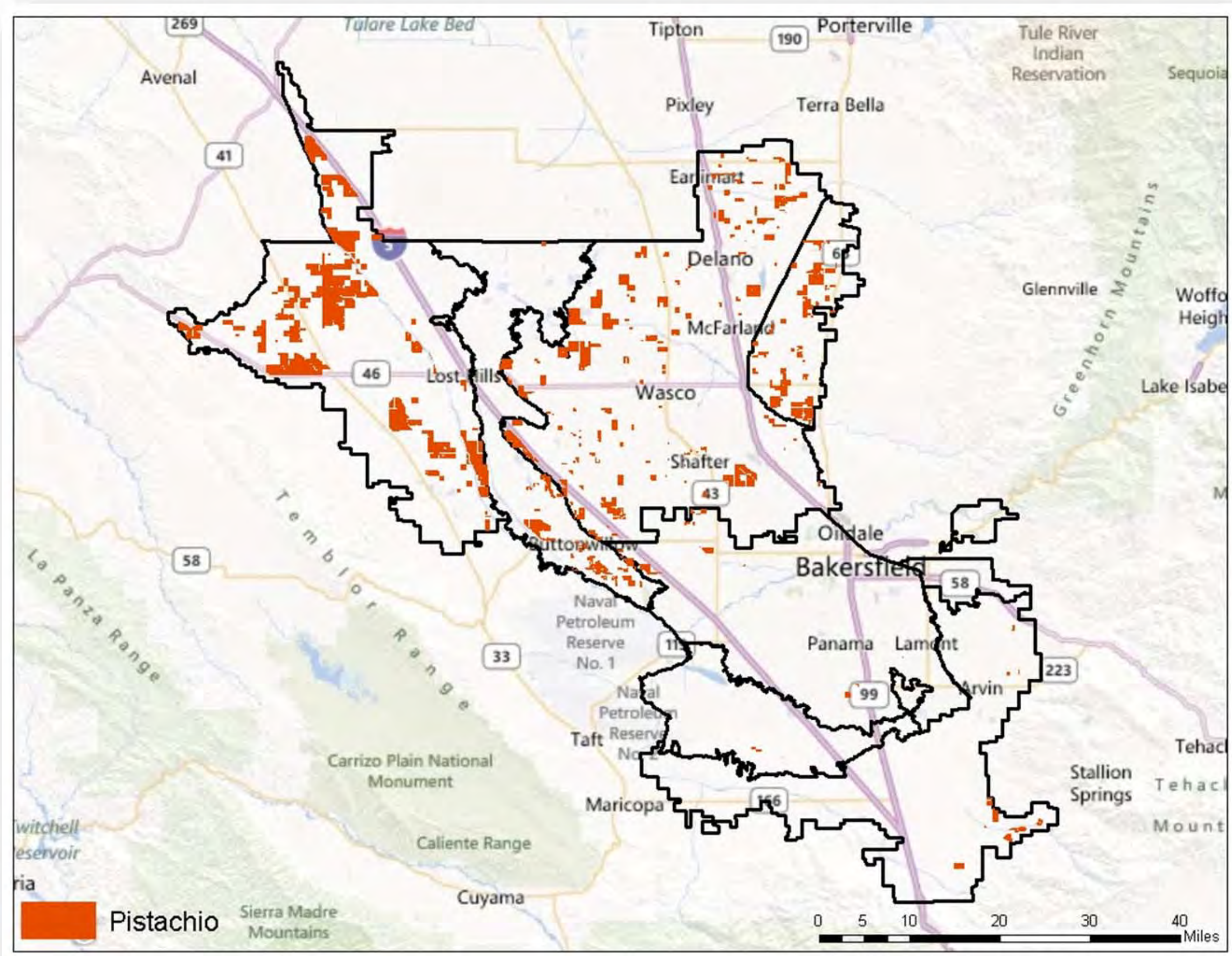


Figure 11. Pistachio production within the KRWCA Sub-Basin.

Historic Cropping Trends and Conversions

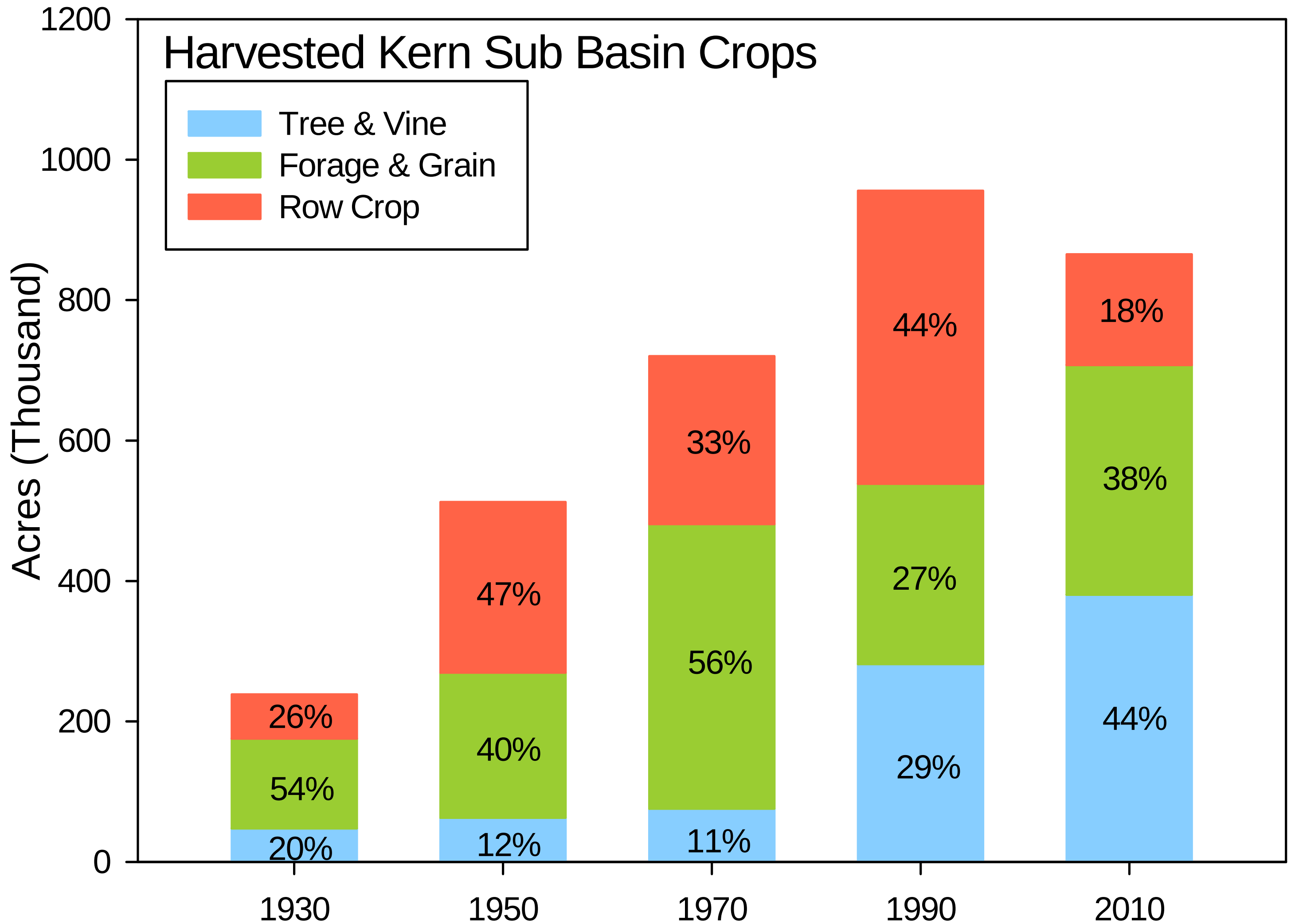
Historic crop trends for Kern Sub-Basin were summarized (Ag Commissioner Records) once every 20 years (1930-2010) to show the growth of agriculture in the county as well as the transition to permanent crops and also the recent (1990-2010) increase in forage crops associated with diaries (Figure 12). Cotton and to a lesser extent other row crops, have significantly been replaced by almonds and other permanent tree crops. This also has resulted in a corresponding shift in irrigation practices from gravity (mostly furrow) to pressurized (mostly drip/micro) systems. This has undoubtedly resulted in a significant reduction of return flows to groundwater and also associated nitrate contributions. The nitrate is allowed to remain in the deeper root zone for longer periods of time with a greater chance of uptake by the crop. It is likely that Kern County is utilizing most of its irrigable land at this point. In fact, the total irrigated acreage actually dropped in 2010 as compared to 1990. Kern County does stretch into agricultural areas of the Antelope Valley; however this area is only sparsely irrigated as related to the remaining part of Kern County within the San Joaquin Valley.

Dairy production has also increased in Kern County over the past 20 years and, as a result so has a significant amount of forage crop production land (Figure 12). For the most part, the lands associated with dairy production are receiving manure as a nutrient source and are, therefore regulated by the CVRWQCB through the Dairy Order. There is, however, forage producing ground that is not regulated under the Dairy Order due the fact that it does not receive manure.

Permanent Crop Irrigation Efficiencies

Irrigation efficiencies in the Kern Sub-Basin are overall, some of the highest in the entire Central Valley. Various resources were used to show the increase in drip/micro irrigation systems in permanent crops (Figure 13). Overall, permanent crops are increasing significantly in the Sub-Basin and in nearly all cases are developed with highly efficient drip and/or micro spray irrigation systems.

This corresponding increase in highly efficient irrigation systems on permanent crops (e.g. grapes) is somewhat similar in other counties (Figure 14), however not to the degree as it has developed in Kern County. This is likely due to the scarcity and expense of water as well as a more dynamic and recent change to permanent crops in Kern County.



Source: Kern County Agricultural Commissioner Crop Reports – Does not include fallow land,1st leaf orchards and is Kern County only

Figure 12. Kern Sub-Basin harvested crop groupings.

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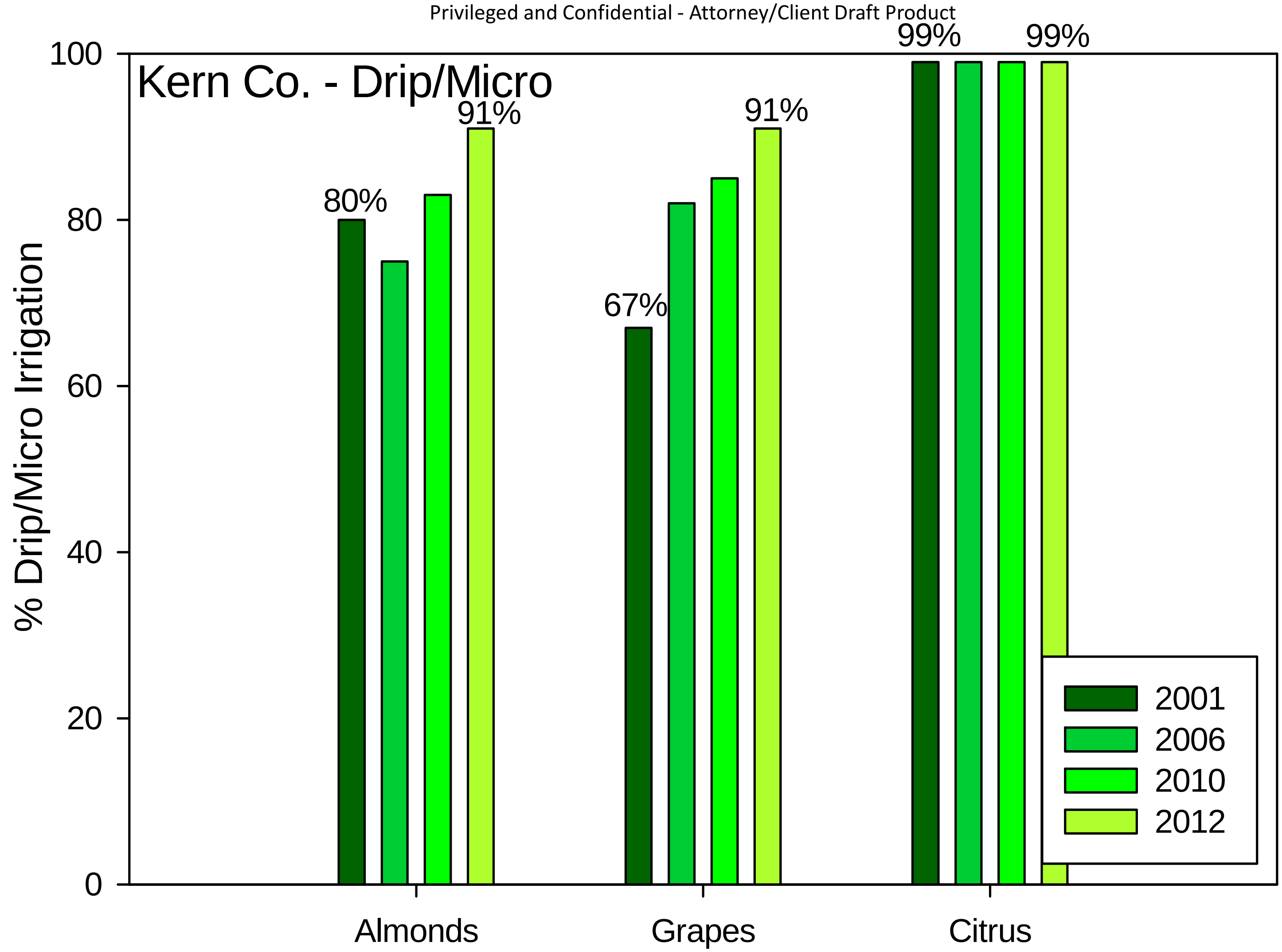


Data Source: 2001, 2010 DWR Irrigation Method Surveys, 2006 DWR Crop Survey, 2012 NewFields

Figure 13. Increase in drip/micro irrigation systems on various permanent crops in Kern County.

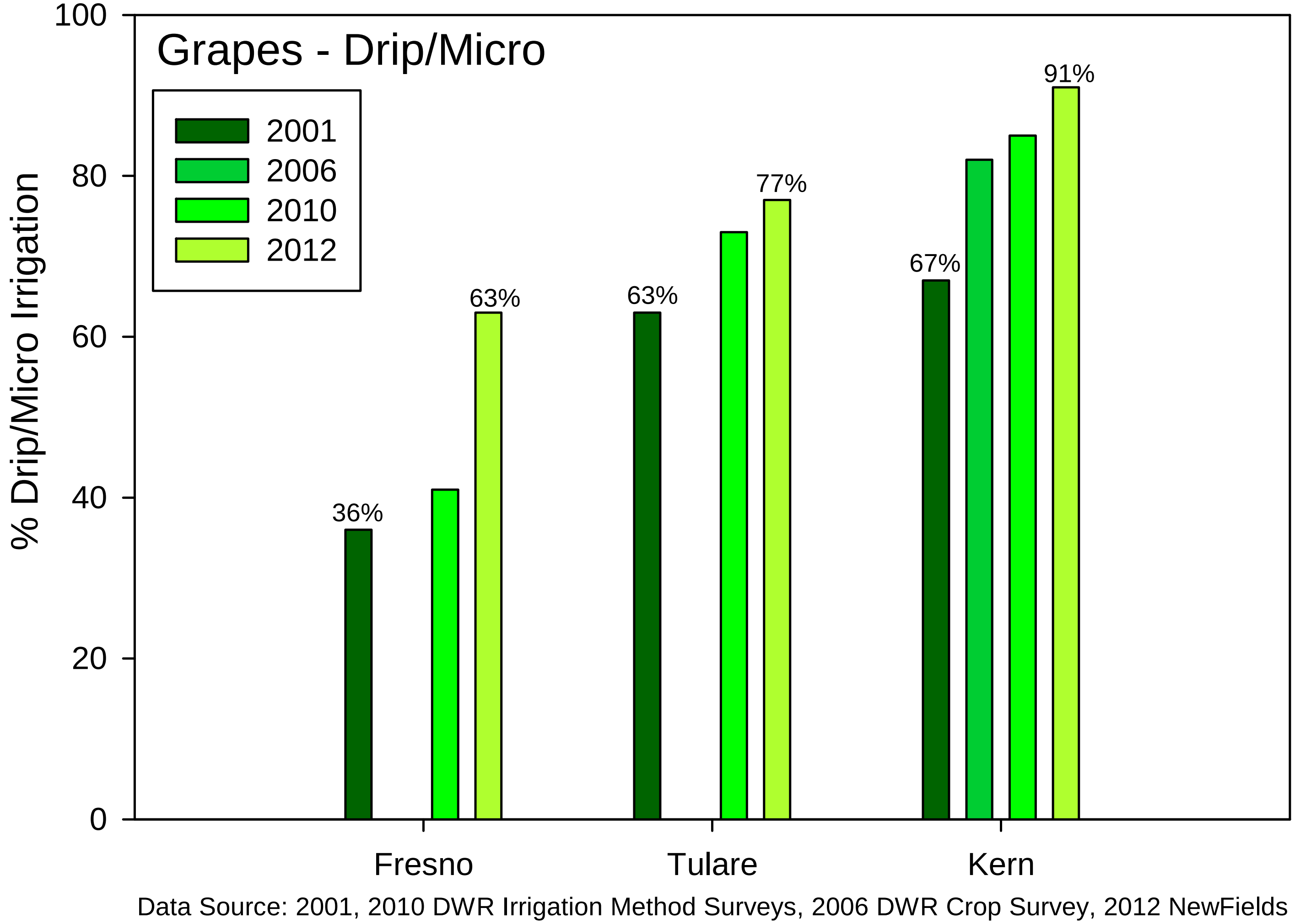


Figure 14. Example (in grapes) of shift to higher efficiency irrigation systems in Fresno, Tulare and Kern Counties.

General Concepts of Nitrogen Fertilizer Recover and Losses

Introduction

A detailed description of nitrogen fertilizer recovery and losses from the literature and applied to the Kern Sub-Basin is provided (Appendix A) as background information to the following sections.

Root Zone Soil Moisture Balance (SMB) Approach

Introduction and Purpose

Soil moisture conditions and nitrate leaching in agricultural systems can vary significantly throughout a year and are impacted primarily by irrigation practices in the Kern Sub-Basin area. This is because effective rainfall (1-3 inches) in this area is insignificant as compared to the range of irrigation water applied to meet crop and environmental demands (28-60 inches (depending on crop type, soil conditions and management practices).

A root zone soil moisture balance (SMB) calculator was used to model and predict potential leaching of available nitrate below the root zone. This was assumed to be nitrate that ultimately would be transported to the first encountered groundwater. It was assumed that any nitrate leached below the specified root zone of the crop was not recoverable by the crop and therefore transportable to groundwater.

The advantages of using a SMB approach include:

- a field- or region-specific tool, commonly used to quantify nitrate leaching below the root zone
- defensible and quantifiable results that can be used as input parameters for groundwater modeling purposes
- inclusion of various input parameters designed to optimize the results for a specific field, scenarios, or a smaller area

The disadvantages of using the SMB approach for the Kern Sub-Basin include:

- relatively in accurate representation of larger areas, thus why only representative scenarios can be developed
- difficultly in spatial application
- unwieldy number of iterations/options due to numerous and detailed input parameters
- complicated numerical applications and summary of results
- variable results over larger areas of land

The purpose of this effort was predominantly for:

- Development of representative scenarios (return flows) as input parameters for modeling work conducted by Rob Gailey/SGI Consultants.

- A better understanding of the unique nature of agricultural practices in the Kern Sub-Basin.
- A better understanding of the diversity of potential results for Basin-wide agricultural practices.

Approach

Twenty one scenarios were developed that represented the major cropping systems across all six regions within the Kern sub basin. Ground truthing efforts were conducted throughout this area that documented irrigation practices on approximately 20% of all irrigated fields. This information was obtained spatially and overlain on the regional areas. When an irrigation practice on a certain crop type was documented greater than 90% of the time, that irrigation method was assigned to that crop type within a specified region. Where irrigation methods varied within crop type, a "mix" of methods was assumed. This resulted in correspondingly lower irrigation application efficiencies as well. Otherwise irrigation application efficiencies were used based on various sources including local knowledge (Sanden, personal communication, 2012) (Paramount Farms, 2012) and irrigation district reporting (Arvin Edison Water Use Report, 2012)

Representative scenarios were developed for common crop systems and soil types and represent the vast majority of cropping systems in the Kern Sub-Basin. For example, much of the Clay Rim area is cropped with cotton and not necessary almonds. Therefore a "cotton on fine textured soils" scenario was developed as was an "almond on medium textured soils." A variety of other representative scenarios including other SMB inputs are summarized (Table 2). These scenarios were developed in conjunction with Blake Sanden, UC Cooperative Extension, Kern County and deemed as representative for the area.

It should be noted that certain set assumptions were developed for the 21 scenarios developed and modeled. Due to the variation in cropping systems, soil types, irrigation practice and management, rooting depths, etc., results for total return flow and to a lesser extent total applied water should be considered as estimates only and specifically for the input parameters of each scenario only. It is entirely possible to find a combination of input parameters somewhere over the nearly 1,000,000 acres of irrigated land in the Kern Sub-Basin that result in less or more return flows or applied water. Again, this work was performed for the purpose of providing reasonable estimates as input parameters for the groundwater modeling work that are representative of the present-day Kern Sub-Basin.

Results and Conclusions

In general, results indicate that perennial crops on high efficiency irrigation systems (common to the Kern sub basin), result in limited return flows to groundwater. The largest return flows occur under corn/wheat, sudan/wheat or alfalfa crop rotations that are commonly associated with feeding operations for dairies. The majority of these systems are regulated under the dairy order. Other row crops such as cotton/wheat and carrot/potato rotations result in moderate return flow estimates mostly because of the types of irrigation methods and management employed.

Again, these estimates of return flows and applied water are based on reasonable input data to the model, however as input data is altered due to site specific conditions, the results will also be modified.

Table 2. Scenario summary for common crop types, regions, soil types and irrigation methods. Summary table also includes assumed irrigation efficiencies, effective rooting depths and resultant return flows and applied water.

Scenario	Region	Crop	Soil	Irrigation Method	Irrigation Efficiency (%)	Rooting Depth (Effective) (ft)	Total Return Flow (in)	Total Applied Water (in)
1	Foothills	Citrus	Medium	Drip/Micro	95%	4	2.3	45.6
2	Foothills	Grape	Medium	Drip/Micro	95%	4	1.9	31.9
3	Kern Fan	Alfalfa	Coarse	Border	85%	6	9.8	61.7
4	Kern Fan	Corn/Wheat	Coarse	Furrow/Border	75%	3	14.8	57.7
5	Kern Fan	Cotton	Coarse	Furrow/Border	80%	3	10.2	40.0
6	Northern	Almonds	Coarse	Drip/Micro (90%) & Flood (10%)	90%	7	5.0	46.2
7	Northern	Grape	Coarse	Drip/Micro (75%) & Flood (25%)	80%	5	7.9	38.1
8	Westside	Almonds	Medium	Drip/Micro	95%	6	2.4	46.6
9	Westside	Pistachio	Medium	Drip/Micro	95%	6	2.7	45.8
10	Westside	Pistachio	Coarse	Drip/Micro	90%	7	5.3	48.3
11	Wheeler Ridge/A-E	Grape	Medium	Drip/Micro	95%	4	2.0	34.1
12	Wheeler Ridge/A-E	Citrus	Medium	Drip/Micro	95%	4	2.9	48.3
13	Wheeler Ridge/A-E	Grape	Coarse	Drip/Micro	90%	5	3.9	36.0
14	Wheeler Ridge/A-E	Carrots/Potato	Coarse	Sprinkler	85%	2	8.2	51.7
15	Clay Rim	Cotton	Fine	Furrow	90%	3	5.2	34.4
16	Clay Rim	Cotton/Wheat	Fine	Furrow/Border	85%	3	8.7	55.2
17	Clay Rim	Alfalfa	Fine	Border	85%	5	9.6	60.3
18	Foothills	Pistachio	Medium	Drip/Micro	95%	6	2.8	42.1
19	Northern	Alfalfa	Medium	Border	85%	6	8.6	60.4
20	Westside	Almonds	Coarse	Drip/Micro	95%	7	2.8	46.6
21	Clay Rim	Pistachio	Fine	Drip/Micro	95%	5	2.6	41.2

Note: Irrigation efficiencies and rooting depths reviewed by Blake Sanden, UCCE Cooperative Extension, Kern County. Other input provided by Boswell and Paramount Farms, etc.

Preliminary Estimated Nitrogen Leaching from Select Cropping Scenarios

Introduction

Preliminary estimates of nitrogen (N) leaching under five cropping scenarios that represent different leaching potentials are provided below. The estimates are given as a range because of the vast variability in factors that influence N leaching within each of these scenarios. The assumptions used to develop these estimates are also provided.

It is imperative to note that estimating nitrate leaching, even under specified conditions, is a highly complex task. Therefore, the results of any N leaching estimating methods should be interpreted as precisely that – estimates only – and are subject to modification with new information.

The significance of the nitrate leaching estimates for diverse cropping scenarios is simply that they are different; crop, irrigation method and soil factors in combination with one another result in a wide range of nitrate leaching estimates. This finding is substantiated by numerous other authors whose work contributes to the scientific literature on N dynamics in cropping scenarios (Viers, 2012), and implies that nitrate leaching from various cropping systems cannot be considered or treated as similar systems.

The most significant effort to date focused on assessing nitrate contamination in groundwater from agricultural sources in California resulted in the UC Nitrate Hazard Index (NHI). This effort intentionally avoided any attempt to place absolute values on total amounts of nitrate leached, for the reasons stated above (Wu et al., 2005). This work was developed and reviewed by the foremost experts in this multi-disciplinary subject, and should serve as an indication of the caution with which estimates of nitrate leaching must be interpreted. This approach was subsequently modified and used to identify agriculture areas in the Tulare Lake Basin and Salinas Valley that are vulnerable to nitrate contamination in groundwater (Dzurella et al., 2012).

Therefore, the estimates of nitrate leaching provided below (Table 6) should be interpreted merely as average ranges for each scenario.

The cropping scenarios are described as follows:

- Surface-irrigated cotton on coarse textured soils
- Micro/drip-irrigated almonds on medium-fine textured soils
- Drip-irrigated grapes on medium-textured soils
- Drip-irrigated citrus on medium- to fine-textured soils
- Surface irrigated silage (summer) and forage grain (over winter) double-crop

Table 6 summarizes the cropping scenarios, typical N inputs, and assumed N losses in each scenario. The assumptions and rationale used to derive these values are described in the sections that follow.

Appendix A provides greater detail of estimated nitrate leaching by representative cropping scenarios for the crops summarized in Table 3. The results presented in the appendix were developed from reviewing scientific literature from peer-reviewed journals, extension publications, personal communications and privately-developed publications. No simulation models or statistical methods were used. The purpose in providing these results is to show the variability in the literature and impactful parameters that can significantly influence potential nitrate leaching.

Table 3. Summary of Findings – Estimates of Nitrate Leaching in Five Major Crop Scenarios in the Kern Sub-Basin.

Crop Type	Irrigation Method	Soil Texture	Typical Nitrogen Application Rate (lb/acre/yr)	Estimated Applied Nitrogen taken up by Crop		Estimated N remaining in soil after crop uptake (lb/ac/yr) [a]	Estimated Losses other than Nitrate Leaching (lb/ac/yr) [b]	Estimated Nitrogen Available for Leaching (lb/ac/yr)	Estimated Potential Nitrogen Leached as Nitrate N (lb N/ac/yr)
				%	lb/ac/yr				
Cotton-wheat double crop	Surface	Medium -coarse	180 – cotton 220 - wheat	30-40 (cotton) 40-50 (wheat)	54-72 (cotton) 88-110 (wheat)	108-125 (cotton) 110-132	74 (cotton) 90 (wheat) 164 (total)	34-51 (cotton) 20-42 (wheat) 54-93 (total)	30-70
Almonds	Micro/drip	Medium -fine	275 (mature trees at least 6 years old)	50-65	138-179	96-138	28	68-110	10-50
Grapes	Drip	Fine	50-100 (mature vines at least 4 years old)	30-40	15-20	30-35	5	25-30	10-20
Citrus	Drip	Fine	80 [c] (mature trees at least 7 years old)	60-70	48-56	24-32	8	16-24	10-20
Silage corn – winter forage grain	Surface	Medium -coarse	350 (corn) [d] 220 (wheat) [d]	30-40 (corn) 40-50 (wheat)	105-140 (corn) 88-110 (wheat)	210-245 (corn) 110-132 (wheat)	154 (corn) 97 (wheat)	56-91 (corn) 13-35 (wheat) 69-126 (total)	50-100

[a] Does not account for immobilization or mineralization.
[b] Denitrification and volatilization. Estimates from Table 4 and Rotz (2004). For silage corn and wheat also accounts for nitrous oxide emissions.
[c] Applied to oranges through fertigation (in addition to 30 lb N foliar application).
[d] Fertilized with dairy slurry.

Nitrate Hazard Index (NHI) Approach

Introduction and Purpose

The NHI was developed by UC Davis and other researchers as a qualitative method to assess the potential for nitrate leaching to groundwater based on at least three initial variables (e.g. crop type, soil type and irrigation method).

The advantages of using a NHI approach include:

- Offers the ability to span and accurately assess large areas of land with a spatial resource
- Easily shows change over time as a result in crop or irrigation method changes
- Easily modified, flexible, and understandable
- Based on a field by field assessment, therefore can be aggregated to a larger area
- Results in strategic and justified locations for monitoring and therefore cost savings
- Approved as an acceptable method for quantifying the potential for nitrate leaching by the State Water Resources Control Board

The disadvantages of using the NHI approach include:

- A qualitative assessment, however is based on quantitative/proven research and local knowledge
- Requires some grouping of input data (e.g. soil type) at times depending on the size of the area and data resources available
- Requires up-to-date crop mapping (available for Kern County on an annual basis, however less frequently available elsewhere)

An excellent discussion of the justification, use, strengths, limitations and results of the NHI for the Southern San Joaquin Valley (including the Kern Sub-Basin) can be found at the following reference below. The reader is strongly encouraged to review section 2.2.3 (pages 12-17) – Leaching Vulnerability Assessment that is included in the link below.

http://groundwaternitrate.ucdavis.edu/files/139103.pdf

or at:

Dzurella, K.N., Medellin-Azuara, J., Jensen, V.B., King, A.M., De La Mora, N., Fryjoff-Hung, A., Rosenstock, T.S., Harter, T., Howitt, R., Hollander, A.D., Darby, J., Jessoe, K., Lund, J.R., & Pettygrove, G.S. 2012. Nitrogen Source Reduction to Protect Groundwater Quality. Technical Report 3 in: Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for the State Water Resources Control Board Report to the Legislature. Center for Watershed Sciences, University of California, Davis.

The purpose of this preliminary effort was predominantly to develop a Kern Sub-Basin specific NHI that would demonstrate the changes over approximately 20 years as well as show the flexibility by addition of Nitrogen Use Efficiency (NUE) estimates.

Approach

The approach for the NHI assessment for the Kern Sub-Basin was similar to that performed by researchers at UC Davis (Dzurella, et al., 2012) however was modified for the unique attributes of the Kern Sub-Basin area. One of the major differences is that previous researchers used DWR crop mapping from 2006, while 2011 crop mapping from Kern County was used for our analysis. Also, soils were likely grouped somewhat differently. Also, irrigation practices specific to the Kern Sub-Basin were considered for this analysis including representative distribution of current irrigation methods.

An NHI was developed based on DWR crop mapping and associated irrigation practice for 1990 and Kern County crop mapping for 2011. Soil type remained constant for all analyses.

An additional NHI was developed for 2011 results only and attempted to incorporate three very broad NUE estimates of 25%, 50% and 75%. The purpose in conducting this analysis was to show the flexibility and additionality of the NHI approach, however is not intended to represent actual field conditions.

Results and Conclusions

A comparison of 1990 and 2012 NHI results (Figures 15 and 16) specifically for the Kern Sub-Basin indicate significant reduction in nitrate risk to groundwater. It is intuitive that this reduction has developed from the conversion of annual field and row crops (irrigated with less efficient surface methods) to permanent tree and vine crops (predominantly (>90%) irrigated with drip and micro-irrigation systems).

The results of this analysis also allow for field-specific location of areas where best use of monitoring and management practices can have the most impactful result. The "high vulnerability" areas can be shown at the field level, rather than at a regional level and better represent existing conditions. Identification of specific circumstances that warrant more than just a "high" and "low" vulnerability designation are possible using the NHI approach.

A second NHI analysis was conducted to simply show the flexibility and additionality of the NHI, by incorporating three sub basin-wide NUE estimates of 25, 50 and 75 percent (Figures 17, 18, and 19). Although this is neither realistic nor appropriate in this area due to the variation in crop type and management practices, it does provide an excellent demonstration of incorporation of additional variables to further refine the power of the NHI analysis. As would be expected, NHI is reduced with increasing NUE. The key result of this additional variable, however, is that results can be shown on a field by field basis annually.

Although we have not conducted specific analyses for areas beyond the Kern Sub-Basin related to this work, based on the information presented by (Pettygrove, 2012) it is clear that the nitrate risk to groundwater is significantly less for the Kern Sub-Basin area compared to other areas to the North.

It should be noted that additional variables can likely be included in the NHI calculation, thus strengthening it predictive capabilities. Some of these additional variables may include, but are not limited to:

- Nitrogen use efficiency
- Effective precipitation
- Depth to groundwater
- Variations in stratigraphy and soil type
- Specific best management practices
- Etc.

Overall the NHI approach is a powerful, flexible, recommended, and defensible tool that can be used for assessing large landscapes over time and documenting relative nitrate leaching hazards.

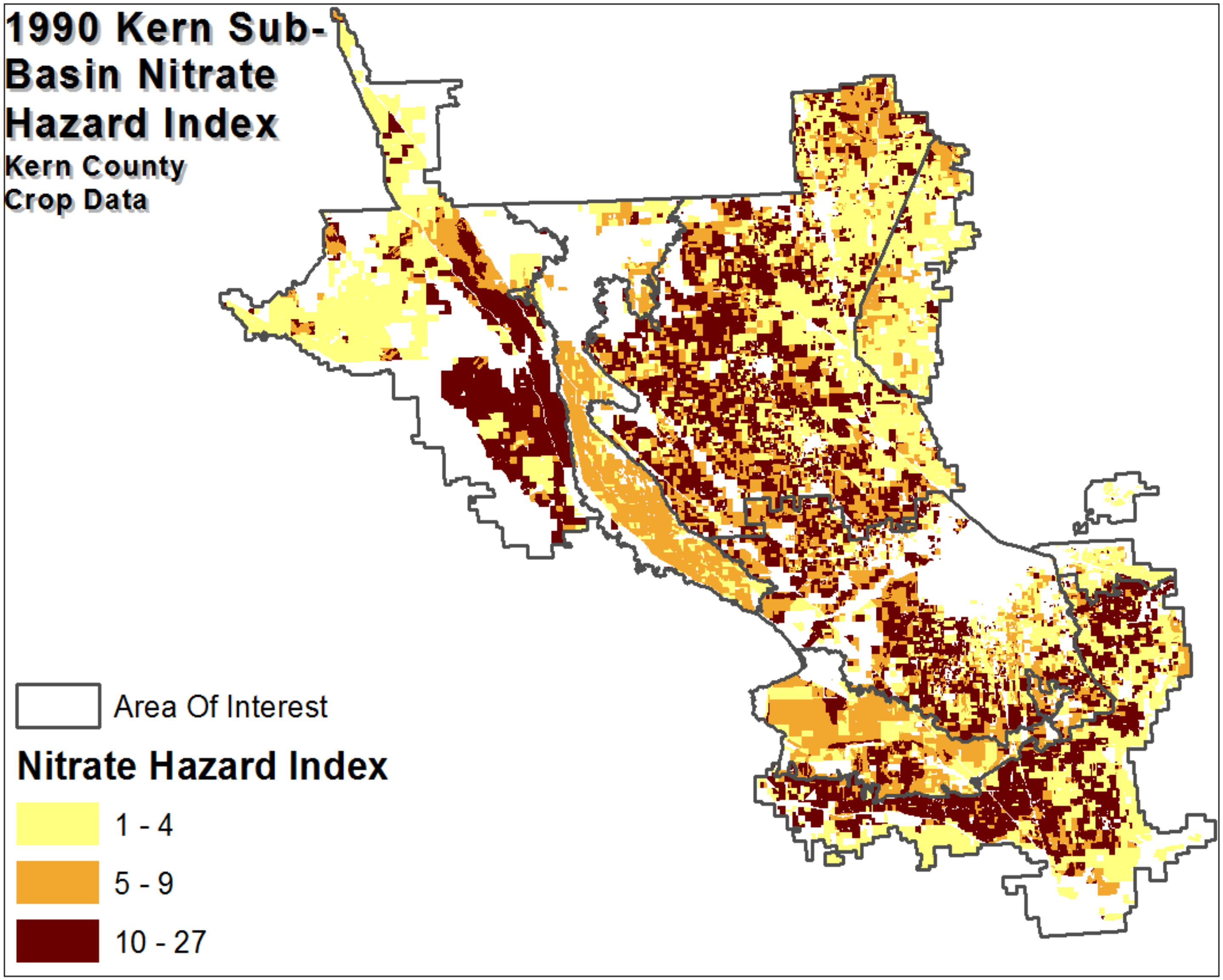


Figure 15. Kern Sub-Basin preliminary Nitrate Hazard Index - 1990

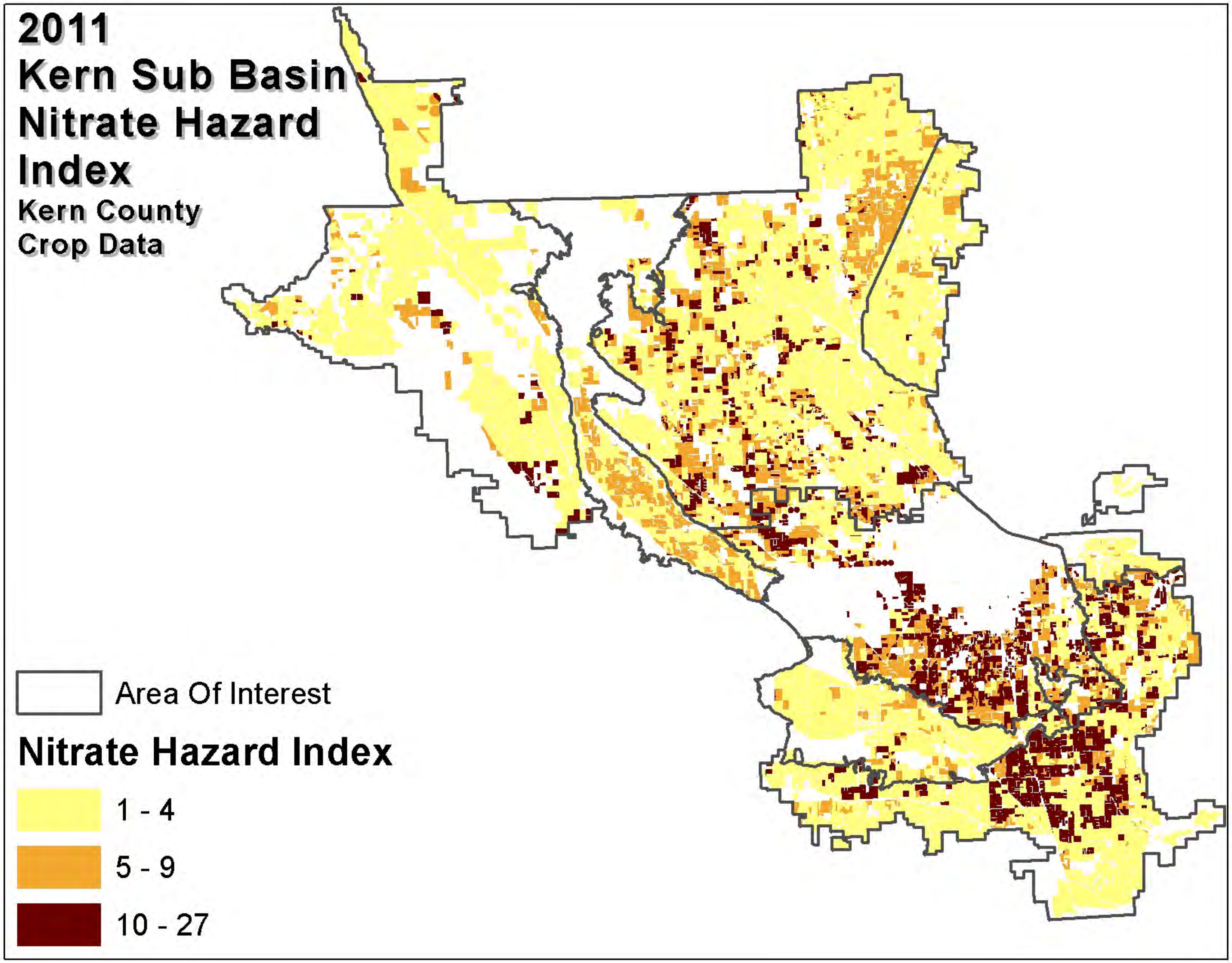

2011
Kern Sub Basin
Nitrate Hazard
Index
Kern County
Crop Data
Area Of Interest
Nitrate Hazard Index
1 - 4
5 - 9
10 - 27

Figure 16. Kern Sub-Basin preliminary Nitrate Hazard Index - 2011

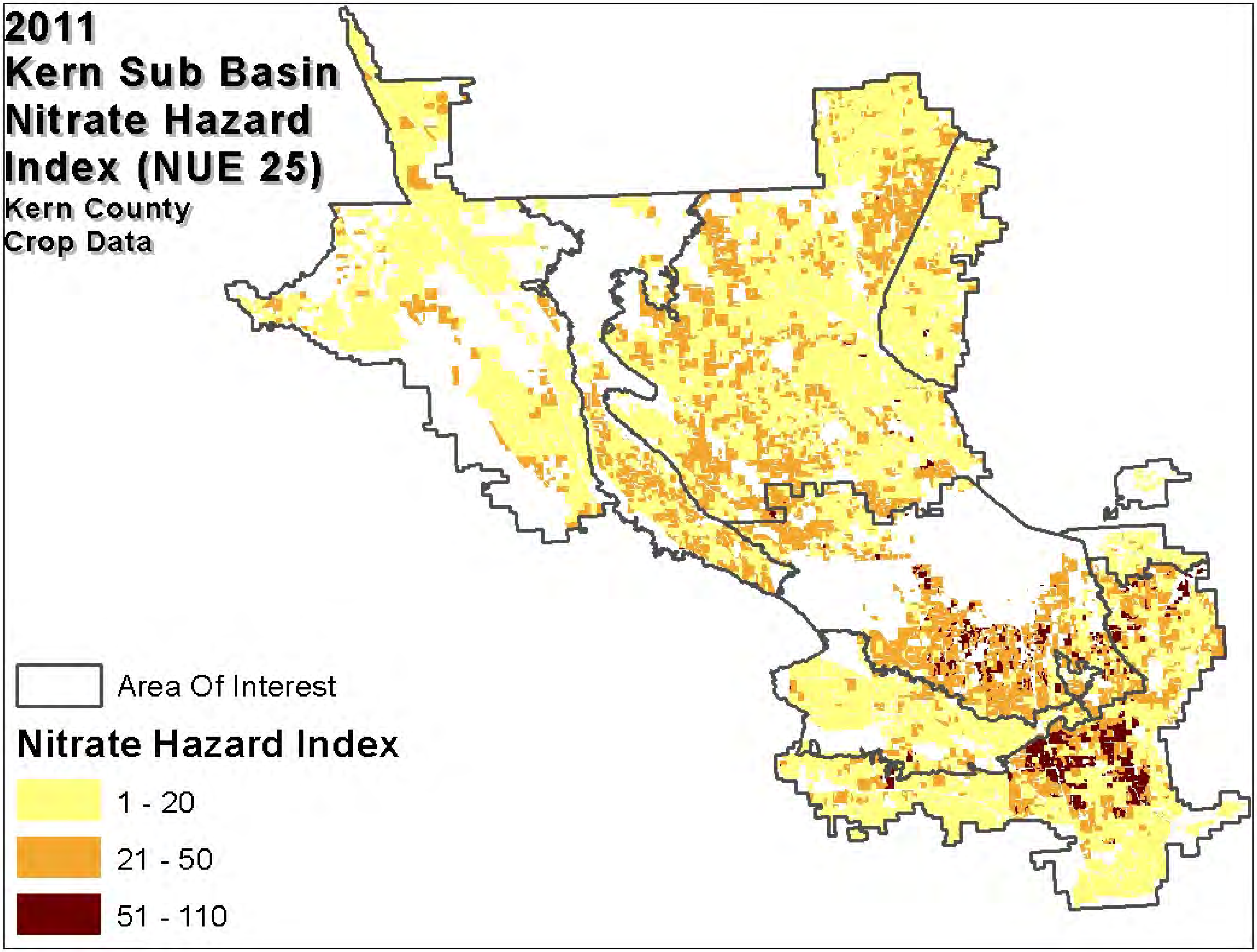


Figure 17. Kern Sub-Basin preliminary Nitrate Hazard Index, including 25% NUE estimate - 2011

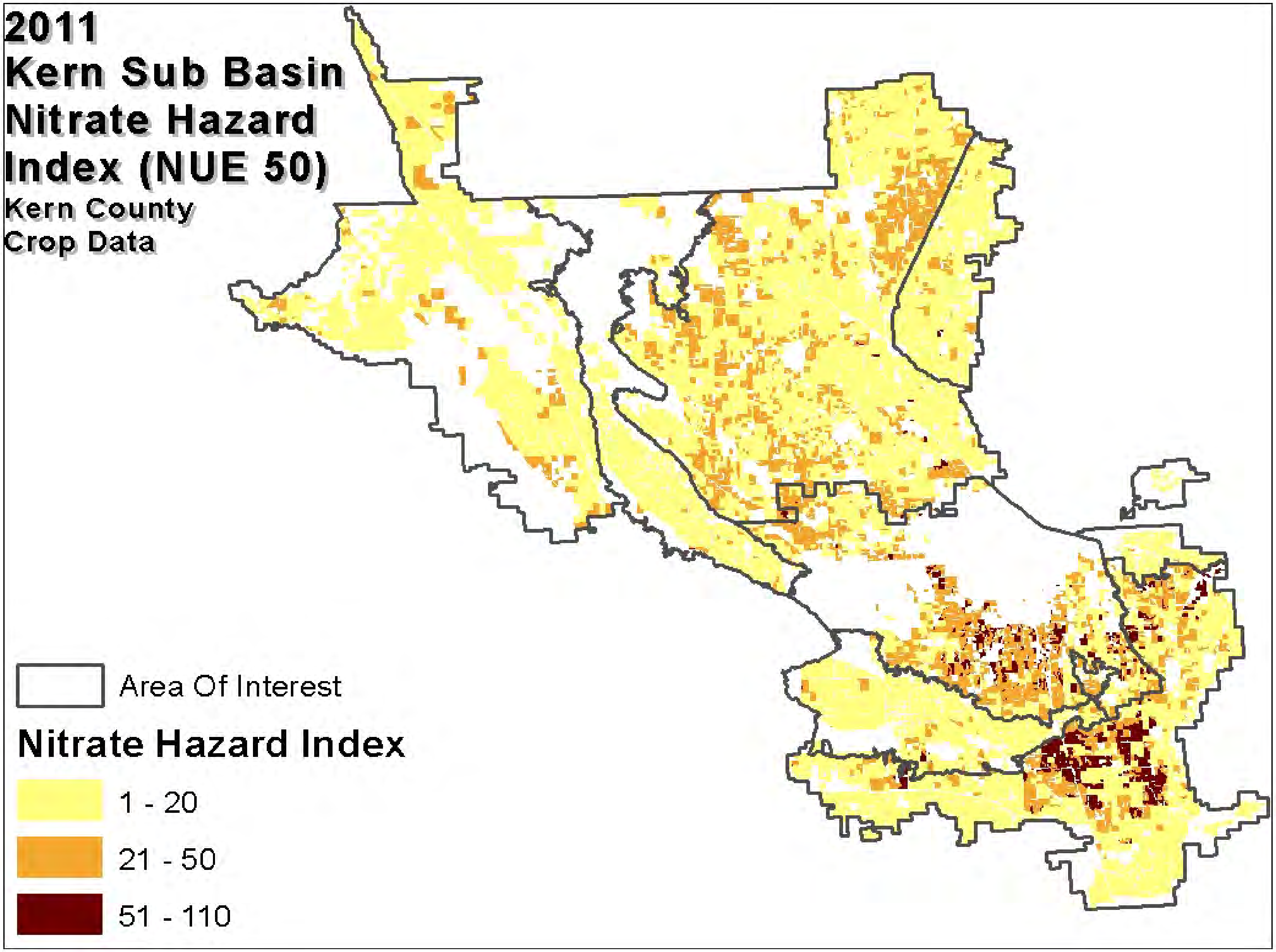
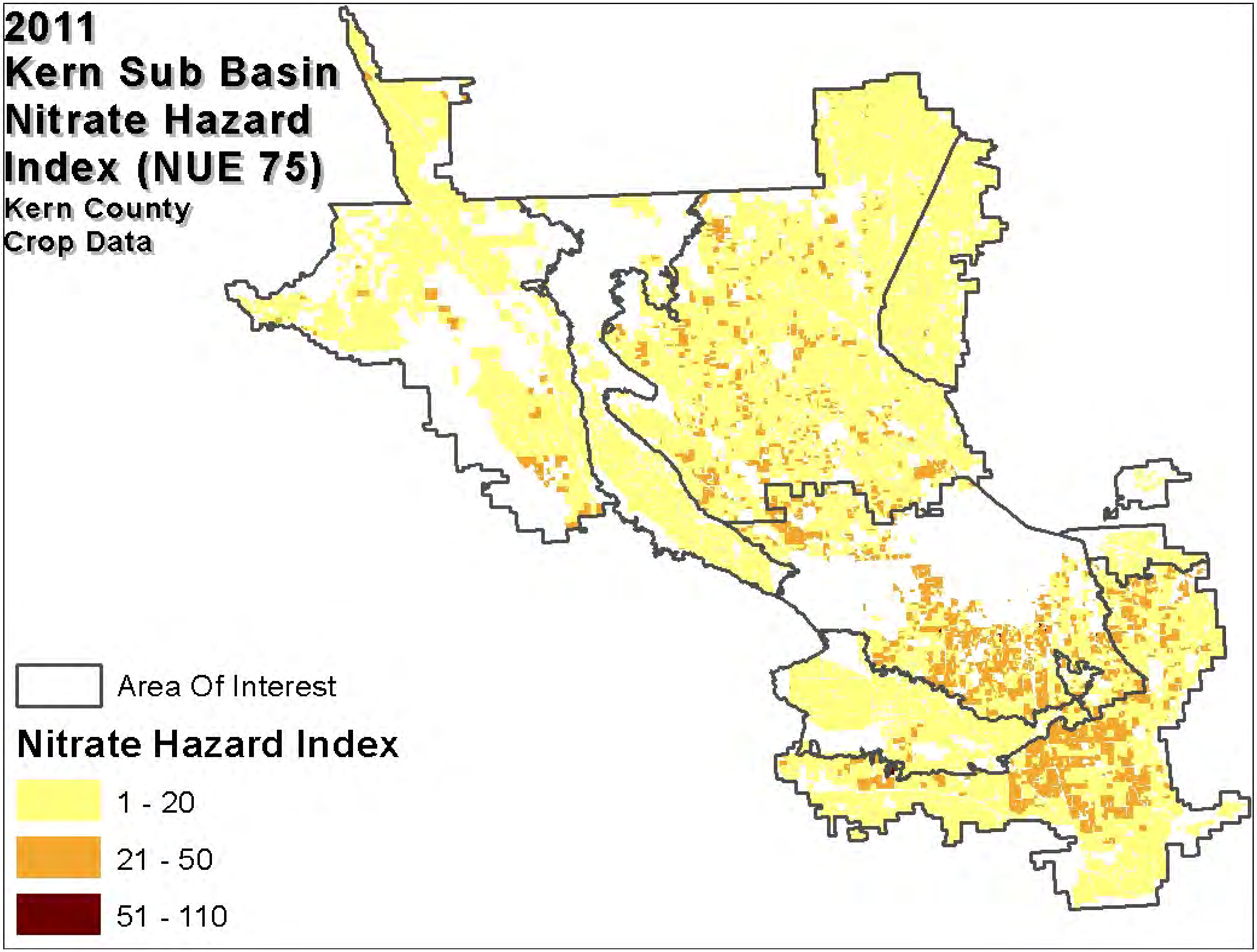


Figure 18. Kern Sub-Basin preliminary Nitrate Hazard Index, including 50% NUE estimate - 2011


2011
Kern Sub Basin
Nitrate Hazard
Index (NUE 75)
Kern County
Crop Data
Area Of Interest
Nitrate Hazard Index
1 - 20
21 - 50
51 - 110

DRAFT

Figure 19. Kern Sub-Basin preliminary Nitrate Hazard Index, including 75% NUE estimate - 2011

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Appendix A – General Concepts of Nitrogen Fertilizer Recovery and Losses

Introduction

No biological system is 100% efficient. A general rule of thumb is that N fertilizer uptake efficiency is 50 percent, on average, for agricultural crops (Meyer, 2008). However, typical fertilizer N uptake efficiencies of major agronomic crops range from less than 30 to greater than 70% because of several factors. First, it is not possible for a plant to deplete the entire inorganic N from the soil solution. As the nitrate and ammonium concentrations decrease in solution, the rate of N uptake also decreases, in a relationship similar to substrate-enzyme reactions (Jackson et al., 1986).

Minimal N concentrations in the soil are required to drive the N influx into crop roots. In addition, some N losses (volatilization or leaching) from the root zone are inevitable during the season. As a result, not all of the N supplied will be available for plant uptake. Finally, and perhaps most importantly that to achieve maximum or near maximum yields, N must be supplied at high levels. According to Mitscherlich's Law, as N supply increases, there is a decrease in the incremental yield increase per unit of N input. As a result, N use efficiency invariably decreases at high levels of N input that are required to achieve maximum yield. On the other hand, if minimal N is supplied so that the soil N is depleted to near zero to minimize nitrate leaching potential, there is an insufficient concentration of soil N to drive maximal rates of N uptake, and crop yield will be limited. For this reason, the presence of residual soil N at the end of a growing season is inevitable in intensively managed cropping systems that are achieving near maximum or maximum economic yields (Hermanson, et al., (undated)).

Nitrogen Uptake and N Fertilizer Recovery

In general, the amount of N accumulated by a crop is affected by:

- the amount of N supplied by the soil or added as fertilizer
- the genetic potential of the species or cultivar to absorb N, which is influenced by genetic factors such as tolerance to biotic and abiotic stresses, rooting pattern and physiological N uptake efficiency
- the growth or yield potential under a set of environmental conditions and soil properties
- the ability to retain N in the root zone during the period of crop N uptake.

Nitrogen fertilizer recovery estimates for different fertilizer management and cropping systems are summarized in Table 1 and show varied and wide differences depending on crop type and timing of application.

Table 1. General guidelines for estimating N fertilizer recovery fraction when using N rates for maximum or near maximum yield [1] (Bock and Hergert, 1991).

Relative Efficiency of N-Application Timing	Perennial Grasses	Upland Cereal Grains	Shallow-rooted Crops	Flooded Crops
Low [2]	0.55	0.45	0.35	0.25
Medium [3]	0.70	0.60	0.50	0.40
High [4]	0.80	0.70	0.60	0.50

[1] N fertilizer recovery fraction values assume medium to high nitrate loss potential as determined by soil type and moisture regime and no or negligible NH3 volatilization losses.
[2] One N application (without nitrification inhibitor) well in advance of the growing season. When nitrate loss potential is low due to soil type or moisture regime, use nitrogen use efficiency values for medium to high efficiency of N application timing.
[3] One N application near beginning of growing season.
[4] Multiple N applications with first application near beginning of growing season; use of nitrification inhibitor may substitute for splitting N applications.

NITROGEN LOSSES

It should be clearly noted that N losses are extremely variable and are influence by a myriad of factors, some of which can be controlled or managed and some of which cannot. Estimating N use efficiencies (NUE) requires an understanding of field by field variables that impact N losses. Therefore, utilizing NUE across large landscapes to ultimately determine nitrate available for plant uptake or leaching is marginal at best. Rather, these approaches are more accurate at the field-scale level where a more detailed understanding of soil type, crop type, management practices, climatic conditions, soil chemistry, etc. can be determined.

The amount of N lost from an agricultural soil-plant system is also affected by many factors, all specific to different types of loss. These losses include volatilization, denitrification, and leaching.

Volatilization

Volatilization can occur whenever free ammonia is present near the surface of the soil. The ammonia concentrations in the soil solution will increase by applying ammonia-based fertilizers or decomposable organic materials to neutral or alkaline soils. The amounts of ammonia volatilized are small when N materials are incorporated into the soil, and ammonia losses are also low (≤15% of applied N) when ammonia-based fertilizers are applied in the surface of acidic or neutral soils.

Ammonia volatilization is a complex process involving chemical and biological reactions within the soil, and physical transport of N out of the soil. The method of N application, N source, soil pH, soil cation exchange capacity (CEC), and weather conditions influence ammonia emissions from applied N. Conditions favoring volatilization are surface applications, N sources containing urea, soil pH above 7, low CEC soils, and weather conditions favoring drying. Precise estimates of ammonia emissions are only possible with direct local measurements. Depending on application conditions, general ranges would be 2 to 50% emissions for soil pH > 7 and 0 to 25%

emissions for soil pH < 7. If the N source is mixed into an acid soil, the emissions are usually greatly reduced (0 to 4% lost) (Meisinger and Randall, 1991).

Ammonia volatilization is a major pathway of N loss from livestock slurries following their application to land. Approximations of ammonia emissions from volatilized dairy manure are listed in Table 2 and shows the extreme variability as associated with ammonia volatilization under manure applied conditions. Research on synthetic fertilizers show similar results.

Table 2. Approximate ammonia emissions of land-applied manure. These values are rough estimates of the percent of applied N lost; actual values depend on weather conditions after application, type of manure, ammonia content, etc. (Meisinger and Randall, 1991).

Manure Application Method	Type of Manure	Short-term Fate		Long-term Fate	
		N (%)			
		Lost	Retained	Lost	Retained
Broadcast, no incorporation	Solid	15-30	70-85	25-45	55-75
	Liquid	10-25	75-90	20-40	60-80
Broadcast, immediate incorporation	Solid	1-5	95-99	1-5	95-98
	Liquid	1-5	95-99	1-5	95-98
Knifed	Liquid	0-2	98-100	0-2	98-100
Sprinkler irrigated	Liquid	15-35	65-85	20-40	60-80

Denitrification

Compared to volatilization, denitrification emissions in agricultural systems are generally lower, however can be significant in some high water table/reduced soil environments. Emissions of N_2O were found to be lower than 5 to 7 % of the applied N, even at high application rates of 680 kg N/ha/year (Ryden and Lund, 1980). Similarly, Mosier et al. (1986) reported that, on well drained clay-loam soil sown with corn in 1982, 2.5% of the 200 kg N/ha applied as (NH4)2SO4 was lost as N_2O or N_2. The following year, only a loss of 1% could be measured from the same soil sown with barley. Denitrification estimates for soils with different organic matter contents and drainage classes are provided in Table 3. Clearly, poorly drained soils with high water tables and substantial organic matter can experience significant losses due to denitrification.

Again, it is imperative to understand each unique soil/crop/management system in order to somewhat reasonably estimate potential losses of N due to denitrification. The Kern Sub-Basin has a variety of soil types and conditions that result in varied losses due to denitrification.

Table 3. Approximate denitrification estimates for various soils. (Meisinger and Randall, 1991).

Soil Organic Matter Content (%)	Soil Drainage Classification				
	Excessively well-drained	Well drained	Moderately well-drained	Somewhat poorly-drained	Poorly drained
	Inorganic Fertilizer N Denitrified (%)				
<2	2-5	3-9	4-14	6-20	10-30
2-5	3-9	4-16	6-20	10-25	15-45
>5	4-12	6-20	10-25	15-35	25-55

Note: Adjust as follows: for no-tillage use one class wetter drainage; for manure N double all values; for tile-drained soils use one class better drainage; for paddy culture use values under poorly drained; for irrigation or humid climates use value at upper end of range; for arid or semi-arid non-irrigated sites use values at lower end of range; for soils with compacted very slowly permeable layer below plow depth, but above 4-ft depth, use one class wetter drainage.

Leaching

The amount of nitrogen lost with percolating water through the root zone depends on the nitrate concentration in the soil profile. This nitrate concentration is strongly influenced by N application rates, methods and management. Cropping systems may be a major factor in regulating nitrate movement below the root zone and toward the water table. Rooting depth, water requirement, water-use rate, N-uptake rate, and time of water and N uptake are all factors involved in nitrate leaching that can be affected by choice of cropping system. For nitrate leaching to occur, appreciable concentrations of nitrates must be present in the root zone at the time that water is percolating. It is known from experiments with mineral N fertilizers that different cropping systems can influence the rate of leaching of N. Generally, the leaching of N is lower on grassland than on tillage land and is lower for plants with a longer vegetation period than those with a shorter vegetation period. This would also be consistent with the Kern Sub-Basin and the predominant population of permanent crops.

Altman et al. (1995) reported NO_3-N losses from crops amounting to 24 to 55% of the N applied at economic optimum rates (typically providing for near maximum crop yields). In Pennsylvania, the apparent recovery of N fertilizer (ammonium nitrate) applied at the economic optimum N rate in 42 experiments averaged 55% (Fix and Piekielek, 1983). Thus, even when using optimum fertilization rates, a potential exists for fertilizer N to accumulate in the soil with subsequent risk of loss through leaching. This risk is reduced in the Kern Sub-Basin due to the predominance of permanent crops.

Perhaps the greatest uncertainty when measuring or predicting deep water percolation and associated nitrate leaching in soil deals with the heterogeneous pore distribution in the root zone where microbial N cycling can greatly alter N availability for leaching. Large pores created by shrinking and swelling of clays, decomposition of roots, and faunal activity can accelerate water movement (two to five times higher for soils without obvious macropores, and as much as twenty times for soils with cracks). This increased water movement will have different effects on nitrate leaching depending on N concentration of those areas of the soil "bypassed" by infiltrating water, the rate of water application, the N concentration of infiltrating water, and other factors. The net result, however, is generally one of increased N amounts being transported beyond the reach of crop roots. Aschmann et al. (1992) detected flushes of nitrate and other ions and attributed them to preferential flow through the profile. The methods of highly efficient irrigation in the Kern Sub-Basin (e.g. drip/micro) coupled with deep-rooted permanent crops reduce this risk significantly.

Randall and Iragavarapu (1995) also showed that the amount of N leaching is related to the amount of percolating water. They conducted a study on a poorly drained clay loam in Minnesota with continuous corn and N fertilization rates of 200 kg N/ha for several years (fertilizer N was applied as one dose in the spring before planting). They found that annual losses of NO_3-N in the tile water ranged from 1.4 to 139 kg/ha. In dry years, losses generally were equivalent to less than 3% of the fertilizer N applied, whereas in the wet years, losses ranged from 25 to 70% of that applied. Pang et al (1997), in an irrigation quantity and uniformity study, concluded that N leaching was very low when the N application was close to crop N uptake and slightly higher when the uniformity coefficient of the irrigation was 90%. When N application exceeded N uptake, N leaching increased dramatically for all uniformity levels.

Hart et al (1993), working with labeled-N in winter wheat, indicated that most of the labeled-N was presumably mineralized during the fall and winter when the losses are high and crop demand is low. They concluded that leaching of NO_3-N from cereals comes predominantly from mineralization of organic N, not from residual unused N. Olson (1982), after working in the fate of N applied in the fall using labeled-N and agronomic rates in winter wheat, found that from all the leaching produced during the winter time, only about 10% of it came from the fertilizer nitrogen.

Gaines and Gaines (1994) indicated that soil texture affects NO_3-N leaching. In coarser soils, NO_3-N will leach faster than from finer ones. The addition of peat in sandy soils helps in reducing the velocity of N leaching. Tindall et al (1995), in a laboratory analysis, indicated that leaching of NO_3-N was significant in both clay and sandy soils. They concluded that in clay soils leaching occurred less rapidly than in sandy soils. Nevertheless, after enough time, 60% of the NO_3-N was leached from the clay soils.

Crop production, irrigation practices and environmental conditions in the Kern Sub-Basin offer very unique attributes that will result in a relatively low nitrate leaching potential. For example much of the irrigated ground in the Kern Sub-Basin is continuing to transition from annual, relatively shallow rooted crops generally irrigated with lower efficiency irrigation systems to permanent, deep rooted, highly efficient irrigated systems. One of the most significant contributors to leaching of nitrate is concentrated and significant rainfall, especially that which is considered as “effective rainfall.” Effective rainfall is defined as the amount of rain that is stored in the soil profile and available for crop use. In the Kern Sub-Basin, the effective rainfall is likely between 1-3 inches annually. With deep rooted crops, this limited effective rainfall available to leach nitrate is most likely stored within the root zone of deep rooted crops.

Appendix B - Preliminary Estimated Nitrate Leaching from Select Cropping Scenarios

The results presented in this appendix were developed from reviewing scientific literature from peer-reviewed journals, extension publications, personal communications and privately-developed publications. No simulation models or statistical methods were used. The purpose in providing these results is to show the variability in the literature and impactful parameters that can significantly influence potential nitrate leaching.

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COTTON

The cotton system that was considered representative of that of the SJV included the following components:

- Applied N fertilizer = 180 lb/ac/yr
- N fertilizer is applied in split-applications
- Cotton fields are double-cropped with wheat or no crop
- Furrow irrigation
- Coarse-textured soils
- Both Acala and Pima varieties
- No nitrification inhibitors are used
- No growth regulators are used
- Denitrification is low to moderate because of coarse soils

Summary

Reported Fertilizer Nitrogen Recovery (FNR) in cotton ranges from 15 percent to 70 percent, mostly depending on irrigation type. In cotton systems that are representative of those used in the SJV, FNR ranges between 30 and 40 percent. Extremely low uptake of 12 to 15 percent is attributed to poor fertilizer management practices that employ one-time applications instead of split-applications of N, coupled with surface irrigation. The amount of N available for leaching losses is for cotton double-cropped with wheat and is estimated at 30-70 pounds N/acre/year.

Literature Review

Bronson et al. (2009) and Bronson (2008) found that NFR was only 12 to 15 percent in their experiments in Arizona on furrow-irrigated cotton, which they attributed partly to timing of fertilizer application; all N was applied in one application near the beginning of the season. Hutmacher's (2005) work substantiated these results; split-applications of N decreased leaching to the lower soil profile (4 to 8 foot depth) compared to one-time applications. In this multi-year study on various soils in California, nitrate losses averaged 20 lb/ac and did not exceed 40 lb/acre.

Cristobal Navarro-Ainza reported FNR in upland cotton of 40 percent in the upper foot of soil. Beyond that depth, FNR decreased and was particularly low beyond the 2-foot depth.

Fritschi et al. (2004) studied NFR on both Acala and Pima cotton irrigated by furrow, and found an average of 42 percent. They submit that their FNR rates of up to 64 percent (on sandy loam) are high compared to other values reported in the literature (between 13 and 35 percent) because their soil sample depth was deeper than that of other studies. Interestingly, they did not find different FNR rates for different soil types. They accounted for 89 percent of total fertilizer in the soil and plant system, leaving 11 percent available for losses.

Wei et al. (2012) reported that 18 percent of applied fertilizer, which equated to 43 to 86 lb/ac in their study, leached from furrow-irrigated cotton. The CRC (2008) estimates that cotton crops use 33 percent of fertilizer, 35 percent is retained in the soil, and approximately 42 percent is lost from the system. Similarly, Silvertooth (2001) estimates cotton FNR at 32 to 36 percent. Similar to the findings of Fritschi et al. (2004), Silvertooth (2006) estimates total crop and plant recovery at 75 to 85 percent. The same author estimates that 40 percent fertilizer N is recovered in cotton plants, while about 60 percent is retained in the soil.

Navarro et al. (1997) conducted a 6-year study on upland cotton using the standard approach of pre-plant N application coupled with in-season side-dress. The optimum FNR in this study was at an N application rate of 130 lb/ac, out of N treatments up to 176 lb/ac. This indicates that typical application rates used in the SJV are not optimally efficient in their uptake. A study in Texas indicated that soil residual N was so high on 22 out of 39 sites that only eight sites responded to N fertilizer. These results indicate that soil residual N can accumulate to significant levels after continuous cotton cropping.

Rationale

Assuming a typical application rate of 180 lb/ac and a FNR or 30 to 40 percent, 108 to 125 lb/ac of N is left in the soil and is available for transformations and losses. Using Table 4, 16 percent (29 lb/ac) is assumed to denitrify. Assuming 25 percent is lost to volatilization in soils of neutral pH (45 lb), 34 to 51 lb N/ac is available to leaching losses from the cotton crop. This does not account for mineralization of organic soil N.

Assuming a winter wheat crop (wheat that is grown in the winter but is actually a spring wheat variety) that is double-cropped with cotton, additional N fertilizer would commonly be added. Typically, at total of 220 lb/ac of N is applied to winter wheat crops in three applications – one before planting, one in February, and one in April. Wheat FNR is usually considered to be higher than cotton because it can sequester N in the form or protein; however, under surface flood, N fertilizer recovery is likely not optimal and is likely between 40 and 50 percent.

Assuming the same values for denitrification and volatilization, an additional 20 to 42 lb N/ac from the wheat crop would be available for nitrate leaching losses. In total, the estimated amount of nitrate available to leaching losses from a cotton-wheat double crop is estimated at 54 to 93 lb N/ac/yr, with the lower end of this range more likely. In the case of cotton cropped alone, the total estimate of N available to leaching losses is 34 to 51 lb N/ac.

ALMOND

The assumptions for the almond cropping scenario include the following:

- Medium-fine textured soils
- Micro/drip irrigated
- Intensive management practices such as split applications of fertilizer
- Mature orchards at least 6 years old
- Applied N fertilizer = 275 lb N/ac/yr (Holtz, 2012)

Summary

Though the potential to reduce N losses from almond orchards is very high and has been proven (Sanden, 2012) the FNR for almonds on drip irrigation and medium to fine textured soils likely ranges between 50 and 65 percent. However, though there may be considerable soil N residual available for N losses, these likely do not occur to the extent that they would in surface-irrigated systems. For example, denitrification is likely low because the 60 percent soil pore saturation that is a requirement for denitrification to occur is usually not met with this method of irrigation (Smart et al, 2008). Matiasek et al. (2008) also reported low denitrification rates under particular almond soils. Similarly, leaching losses are likely very low because of the temporal distribution and rates of irrigation applications, as well as the low leaching fraction. The amount of N estimated to be available for potential leaching losses in the Kern Sub-Basin is between 10-50 pounds of N/acre/year depending on a variety of variables. It should be noted that NFR rates in the Kern Sub-Basin are likely some of the highest in the state due to the highly efficient and managed predominantly drip irrigation systems couples with the very low effective rainfall and denitrification potential.

Literature Review

Much of the literature on N use in almond orchards comes from California and is highly applicable to the purpose of this effort. Weinbaum et al. (1995) found a NFR rate of 30 percent, using rates typical of current practices, in a 5-year study on almonds in Stanislaus County, California. Though Zasoski (1994) noted that almond NFR is estimated at 30 to 40 percent, he concluded that 21 to 31 percent of fertilizer N was recovered in his study on drip irrigated almond trees.

Meyer (1992) found that using rates of N needed to produce optimum yields and optimum irrigation rates did not result in large amounts of nitrate leached below the root zone. The same author estimates that average NFR is 50 percent on average in California almonds.

Brown (2011) achieved a NFR rate of 81 percent in a study on almonds in the SJV, admittedly among the highest recorded in a production setting. Brown has conducted numerous long-term studies on N fertilizer use in almond orchards, and concludes that although 65 to 75 percent FNR can result from using best management practices, most of the almond industry is not at this level of efficiency (i.e. below 65 percent). Similarly, Sanden (Personal Communication, 2012) found that very high efficiencies over 90 percent are possible, but concedes that this is not likely for the majority of almond production in California.

Rationale
Almond NFR in SJV almond orchards is likely between 50 and 65 percent, considering the assumptions listed above. Denitrification is likely relatively low because of the intermittent nature of conditions that are conducive to it.

Sanden's work (2012) showed that at 95 percent NFR, about half of the N that was available for leaching as nitrate-N (13.75 lb, or 5 percent of 275 total applied N) leached below the root zone. This fraction amounted to 7 lb nitrate-N/ac.

If NFR is between 50 and 65 percent, approximately 96 to 138 lb N/ac would be available for leaching and other losses. Losses to denitrification and volatilization are assumed to be relatively low and total 10 percent of applied N (28 lb/ac). Half of the residual amount (68-110 lb) lost to leaching would be 34 to 55 lb N/ac. Though the relationship between the amount of N available for leaching and actual amount leached is not necessarily linear, it is reasonable that conditions that lead to lower NFR also contribute to higher leaching potential. These include conditions resulting from poor fertilizer management, poor irrigation management, and inappropriate N rates.

Grapes

The assumptions for the grape cropping scenario include the following:

- Medium to fine textured soils
- Drip irrigation
- Table varieties

- 50 - 100 lb N/ac applied annually
- No winter cover crop
- Best management practices including optimum N fertilizer distribution

Literature Review

Peacock et al. (undated) summarized the results of studies on N fertilization in SJV grapevines. Their main conclusions are as follows:

- Grapevines depend heavily on redistribution of N previously stored in non-fruit plant parts to support spring growth. For this reason, N should be applied after bud break through fruit set, or post-harvest; N applied earlier (at bud break) has insufficient time for uptake and can be severely leached.
- The N requirement for Thompson Seedless used for raisin production in the SJV was 73 lb N/ac (as measured in stems, leaves and fruit). Approximately 30 lb N/ac (40 percent of applied N) was removed by the crop and the remainder of the N was recycled from other plant parts.
- Thompson Seedless yields and fruit quality can be sustained with 22 to 44 lb N/ac, but the amount of N fertilizer required varies with yield, soil type, and irrigation efficiency as well as N inputs from irrigation water, crop residue and N mineralization.
- Efficient drip irrigation schedules have been developed in the SJV as a result of relatively consistent evaporative demand and availability of long-term ET records.
- Drip irrigation provides an ideal environment for N uptake applied through fertigation, largely because it wets a limited area of the root zone.
- Multiple applications of N (split applications) do not necessarily improve N uptake efficiency.
- Winter cover crops can reduce nitrate leaching to groundwater in cases of excess N by taking up excess nitrate in the soil during an otherwise fallow winter period; however, they also affect the N status of grapevines because they compete for N.

The information above indicates that about 40 percent of fertilizer N is taken up by grapevines. Other studies report similar findings: Drip irrigated grapes were reported by two authors to have NFR of 42 percent (Thompson seedless on drip getting one N application in the spring), 34 percent (Thompson seedless on drip getting split N applications), 50% (wine grapes on sandy soil) and 30 percent (wine grapes on sandy loam) (Hanson and Howell, 1995). In a study by Williams (1987), NFR in grapevines grown on the California Central Coast was 40%, which is lower than that found on Thompson seedless in the SJV (42 to 50 percent). However, the author notes that in this latter study, all plant parts were analyzed for N while in the former study not all of the plant parts were included.

Barghava (1991) showed that NFR varies from 20 to 40 percent in grapes and depends on organic matter in soil. This author also demonstrated that similar to other crops, the efficiency of fertilizer N recovery is inversely related to the amount of N applied. These two findings are likely attributed to the ability of grapevines to redistribute N previously stored in roots and other plant parts in the spring to support growth (Peacock et al., 1989). Peacock et al. (1989) also demonstrated that only <1 to 12 percent of total tissue N was derived from fertilizer, which is relatively low. They submit leaching losses have high potential when N fertilizer is applied to vineyards in dormancy on moderate to rapidly drained soils, where much of the SJV grape industry is located.

Because of the capacity of grapevines to redistribute and use N previously stored in plant parts, the recovery of fertilizer N, especially during the early part of the growing season, is relatively low. With good water and N temporal distribution practices already in use, the NFR of grapevines is likely approximately 40 percent and is not expected to increase because most are already irrigated with systems that provide optimum water and N uptake efficiency.

Rationale

The UC Davis Cost and Return Study for Thompson Seedless grapes in the SJV (2007) was developed on the assumption that 50 lb N/acre is applied to mature vines (at least 4 years old) annually. An 8 ton/ac grape crop removes 66 lb N/ac (Weinbaum et al., 1995). Assuming 30 to 40 percent fertilizer N recovery, that 15 to 20 lb N/ac are taken up by the crop. Assuming this rate of annual N uptake, 30 to 35 lb N/ac remains as residual N. The rates of denitrification and volatilization are likely low in drip irrigated grapes (assumed at 10 percent); however, the potential for leaching is also likely low because of soil moisture conditions to drip-irrigated systems (Smart et al, 2008). Therefore, the proportion of N estimated to leach from vineyards is much lower than the amount of residual N in the soil and is estimated at 10-20 pounds N/acre/year.

CITRUS

The assumptions for the citrus cropping scenario include the following:

- Medium to fine textured soils
- Drip irrigation
- Average 120 lb N (110 to 130 lb N/ac applied annually to Navel and Valencia, mandarins and lemons respectively) total; 80 lb N applied through fertigation; 30 lb N applied as foliar.
- Best management practices including optimum N fertilizer distribution

Summary

Studies from California and elsewhere are relatively consistent in their findings that NFR under drip irrigated citrus is around 70 percent and therefore the potential amount leached from this system is approximately 10-20 pounds of N/acre/year.

Literature Review

Most researchers have found that NFR under drip irrigated citrus orchards is approximately 70 percent. Arpaia and Lund (2003) noticed differences in NFR between treatments that compared early season N applications with late season N applications, but noted that on average, N recovery in the soil-plant system was about 71 percent. However, they also noted that soil residual of isotopically-labeled N ranged from about 10 to 16 percent under the late season and early season applications, respectively. Fertilizer supplied N in this trial was 50 g or 0.1 lb per tree, which by the author's judgment, is a relatively low application rate; they submit that rates of up to 2 lb per tree are used even though they are excessive.

Quinones et al. (2003) investigated N uptake in orange trees in Spain and found that NFR of the whole tree was 75 percent (compared with 64 percent on flood-irrigated trees). Interestingly, they also measured the amount of N that was immobilized in the organic fraction of the soil, a fate of fertilizer N that is often not accounted for, and found it to be similar for both irrigation methods at approximately 13 percent. Another significant result of this study was that residual N as nitrate measured in the soil under drip irrigation was only 1 percent of applied fertilizer N, whereas under flood irrigation it N as nitrate represented 10 percent of applied fertilizer N. Though the rates used in this study were lower than those used currently in California, these results indicate that not only does drip irrigation leach less N, it also does not provide the conditions that are conducive to nitrification without uptake.

Syvertsen and Smith (1996) studied N dynamics in grapefruit, orange and lemon in lysimeters. They found that average N uptake efficiency was between 61 and 70 percent. Martinez-Alcantara et al. (2012) reported mean NFR of 71 percent in a pot experiment that investigated the effect of fertilizer timing on 5-year old orange trees.

Morgan and Hanlon (undated, extension) estimate that NFR in citrus trees ranges between 40 and 60 percent and recommend that the upper end of this range should be a management goal. However, humid environments often receive more precipitation than arid environments such as the SJV and can reasonably be assumed to cause lower N efficiencies, largely because profile percolation is less controlled.

Boaretto et al. (2010) reported NFR rates of 36 percent in orange trees and 52 percent in lemon trees grown in lysimeters. This study was done on a clayey soil. Lea-Cox and Syvertsen (1996) also studied citrus N uptake in a controlled environment, and found that NFR decreased from 60 percent to 33 percent as N treatments increased beyond agronomic rates.

Rationale

The literature indicates that citrus grown in the SJV with drip irrigation and managed with split and foliar N applications likely achieve a NFR between 60 and 70 percent. However, only a portion of the assumed applied N is applied through fertigation; assuming 30 lb is applied as foliar N on average, only 80 pounds of N is considered in the N soil balance. Embleton et al. (1980) demonstrated that foliar applied N (low biuret urea sources) that reaches the ground is mostly volatilized.

Assuming 60 to 70 percent of 80 lb (48 to 56 lb) of applied N is retained by the trees, 24 to 32 lb N/ac is available for transformations and losses. It is reasonable to assume that volatilization and denitrification are relatively low owing to drip irrigation and are assumed at 10 percent of applied N (8 lb). However, leaching potential is also likely relatively low because of high irrigation efficiency. Viers et al. (2012) cite a study where 134 lb N applied per acre to lemons resulted in 35 lb of leached N. Therefore, the amount of N available for leaching is estimated at 16 to 24 lb/ac/yr, and the estimated amount that is actually leached is likely around 10-20 pounds N/acre/yr.

Silage/Winter Forage Grain Rotation

Summary

The assumptions for the silage/winter forage grain rotation cropping scenario include the following:

- Medium to coarse textured soils
- Silage corn grown in summer double-cropped with winter forage grain (mostly wheat, some triticale)
- Typical application rate is 350 N lb/ac/yr on silage corn (UC Davis cost and return study for silage corn, double-cropped in SJV) and 220 lb/ac on wheat
- Surface-irrigated with either flood or border check

Literature Review

In general, the percentage of fertilizer N recovered in corn biomass is relatively low at <50 percent (Cassman et al. 2002; Balasubramanian et al. 2004; Krupnik et al., 2004). Using manure to supply N at near optimum economic rates may lead to higher losses than using inorganic fertilizers as the N source. A substantial quantity of inorganic N may be produced from mineralization of organic N after the crop has ceased to absorb N. This manure-derived nitrate may be subject to leaching during the winter and spring (Schepers and Fox, 1989). A number of investigations have indicated that using manure to supply N at recommended agronomic rates may result in significantly higher leaching loss of nitrate than when inorganic N fertilizer is applied (Sims, 1987). Typically, about 30% of the organic matter is mineralized during the first cropping season.

After application to soil, manure N losses through volatilization range from 20 to 40 percent, nitrate loss ranges from 1 to 25 percent, and nitrous oxide emissions from 1 to 4 percent of applied N (Rotz, 2004). Therefore, the potential for ammonia losses via volatilization is greater than for those from nitrate leaching. Powell et al. (2011) found that incorporation reduced N loss in all forms during a trial in Wisconsin, but did not improve N uptake efficiency in corn fertilized with dairy manure. These results indicate that N conservation in the soil and plant system through best management practices is not necessarily evident in N uptake efficiencies.

In a typical manured field there are uncertainties about the quantity of manure N applied, the amount of ammonia N volatilized, the proportion of manure organic N mineralized in a growing season, and the amount denitrified. Therefore, it is difficult to use an N balance approach (Schepers and Fox, 1989). Managing organic wastes to supply crops at recommended agronomic rates is challenging because organic wastes are a slow release source of N, often with effects beyond the growing season of the application. (Hermanson et al., undated)

Sims (1987) found that at near optimum N rates, even with poultry manure that has a high proportion of its N available, only 36% of the N was removed by a maize crop, compared to 56% of inorganic fertilizer N applied. Saint-Fort et al. (1991), analyzing a number of investigations, also concluded that using manure to supply N at near economically optimum rates may result in significantly higher leaching loss of nitrate than when inorganic N fertilizer is applied. This increase is thought to be due to late fall or early spring mineralization of manure (Hermanson et al., undated).

Jemison et al. (1994) indicated that excessive N application increases the potential for nitrate leaching, but not much research has evaluated nitrate leaching from corn (*Zea mays* L.) receiving economic optimum N rates (EON). Their study assessed a) flow-weighted average concentration and mass of NO_3-N leached from non-manured and manured corn treated with five fertilizer N levels and at EON, and b) the relationship between NO_3-N mass in the 1.2 m soil profile following harvest and the flow-weighted average leachate concentrations. Following application of liquid dairy manure each April, the field was chiseled and disked prior to planting. Ammonium nitrate was broadcast at planting (0-200 kg N/ha in 50 kg increments and 0-100 kg N/ha in 25 kg increments) in non-manured and manured corn. Zero-N plots had 3-yr average flow-weighted leachate concentrations less than 10mg NO_3-N/L. At EON, the 3-yr averages were 18.8 and 19.3 mg NO_3-N/L for non-manured and manured corn. The mass of NO_3-N leached was 107kg/ha or 36% of the N applied at EON.

Jayasundara et al. (2007) investigated methods to minimize N losses from a corn-soybean-winter wheat rotation in Eastern Canada and found that unaccounted gaseous losses of mineral fertilizer were 27 percent in a conventionally managed system. They also found that most of the leaching occurred during corn years.

Rationale

Given the source and form of N fertilizer and the type of irrigation used, the literature indicates that NFR on silage corn fields double-cropped with winter forage grains is likely relatively low; however, losses of N other than nitrate leaching are also likely relatively high.

Assuming 350 lb of applied N per acre per year (UC Davis Cost and Return Study for silage corn in SJV), N uptake by corn crop is likely 30 to 40 percent, or 105 to 140 lbs/ac/yr. Denitrification and volatilization rates are likely relatively high, and are assumed to be an average value of 30 percent for volatilization, 12 percent for denitrification, and 2 percent for nitrous oxide emissions (Rotz, 2004) for a total of 44 percent of applied N lost to gaseous emissions. This equates to 154 lb N/ac/yr of losses other than nitrate leaching. As a result, estimated N available for leaching is estimated at 56 to 91 lb N/ac/yr for the silage corn crop.

Assuming a 40 to 50 percent NFR for wheat (which would generally be higher on wheat fertilized with inorganic fertilizers), 88 to 110 lb N would be taken up by the wheat crop, leaving 110 to 132 lb N as residual in the soil. Gaseous losses are assumed to be similar (44 percent of applied N) because the irrigation method and fertilizer source is the same as in the silage corn crop, and are estimated at 97 lb N/ac/yr. This estimate leaves 13 to 35 lb N/ac/yr available for leaching in the wheat crop.

In total, 63 to 118 lb N/ac/yr are estimated to be available for leaching in a silage corn-wheat double crop fertilized with dairy manure.

<u>DRAFT</u>

COMMENTS ON HYDROGEOLOGIC POINTS OF CONCERN FOR THE KERN RIVER WATERSHED COALITION AUTHORITY AREA

Regarding Monitoring and Reporting Program Draft Order R5-2013-XXXX Waste Discharge Requirements General Order for Growers within the Tulare Lake Basin Area that are Members of the Third-Party Group

01-KRW-001

Prepared For:

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February 13, 2013

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Principal Hydrogeologist

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1.0 INTRODUCTION

My name is Robert M. Gailey. I am licensed as a Professional Geologist and Certified Hydrogeologist in the state of California. Having practiced in the field of hydrogeology since 1985, my technical background includes both contaminant and water supply hydrogeology applied to urban, industrial and rural settings. I have technical degrees in Geology/Biology (Bachelor of Science) and Applied Hydrogeology (Master of Science), as well as a Master of Business Administration. My curriculum vitae is attached as Appendix A.

I have been retained on behalf of the Kern River Watershed Coalition Authority (KRWCA) to review and comment on the Monitoring and Reporting Program portion of *Draft Order R5-2013-XXXX, Waste Discharge Requirements General Order for Growers within the Tulare Lake Basin Area that are Members of the Third-Party Group* dated January 2013. My area of focus is how hydrogeologic characteristics specific to the KRWCA area relate to the groundwater monitoring requirements, specifically the management practice evaluation and trend monitoring requirements for nitrate, stated in the draft order.

The following information is a brief presentation of my review to date. My evaluation of the salient issues is ongoing and I may present additional comments in the future.

2.0 SUMMARY OF COMMENTS

From a hydrogeologic perspective, the KRWCA area is notably different from other parts of the Tulare Lake Hydrologic Region (TLHR) and also the East San Joaquin Watershed (ESJW) with respect to groundwater basin configuration, hydrologic stresses and depth to first-encountered groundwater. These hydrogeologic differences have the potential to greatly complicate groundwater monitoring as described in the draft order. Among the issues that require additional consideration before the order is finalized are:

1. Time lags between agricultural activities at ground surface and changes in groundwater quality as a result of a thick unsaturated zone,
2. Nitrate residing in the unsaturated zone that acts as an ongoing source to groundwater years after nitrogen is applied at ground surface,
3. Processes acting on return flows during transit through the unsaturated zone,
4. Horizontal migration within the saturated zone and the resulting difficulty in attributing observed nitrate to specific source areas, and
5. The potential costs of an insufficiently planned groundwater quality monitoring program and the need for further study, or a pilot program as an interim regulatory step before any full-scale monitoring occurs.

The above-referenced points call into question the scientific basis, efficacy and cost effectiveness of groundwater monitoring as currently required in the draft order and should be addressed in finalizing the draft order.

3.0 PHYSICAL BACKGROUND

Figure 1 indicates the boundary of the KRWCA area. This area, a subsection of the South San Joaquin Valley Water Quality Coalition (SSJVWQC) and TLHR areas, contains a significant portion of Kern County and small portions of Tulare and Kings Counties, and is based upon water district boundaries. The primary groundwater subbasin in the KRWCA area as defined by the California Department of Water Resources (DWR) is the Kern County Subbasin (DWR Subbasin 5-22.14); however, small portions of the Tulare Lake and Tule subbasins (DWR Subbasins 5-22.12 and 5-22.13) are also included in the northern portion of the area. While Attachment A of the draft order (Information Sheet) provides a brief summary of the geology, hydrogeology and groundwater quality for the TLHR area as a whole, the following sections present pertinent information on these topics specific to the KRWCA area.

3.1 Geology

The KRWCA area geology consists of sedimentary deposits located in the southernmost portion of the San Joaquin Valley that have been derived from the surrounding mountain ranges. The shallower deposits are continental in origin with a range of types that generally include alluvial fan, lacustrine and river (Page, 1986 and Gronberg et al, 1998). These deposits are as much as 15,000 feet thick resulting from structural deepening of the basin (Lofgren, 1975 and Page, 1986). The combination of deposits throughout the KRWCA area is a heterogeneous assemblage of alluvial fan deposits, both coarse- and fine-grained, interfingered with valley stream (coarser) and lake (finer) deposits (i.e., Wood and Dale, 1964; Dale et al, 1966; Croft, 1972) formed by processes that responded to changes in glacial activity in the Sierra Nevada as described by Weissmann et al (2002).

3.2 Groundwater Hydrology

The KRWCA area is part of a closed groundwater basin (Croft, 1972 and Bertoldi et al, 1991). Natural patterns and rates of groundwater flow, recharge and discharge have been significantly changed as a result of groundwater pumping, surface water importation, crop irrigation and artificial recharge (Bertoldi et al, 1991, Gronberg et al, 1998 and DWR, 2006)[1]. Groundwater pumping performed by, among others, agricultural, municipal and water banking operations extracts in excess of 2 million acre feet of groundwater per year (KCWA, 2008) from locations spread throughout the KRWCA area (Boyle et al, 2012). Recharge operations performed by many water storage districts and other entities (DWR, 2006; KCWA, 2008) introduce water to the subsurface through natural channels, irrigation canals, spreading basins. From 1971 through 2008, recharge operations introduced in excess of 27 million acre feet of water to the subsurface. In addition, some amount of groundwater recharge occurs as a result of irrigation return flows. Locally,

[1] See Figure 2 from Shelton et al (1998) for a graphical depiction of the extensive area within the KRWCA area that is involved in groundwater banking operations.

groundwater generally flows toward locations of groundwater pumping and away from locations of groundwater recharge.

First-encountered groundwater is relatively deep in the KRWCA area. Figures 2a and b display depth to water contours for first-encountered groundwater during the spring of 2010 as determined by the DWR and Kern County Water Agency (KCWA), respectively[2]. The depth to water ranges from as little as approximately 50 feet to as much as approximately 700 feet. Water in much of the area is between 150 and 300 feet deep. Figure 3 displays depth to water contours for first-encountered groundwater during the spring of 1988 as determined by the DWR. Comparison of Figures 2a and 3 indicates that first encountered groundwater is currently deeper than it was approximately two decades ago.

3.3 Groundwater Quality and Potential Sources of Nitrate

Nitrate in first-encountered groundwater is the primary focus of the draft order. Boyle et al (2012) summarized information on nitrate concentrations in groundwater for the TLHR including the KRWCA area. Burton et al (2012) also investigated the occurrence of nitrate in groundwater in these areas. Several other studies have also investigated nitrate in groundwater in the San Joaquin Valley[3]; however, these studies focused on locations north of the KRWCA area (in other parts of the TLHR and in the ESJW) where, as discussed in later sections of this report, first-encountered groundwater is shallower and water quality impacts appear to be more pronounced.

Potential anthropogenic sources of nitrate to groundwater in the KRWCA area include: confined animal feeding operations, crop agriculture (past and current), dairies, municipal and industrial wastewater and sludge disposal, and septic systems[4]. Figure 4 indicates the current locations of various potential anthropogenic sources of nitrate throughout the KRWCA area, and Figure 5 (adapted from Harter et al, 2012) indicates the relative magnitudes of various sources at present[5]. While crop agriculture is a significant potential source, manure from dairies and other operations is also a significant potential source. Moreover, consideration of current potential sources is not sufficient to fully assess the potential sources of the observed nitrate in groundwater. Because the KRWCA is part of a closed groundwater basin, impacts accumulate over time (KCWA, 2008). Accordingly, Figure 6 builds upon Figure 5 by adding past potential sources starting in 1945 using

[2] The contours presented are for the geographically extensive first-encountered groundwater and do not include the limited areas of shallow groundwater outlined on Figure 2a.

[3] These studies include Botros et al (2012), Botros et al (2009), Burow et al (1998), Burton and Belits (2008), Domagalski et al (2008), Dubrovsky et al (1998), Dubrovsky et al (2010), Fischer and Healey (2008), Green et al (2008a), Green et al (2008b), Harter et al (2005), Landon et al (2010), Lindsey and Ruperet (2012), Onsoy et al (2005), Puckett et al (2008), Schmidt et al (2011), Singleton et al (2011) and Tesoriero (2007).

[4] Burton et al (2012) used available data sets from the KRWCA area to document statistical correlations between nitrate concentrations in groundwater and 1) dissolved oxygen content and 2) proximity to only certain types of crop agriculture (orchards and vineyards) and septic systems.

[5] The results of Harter et al (2012) are presented for discussion purposes. That work has not been reviewed in detail.

the information plotted on figures 7 through 10[6]. When accumulation over time is considered[7], past potential sources related to crop agriculture and manure are revealed as the most significant potential sources with approximately 79 percent of the total potential source contribution. Clearly, understanding the distribution of nitrate in groundwater in the KRWCA area must include consideration of historic activities. While the Central Valley Regional Water Quality Control Board has stated the order will not address the legacy issue in terms of regulating groundwater impacts from past land use practices, these impacts will affect groundwater quality monitoring conducted under the order.

3.4 Differences between KRWCA Area and Areas to the North

The KRWCA area differs from areas located farther north in the San Joaquin Valley: 1) the rest of the SSJVWQC/TLHR area and 2) the East San Joaquin Water Quality Coalition (ESJWQC)/ESJW area. The three points discussed below will be considered in the following sections of this report.

First, the depth to groundwater in the KRWCA area is significantly greater than in the areas located to the north. Table 1 compares the depths to first-encountered groundwater for the groundwater subbasins in the areas being discussed. Groundwater in the KRWCA area is by far the deepest based upon both the averages and maximum data. Boyle et al. (2012) graphically depict this condition (see Figure 2 of the cited document). As a result, it takes longer for agricultural return flows, where they exist, to reach first-encountered water in the KRWCA area.

Second, nitrate impact to first-encountered groundwater is less pronounced in the KRWCA area than it is to the north. Boyle et al. (2012) provide a graphical comparison of the areas (see Figures 41 through 44 of the cited document). Burton et al. (2012) provide statistics that support this conclusion. The aggregate conditions in the KRWCA area (i.e. hydrogeologic conditions and agricultural management practices) appear to be more protective of groundwater quality than is the case for areas located to the north.

Finally, there are significant hydrologic stresses imposed upon the groundwater system in the KRWCA area. With rainfall being approximately one-half to one-third of that for the above-referenced areas located to the north (Williamson et al, 1989; Gronberg et al., 1998), a substantial amount of groundwater pumping occurs in order to meet the water demand. Given the demand on the groundwater resource and decline in water levels over time mentioned in Section 3.2, a substantial amount of groundwater recharge has been performed to maintain the resource. These

[6] Estimation of past potential nitrate sources (crop, manure and other) for Figure 6 involved scaling the values presented by Harter et al (2012). The scaling value for each category was calculated as the ratio of past (1945 to 2002) to current (2003 to 2007) for an indicator variable that was summed over the two time intervals. For the Crop category, the indicator variable was the product of acres in production (Figure 7) with synthetic nitrogen applied (Figure 8). For the Manure category, the indicator variable was the manure nitrogen applied (Figure 9). For the Other category, the indicator variable was the Kern County population (Figure 10).

[7] It is assumed that all nitrogen is converted to nitrate and there are no losses over time.

pumping and recharge operations have created the potential to induce lateral flow of groundwater and migration of dissolved constituents over significant distances.

Table 1
Summary of Depth to First-Encountered Groundwater within the ESJW and TLHR Areas

DWR Groundwater Subbasin or Group	Minimum	Average	Maximum
East San Joaquin Watershed (ESJWQC)	1	88	277
Kings Subbasin	0	87	254
Kaweah Subbasin	6	102	214
Tulare Lake Subbasin	1	77	309
Tule Subbasin	2	159	440
Kern County Subbasin (KRWCA)	100	265	634

Notes:
1) Results are in feet and rounded to the nearest foot.
2) Analysis performed on DWR monitoring data for spring 2010.
3) Averages were calculated on data declustered at the township-range level.
4) East San Joaquin Watershed water level data from the following DWR groundwater subbasins were used: Chowchilla, Madera, Merced, Modesto and Turlock
5) Consistent with Figures 2a, 2b and 3, the KRWCA entries do not address the limited areas of shallow groundwater outlined in Figure 2a.

4.0 SCIENTIFIC CHALLENGES FOR MONITORING GROUNDWATER QUALITY IN THE KRWCA AREA

The premise for groundwater quality monitoring in the draft order is that collecting information will allow the effectiveness of irrigation and fertilizer management practices to be evaluated and improved where necessary in order to protect the quality of first-encountered groundwater. However, there are several aspects the hydrogeology in the KRWCA area that will complicate interpretation of the collected monitoring data. As observed in a United States Geological Survey (USGS) study conducted in both the TLHR and the ESJW areas by Burow et al. (2008), "Protection of groundwater for present and future use requires monitoring and understanding of the mechanisms controlling long-term quality of groundwater." The following sections identify some of the more important mechanisms that influence groundwater quality and discuss the implications for the Management Practice Evaluation and Groundwater Trend Monitoring programs required by the draft order.

4.1 A Thick Unsaturated Zone Creates Time Lags Between Activities at Ground Surface and Changes in Groundwater Quality at Depth

As indicated on figures 2a and b, the depth to first-encountered groundwater in the KRWCA area varies greatly. Table 1, presented previously, summarizes the range in depth to water across the area and compares this condition to other areas within the TLHR and ESJW areas. Most of the studies conducted in the San Joaquin Valley and cited in the draft order as a basis for regulating irrigated agriculture have been conducted in areas other than the KRWCA area, in areas where groundwater is much shallower. As indicated on Figure 11, the depth to first-encountered groundwater in the vast majority of the KRWCA area is much greater than that in the types of studies referenced in the draft order[8]. The significant distance between ground surface and first encountered groundwater over much of the KRWCA area (hundreds of feet) increases transit times for return flows migrating down through the unsaturated zone to saturated groundwater. This condition creates a time lag between 1) irrigation and nitrogen management activities at ground surface and 2) changes in the quality of first-encountered groundwater[9].

Appendix B presents the results of nitrate travel time calculations for bulk flow through the unsaturated zone under the range of conditions that occur in the KRWCA area. Both agronomic factors (return flow and nitrogen lost below root zone) and hydrogeologic factors (unsaturated zone stratigraphy and depth to first encountered groundwater) were considered. The results indicate that nitrate may reach first-encountered groundwater in as little as 10 to 15 years in some areas, but requires many decades to several centuries for the migration path to be completed in other

[8] See references in Footnote #3.

[9] This condition may exist in other parts of the TLHR and in some parts of the ESJW as well. However, the greater depths to groundwater in the KRWCA area make the condition more significant to the interpretation of groundwater quality in the KRWCA area.

areas where first encountered groundwater is deeper. It is acknowledged that a variety of processes may lead to a range of travel times with migration occurring faster or slower than the estimates presented here[10]. However, it appears that the processes are very site-specific and those which might lead to faster migration are not likely to occur consistently over significant unsaturated zone thicknesses and across changes in lithology (i.e., interlayered sands and clays). This view is consistent with research conducted on relatively thick unsaturated zones[11]. Furthermore, these calculations are consistent with the observation that water quality is less impacted in the KRWCA area than in the northern portion of the TLHR and the ESJW where groundwater is generally shallower (see Section 3.4).

The implication of the presence of a thick unsaturated zone across much of the KRWCA area is that a significant portion of the nitrate from past fertilization practices currently remains in-transit in the unsaturated zone. As a result, current changes in groundwater quality are associated with return flows resulting from past farm practices as opposed to current practices. A trend monitoring program conducted under such conditions cannot meet the monitoring goals of the draft order because there is a temporal disconnect between actions at ground surface and reactions in groundwater located at depth. Changing current irrigation and fertilization practices cannot affect what has occurred in the past.

4.2 Nitrate in the Unsaturated Zone Acts as an Ongoing Source to Groundwater

In situations where transit times from ground surface to first-encountered groundwater are significant (many years or more), the unsaturated zone effectively acts as a reservoir for nitrate to be released to groundwater at a later time. This condition complicates trend monitoring and makes effective regulation of current farm practices very difficult.

While some researchers have interpreted data for shallow groundwater sites to indicate that nitrate migrates through the unsaturated zone quickly and leaves little residual, this does not appear to be the case in much of the KRWCA area partly because first-encountered groundwater is deep and the unsaturated zone has a significant storage capacity. Figure 12 demonstrates that the unsaturated zone can, in fact, act as a long-term reservoir for nitrate. The monitored site was farmed until approximately the year 2000 and then converted into a spreading ground for groundwater recharge. The nitrate concentration in groundwater when the land was used for farming was slightly below the drinking water Maximum Contaminant Level of 45 milligrams per liter (mg/l). After groundwater recharge operations began, the concentration rose to a high of

[10] For faster migration, these processes may include anion exclusion, fingering, funneling and flow along high hydraulic conductivity pathways. For slower migration, these processes may include physical interaction with soil, diffusion into slow velocity or immobile zones and denitrification under some conditions (Kung, 1990a and 1990b; Green and Bekins, 2010).

[11] McMahon et al. (2006) evaluated the transit times for chemicals through thick unsaturated zones in the High Plains region of the United States. For irrigated croplands with unsaturated zone thicknesses ranging from approximately 55 to 160 feet, they found that travel times to groundwater varied between approximately 50 and 370 years.

slightly more than 80 mg/l, and the elevated concentrations persisted for more than a decade as the newly established recharge operation continued. A reasonable interpretation of this information is that 1) the downward migration rate through the unsaturated zone increased as a result of the recharge operation, 2) groundwater concentrations increased as a result of the large amount of nitrate from past farming migrating downward at an increased rate and 3) the increased nitrate concentrations persisted because the reservoir of nitrate in the unsaturated zone was large[12]. Most recently, the nitrate concentrations in groundwater have begun to decrease. This development may be the result of the nitrate reservoir in the unsaturated zone being depleted over time by the flushing associated with the recharge operation.

Figure 13 presents data from an area not used as a spreading ground. Here, there is clearly a positive correlation between water level and nitrate concentration. Although the monitoring data early in the period of record are sparse, a reasonable interpretation of this information is that the unsaturated zone acts as a reservoir for nitrate which is released to groundwater during periods of high water levels when saturated groundwater conditions rise up into previously unsaturated sediments. As a result, in order for groundwater quality trend monitoring to be effective, the legacy issue discussed above must be considered and incorporated into the approach before the draft order is finalized.

4.3 Processes Acting on Return Flows During Transit Through the Unsaturated Zone Can Affect Trends Observed in First-Encountered Groundwater

As noted above, several processes can lead to a range of travel times through the unsaturated zone beneath a single parcel. When thick unsaturated zones and long travel times to groundwater are also involved, there is the potential to mix older and younger return flows at the point where faster and slower migration paths terminate (first-encountered groundwater). To the extent that these flows are significantly different in age, they may have originated during times of different nitrogen management practices. Mixing of such flows could blur differences in water quality trends associated with past and current management practices that might otherwise be apparent.

The processes involved in creating the different flows may include 1) for faster migration, anion exclusion, fingering, funneling and flow along high hydraulic conductivity pathways and 2) for slower migration, physical interaction with soil, diffusion into slow velocity or immobile zones (Green et al., 2005) and denitrification under some conditions[13] (Dubrovsky et al., 2010; Landon et al., 2010; Schmidt et al. 2011). However, a USGS study conducted in the SSJVWQC area (Burow et al., 2008) noted that "few wells have been sampled over time spans long enough to assess the

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[12] This example should not be interpreted as an indication that all recharge operations flush nitrate into the saturated zone. Land use history is a very important factor that must be considered. The purpose of this discussion is to provide evidence that past farming practices, as opposed to current farming practices, have added large amounts of nitrate to the unsaturated zone.

[13] For instance, above clay strata where the moisture content may increase and contact with air in the pore space may decrease. The decrease in dissolved oxygen and long travel times could create conditions conducive to nitrate loss by denitrification.

relation between regional management practices and potential long-term degradation of water quality in the eastern San Joaquin Valley aquifer system." So, it isn't clear what unresolved scientific questions may be encountered as the monitoring data are collected. Successful water quality trend analysis requires a favorable signal to noise ratio, and concentration data effectively contain noise when they are affected by processes that are not understood. Therefore, travel through a thick unsaturated zone is expected to increase the noise and complicate interpretation of actual trends unless the processes acting on the return flows are understood. The complexities that may be encountered during monitoring should be considered before the large-scale monitoring program in the draft order is finalized. One approach for acquiring the necessary experience with monitoring deep groundwater would be to conduct a pilot monitoring program in a small portion of the KRWCA area.

4.4 Horizontal Flows in Subbasin Can Complicate the Attribution of Observed Nitrate to Specific Source Areas

As noted in Section 3 above, the KRWCA area is located within a closed groundwater basin that experiences relatively large artificial hydrologic stresses in the forms of water supply well pumping and recharge operations. In addition, many potential sources of nitrate are located close together (Figure 4). Under these conditions, nitrate from different sources likely mixes. In fact, a study of domestic well water quality in the SSJVWQC area (Singleton et al., 2011) found that many wells contained mixtures of nitrate from many sources (manure, fertilizer and septic/community wastewater). This finding is consistent with a USGS study conducted in the SSJVWQC area (Burow et al., 2008) that noted "Predicting the long-term fate of nitrate and pesticides in ground water in this region is difficult owing to intensive ground water pumping, mixed sources of recharge water, and complex flow paths through heterogeneous alluvial fan sediments." This situation can make the draft Management Practice Evaluation Program quite difficult to implement as existing water quality impacts may not be attributable to the monitored, or even specific, locations.

In addition, horizontal migration can induce changes in concentrations over time and complicate draft trend Monitoring. Figure 14 provides an example. Two fairly similar periods of high water are contained in the plotted record; however, the concentration responses during those periods are quite different. The history of extraction and recharge in this part of the subbasin is indicated along the top of the figure.` While changes in the locations of extraction and recharge are not indicated, it is clear that there are differences in timing, duration and the cumulative magnitude of the hydrologic stresses. A reasonable interpretation of this information is that nitrate in the saturated zone migrates horizontally under the influence pumping and recharge.

In another USGS study that included locations in the San Joaquin Valley, Rupert (2008) noted the complexities associated with evaluating trends in groundwater quality data. Two of the points made were that 1) it is difficult to evaluate trends unless the recharge age is known so that correlation with changes in land use can be made and 2) changes in oxidation-reduction conditions can significantly affect trends. These are just some of the complexities that should be considered and evaluated before the large-scale monitoring program in the draft order is finalized.

4.5 The Potential Costs of Insufficiently Planned Groundwater Quality Monitoring are Significant

Evaluations of potential costs associated with the monitoring programs required in the draft order have been made on behalf of the State and continue to be revised. While a final assessment of the costs has not yet been prepared, it is clear that the program will be costly. Moreover, costs in the KRWCA area are likely to be higher than the average for the SSJVWQC area because the depth to first-encountered groundwater is greater than in other parts of the SSJVWQC area. Given the costs, details of the monitoring program should be carefully planned to increase the likelihood of successful implementation. Consideration of the issues raised above should be incorporated into that planning. The primary implication of these issues is that the monitoring program goals (evaluating the effectiveness of irrigation and fertilizer management practices and improving them where necessary in order to protect the quality of first-encountered groundwater) may not be achievable through the monitoring programs required in the draft order. That possibility stems from problems with data interpretation that may be encountered, for the reasons stated above, when trying to attribute water quality conditions to farming activities at specific locations and times.

Potentially more costly than implementation of a flawed monitoring program would be regulatory required changes in farm management practices based upon incorrect conclusions from an insufficiently planned monitoring program (i.e., possibly contained in Groundwater Quality Management Plans). Acting on false positives would not achieve the goals of the monitoring program and would create additional costs (both direct costs associated with compliance activities and opportunity costs associated with any decreases in yield) for farmers. Further study or, possibly, a pilot program as an interim regulatory step should be considered before creating a comprehensive set of monitoring regulations given the, as yet, rudimentary understanding of how nitrate moves through subsurface in the KRWCA area.

5.0 COMMENTS ON SPECIFIC ASPECTS OF THE ORDER

The following sections highlight some of the more obvious shortcomings of the draft order if it were applied to the KRWCA area. These comments are not intended to be presented as a comprehensive evaluation of the draft order.

5.1 General Order

The details set forth in Section VIII (Required Reports and Notifications – Third Party) D (Groundwater Quality Assessment Report and Evaluation/Monitoring Workplans) involve 1) evaluation of groundwater quality vulnerability to impacts from irrigated agriculture (Management Practice Evaluation) and 2) observation of current and future groundwater quality trends attributable to irrigated agriculture (Trend Monitoring). It is important to note that complications associated with identifying sources, or potential sources, of groundwater contamination - both in space (i.e., impacts that migrate away from source locations) and time (i.e., the legacy issue) as noted in Section 4 of this report - will likely be encountered during the performance of the required work. Furthermore, it is likely that more questions than answers will be encountered in many instances. Some recognition of and allowance for these potential technical complications should be included in the draft order. For example, the development of a Groundwater Quality Management Plan (Section VIII.H.2) should not be required of a current irrigated agricultural operation if there is evidence that an exceedance may have resulted from past (legacy) activities.

5.2 Attachment B – Monitoring and Reporting Program

The reasoning upon which the groundwater portion of this section of the draft order is based follows from previous sections where there appears to be an implicit assumption that groundwater quality responds to activities occurring at ground surface over a relatively short time period[14]. As an example, Section IV (Groundwater Quality Monitoring and Management Practice Assessment, and Evaluation Requirements) requires that "The third party must collect sufficient data to describe irrigated agricultural impacts on groundwater quality and to determine whether existing or newly implemented management practices comply with the groundwater receiving water limitations of the Order." This task may require decades or more for areas where first-encountered groundwater is located deep beneath the ground surface and transit times are long. (See Section 4.1 of this report for supporting discussion.) Therefore, allowance for potentially long monitoring periods must be reflected in compliance schedules.

As stated above in these comments, there are several complex processes occurring in the KRWCA area that must be interpreted before attempting to link current changes in the quality of first encountered groundwater with current irrigation and fertilizer management practices. As a result, difficulties associated with identifying sources of groundwater contamination – both in space

[14] For the purposes of developing the draft order, a very simple conceptual model of cause and effect has been applied to a situation where the aggregate effect of active transport processes could be significantly more complicated.

and time – will likely be encountered during the performance of the required work in many instances. Some recognition of and allowance for these potential technical complications should be noted.

Large-scale implementation of the monitoring concept is not appropriate for much of the KRWCA area without further consideration of the issues presented in these comments. Rather, a phased approach should be implemented with initial work being performed on a limited group of areas where technical interpretation of the water quality data is anticipated to be the least complicated. Areas of shallowest first-encountered groundwater may be appropriate candidates for the initial phase of work.

5.3 Appendix MRP-1, Management Plan Requirements, Surface Water and Groundwater

The details presented in Section I (Management Plan Development and Required Components) D (Monitoring Methods) 3 (Groundwater – Additional Requirements) involve evaluation of groundwater quality trend monitoring data in order to draw conclusions regarding additional monitoring requirements. As discussed above, there may be difficulties interpreting the data as a result of unique technical challenges that exist for the KRWCA area. Some recognition of and allowance for these potential technical complications should be noted.

Section I (Management Plan Development and Required Components) G (Source Identification Study Requirements) allows for the identification of sources other than irrigated agriculture that are responsible for groundwater quality impacts. The text should state that past irrigated agriculture is a potential source that is distinct from current irrigated agriculture. It is appropriate to include past irrigated agriculture as a distinct potential source because regulation of current agricultural practices will have no effect on impacts resulting from past practices.

5.4 Appendix MRP-2, Monitoring Well Installation and Sampling Plan and Monitoring Well Installation Completion Report

The reasoning upon which this section of the draft order is based follows from previous sections where there appears to be an implicit assumption that groundwater quality responds to activities occurring at ground surface over a relatively short time period. As an example, Section II (Monitoring Well Installation and Sampling Plan), A (Stipulations), 4 states that "Groundwater monitoring shall…be of sufficient frequency to allow for evaluation of any seasonal variations." This assumption is flawed. Please refer to the discussion of complexities associated with the KRWCA area presented above.

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FIGURES

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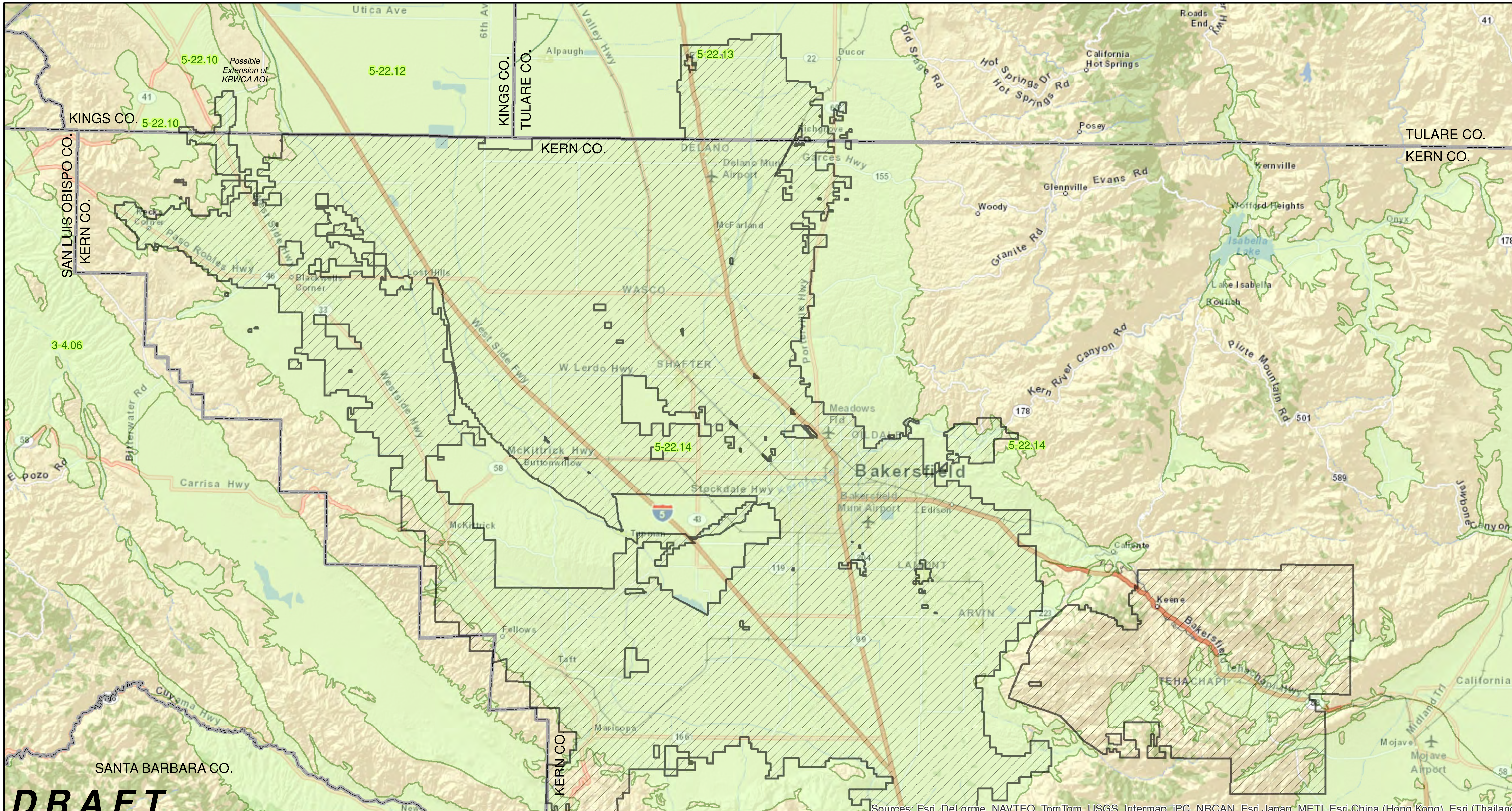

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DWR Groundwater Basin/Subbasin (ID Label)

County

KRWCA Boundary

Kern County Irrigated Lands Program
Kern Sub-Watershed

KRWCA Area

FIGURE 1

2/5/2013: V:\Clients\Kern River Watershed Coalition Authority-3484\348412V1-ILRP 2012\GIS\Map\DataProcessingForRobGailey\ReportFigs\figure1.mxd

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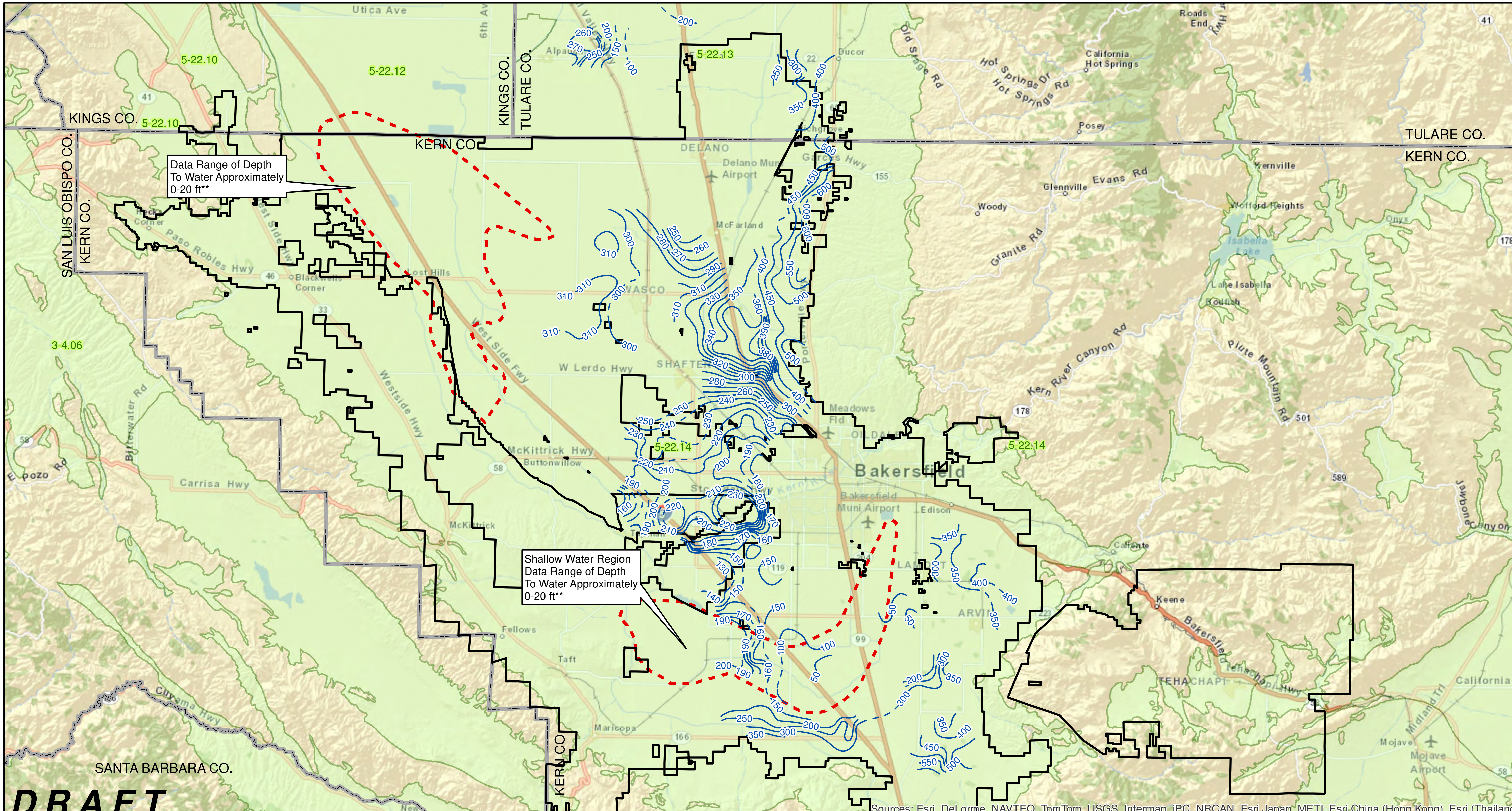

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DWR Groundwater Basin/Subbasin (ID Label)

County

KRWCA Boundary

Shallow Water Region - Approximate**

Depth To Water - Unconfined Aquifer***

High Degree of Confidence

Inferred

Data References:

**Areas digitized from CA DWR "Present and Potential Drainage Problem Areas" survey map, 2010
http://www.water.ca.gov/pubs/drainage/2010_shallow_groundwater_map__san_joaquin_valley/sgw10.pdf

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http://www.water.ca.gov/groundwater/data_and_monitoring/south_central_region/images/groundwater/sjv2010spr_unc_depth.pdf

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Kern County Irrigated Lands Program
Kern Sub-Watershed

Spring 2010
Depth To Water In Wells
DWR Representation

FIGURE 2A

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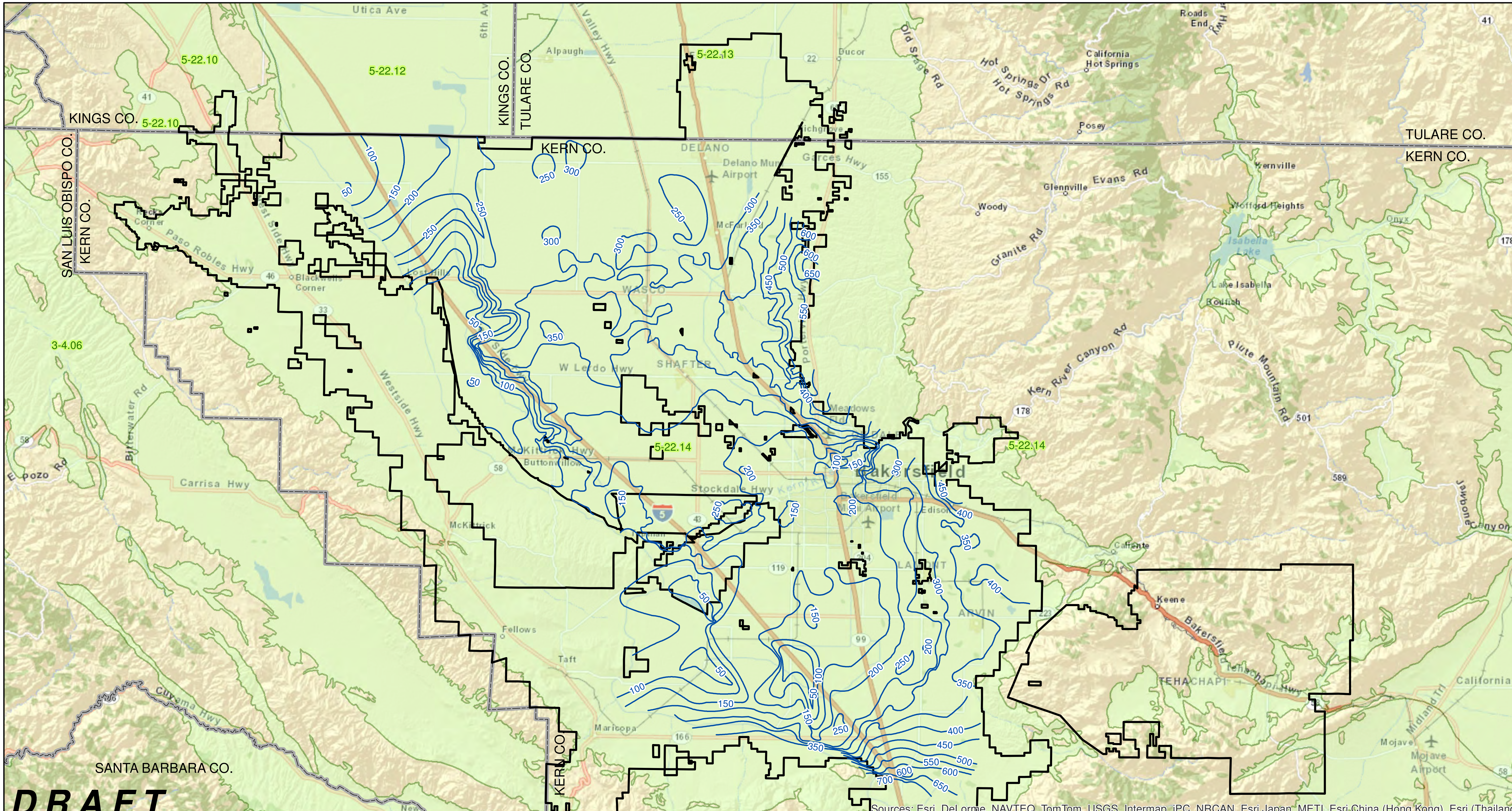

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DWR Groundwater Basin/Subbasin (ID Label)

County

KRWCA Boundary

Depth to Water - KCWA Spring 2010, 50 ft interval**

Data References:

**Isopleth lines digitized from Kern County Water Agency, published map of Depth to Groundwater, Unconfined Aquifer, Spring 2010. Published 07/2010.

Kern County Irrigated Lands Program
Kern Sub-Watershed

Spring 2010
Depth To Water In Wells
KCWA Representation

FIGURE 2B

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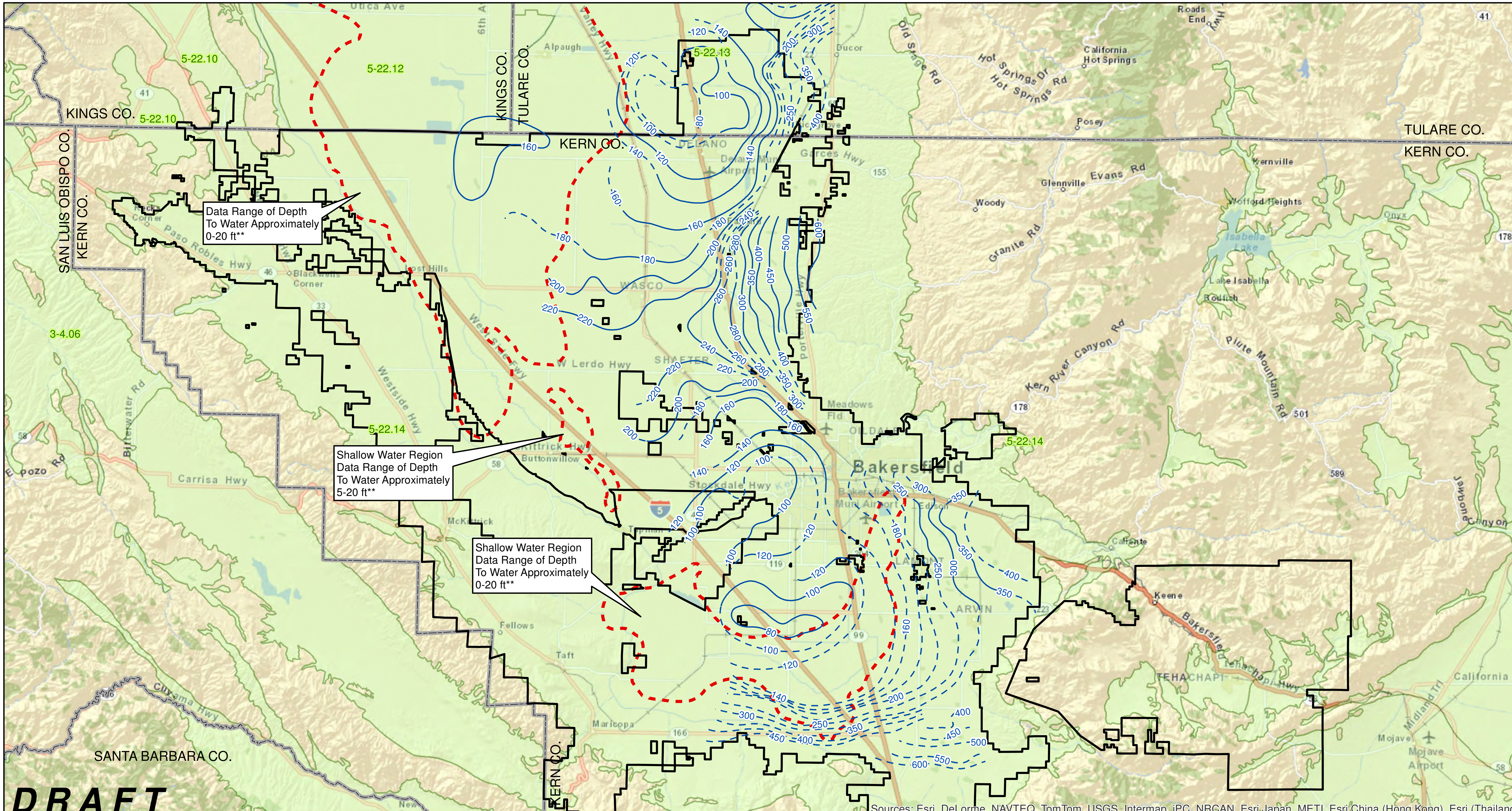

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DWR Groundwater Basin/Subbasin (ID Label)

County

KRWCA Boundary

Shallow Water Region - Approximate**

Depth To Water - Unconfined Aquifer***

High Degree of Confidence

Inferred

Data References:

**Areas digitized from CA DWR "Present and Potential Drainage Problem Areas" survey map, Figure 4, data from 1986. Map dated April 1987. Report dated April 1988.
http://www.water.ca.gov/pubs/drainage/1986_drainage_monitoring_report__san_joaquin_valley/86dmr.pdf

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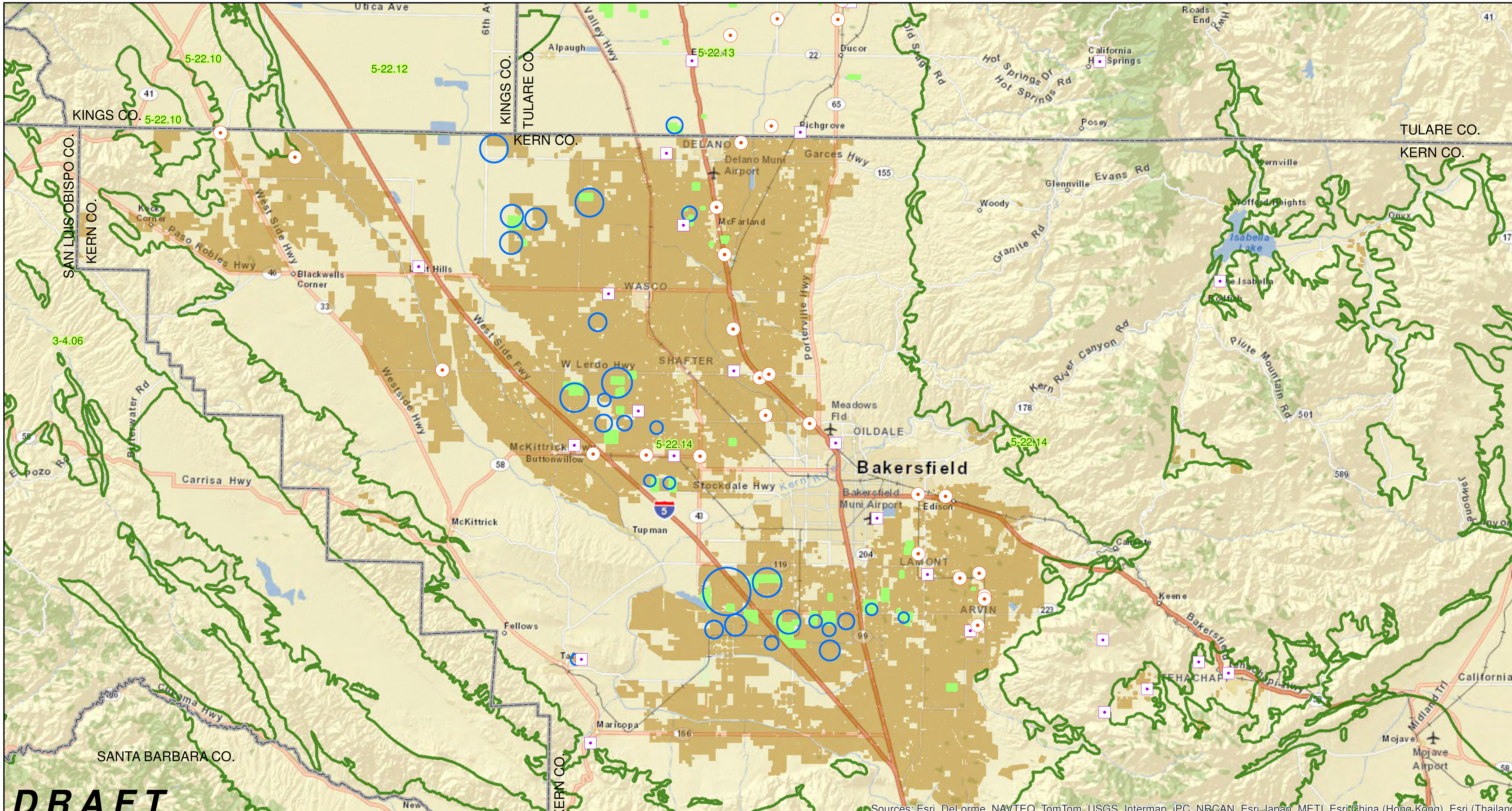
http://www.water.ca.gov/groundwater/data_and_monitoring/south_central_region/images/groundwater/sjv1988spr_unc_depth.pdf

Kern County Irrigated Lands Program
Kern Sub-Watershed

Later 1980's
Depth To Water In Wells
DWR Representation

FIGURE 3

2/5/2013: V:\Clients\Kern River Watershed Coalition Authority-3484\348412V1-ILRP 2012\GIS\Map\DataProcessingForRobGailey\ReportFigs\figure3.mxd



0 5 10 Miles

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- Food Processor (Approx. Location)*
- Waste Water Facility (Approx. Location)**
- Effluent, Biosolids, and On-Dairy Manure N for Cropland Application***
- Dairy Facility****
- Irrigated Lands - Kern County Crop Survey 2011
- DWR Groundwater Basin/Subbasin (ID Label)
- County

Data References:

* Approximate locations. UC Davis Report for the SWRCB SBX2 1 Report to the Legislature, Addressing Nitrate in California's Drinking Water. Technical Report 2. Hater et al. July 2012. Appendix Fig. 1.

**Approximate locations. UC Davis Report for the SWRCB SBX2 1 Report to the Legislature, Addressing Nitrate in California's Drinking Water. Technical Report 2. Hater et al. July 2012. Appendix Fig. 2.

***Generalized areas of modeled Nitrate applied to croplands, kg N/ha/yr >500 . UC Davis Report for the SWRCB SBX2 1 Report to the Legislature, Addressing Nitrate in California's Drinking Water. Technical Report 2. Hater et al. July 2012. Fig. 11.

****SWRCB draft dairy facilities parcels.

Kern County Irrigated Lands Program
Kern Sub-Watershed

Potential Nitrate Sources

FIGURE 4

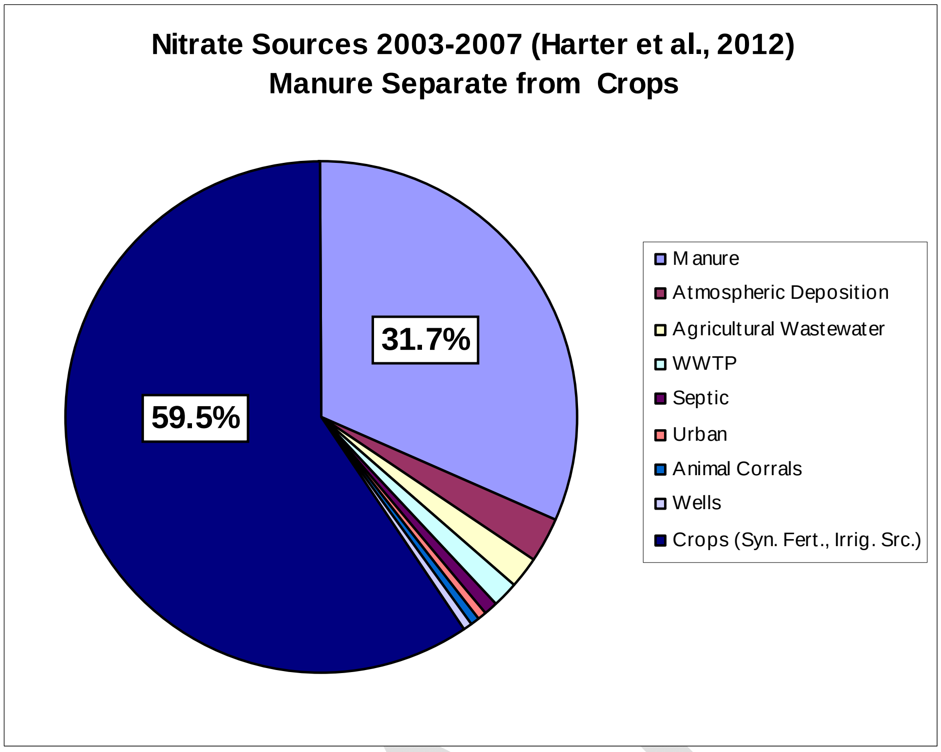


Figure 5: Current Nitrate Sources 2003 – 2007

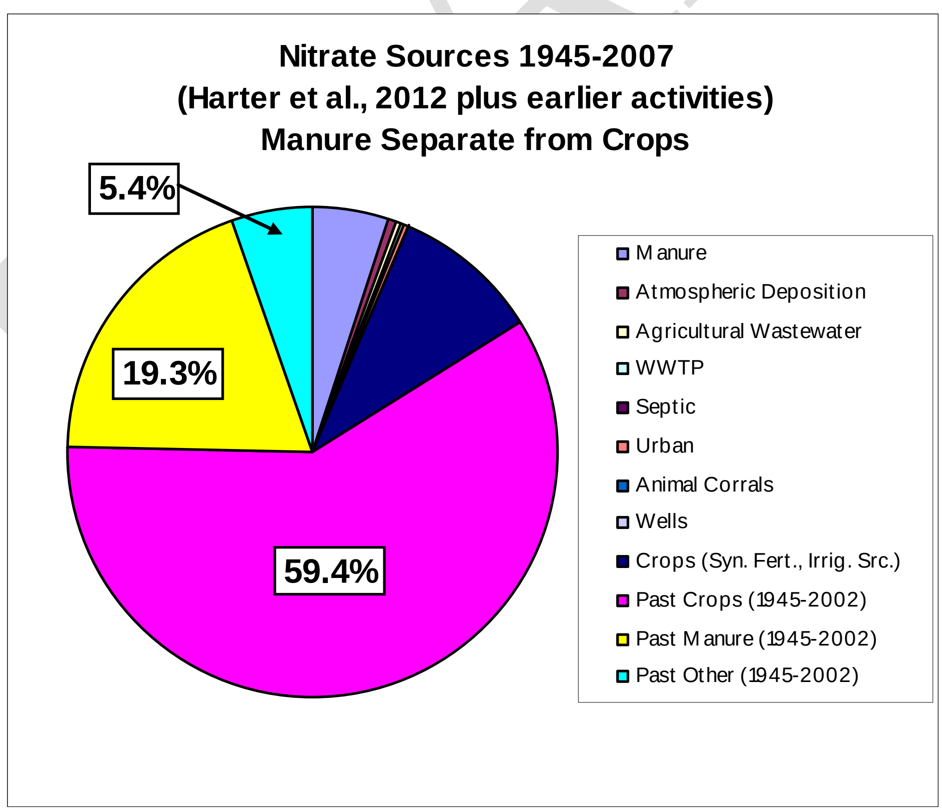


Figure 6: Current and Past Nitrate Sources 1945 – 2007

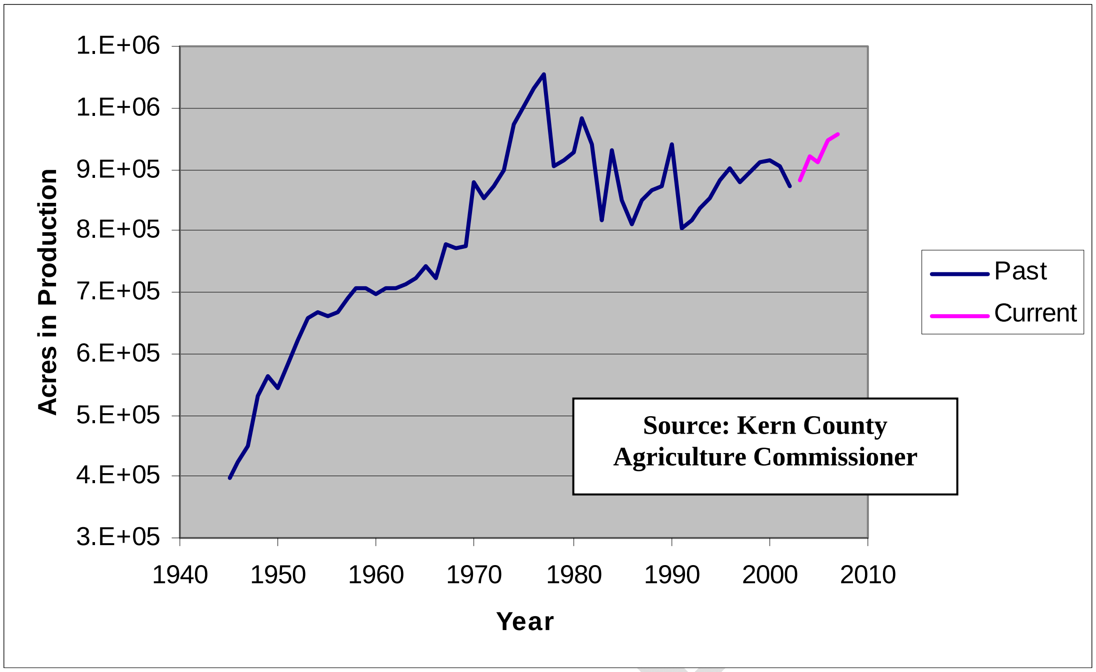


Figure 7: Historical Record of Kern County Acres in Crop Production

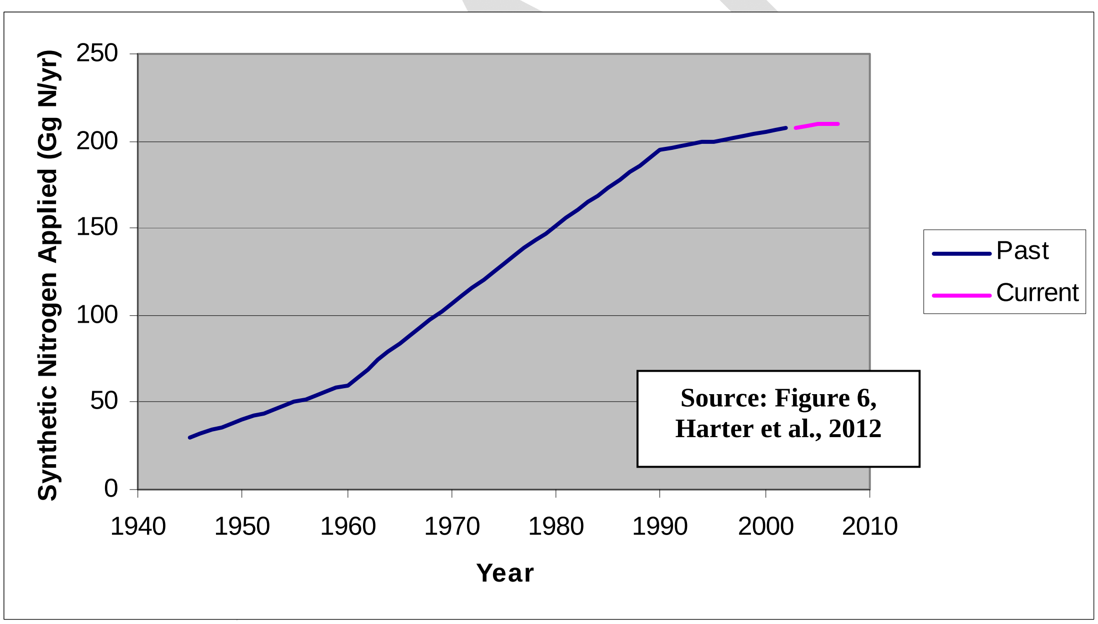


Figure 8: Historical Record of Fertilizer Nitrogen Applied to Crops in the United States

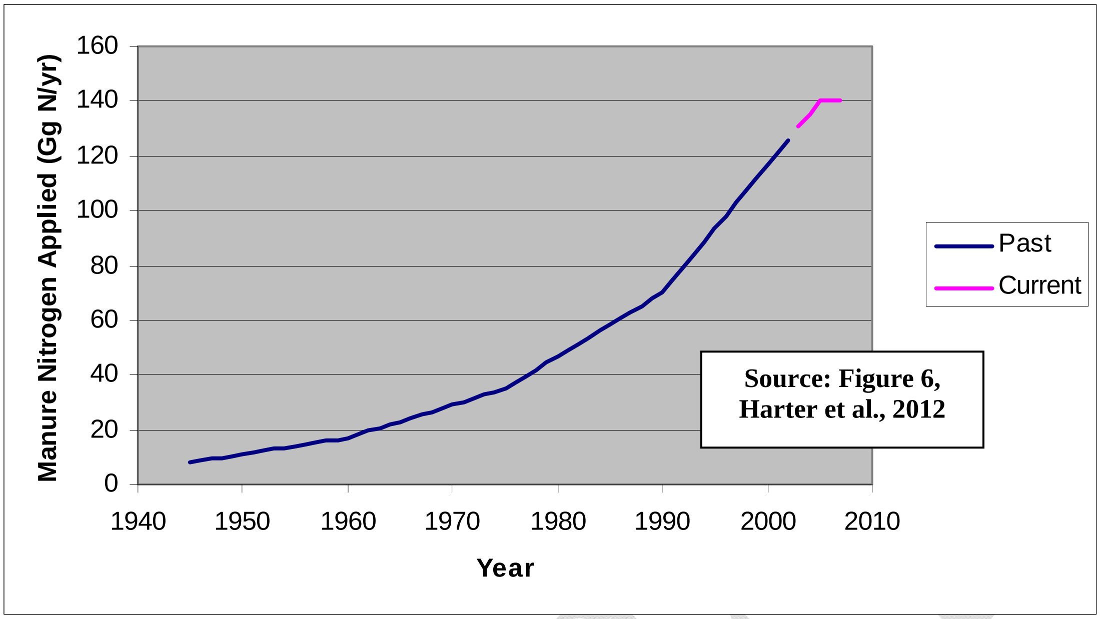


Figure 9: Historical Record of Manure Nitrogen Applied to Crops in the United States

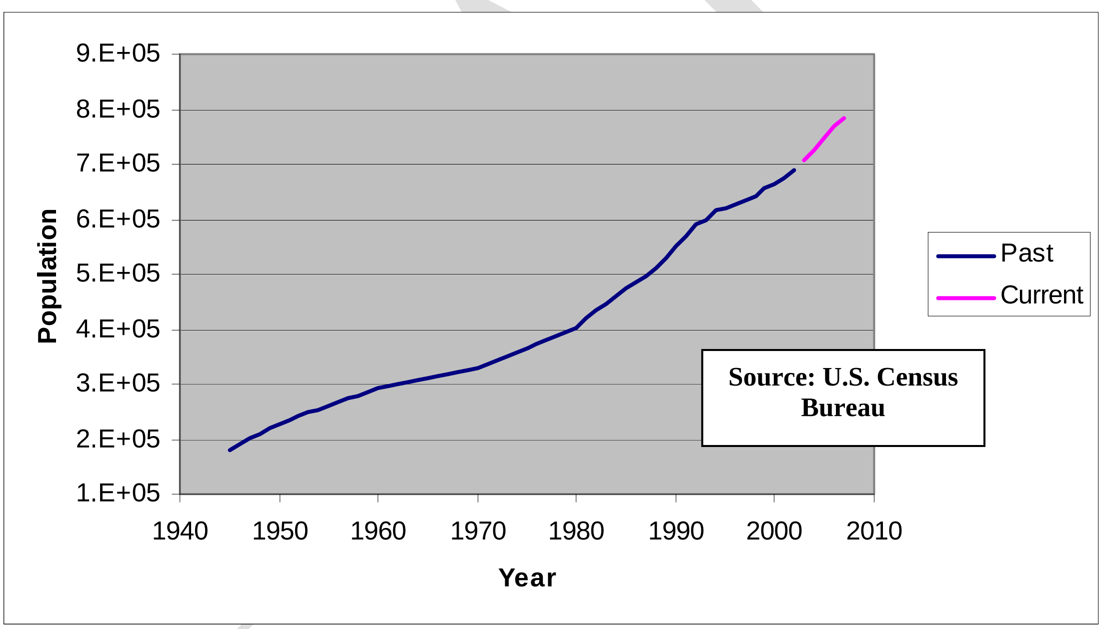


Figure 10: Historical Record of Kern County Population

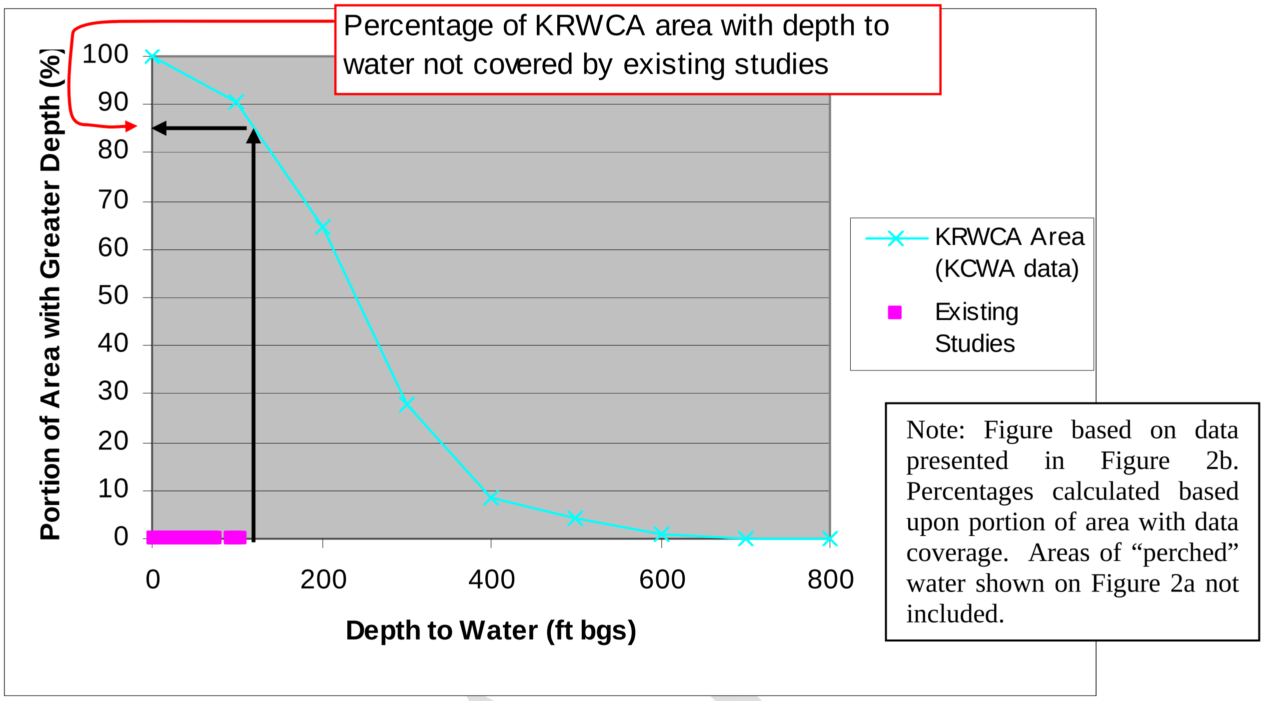
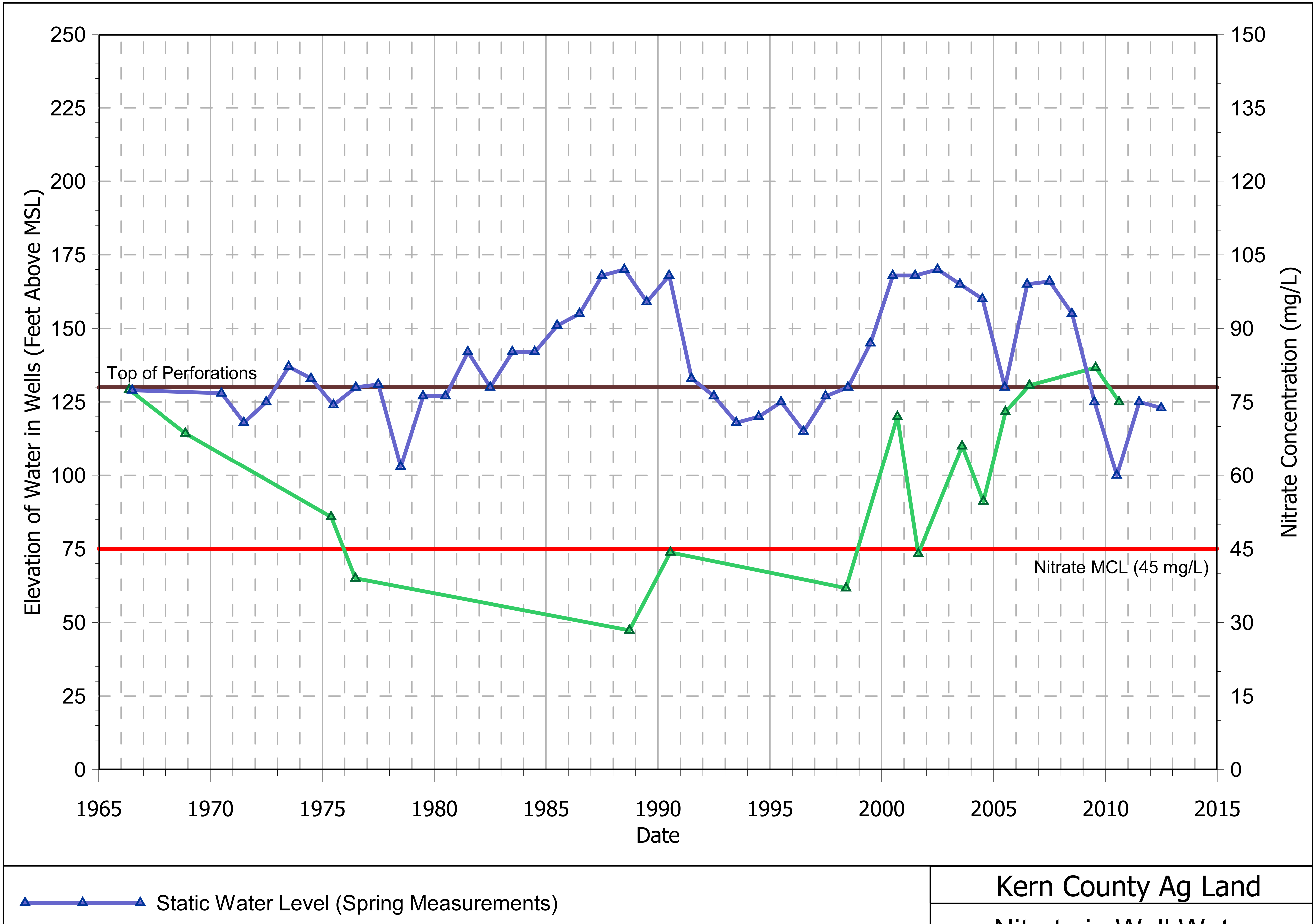


Figure 11: Portion of KRWCA Area with First-Encountered Saturated Zone Water Deeper than a Specified Value

DRAFT

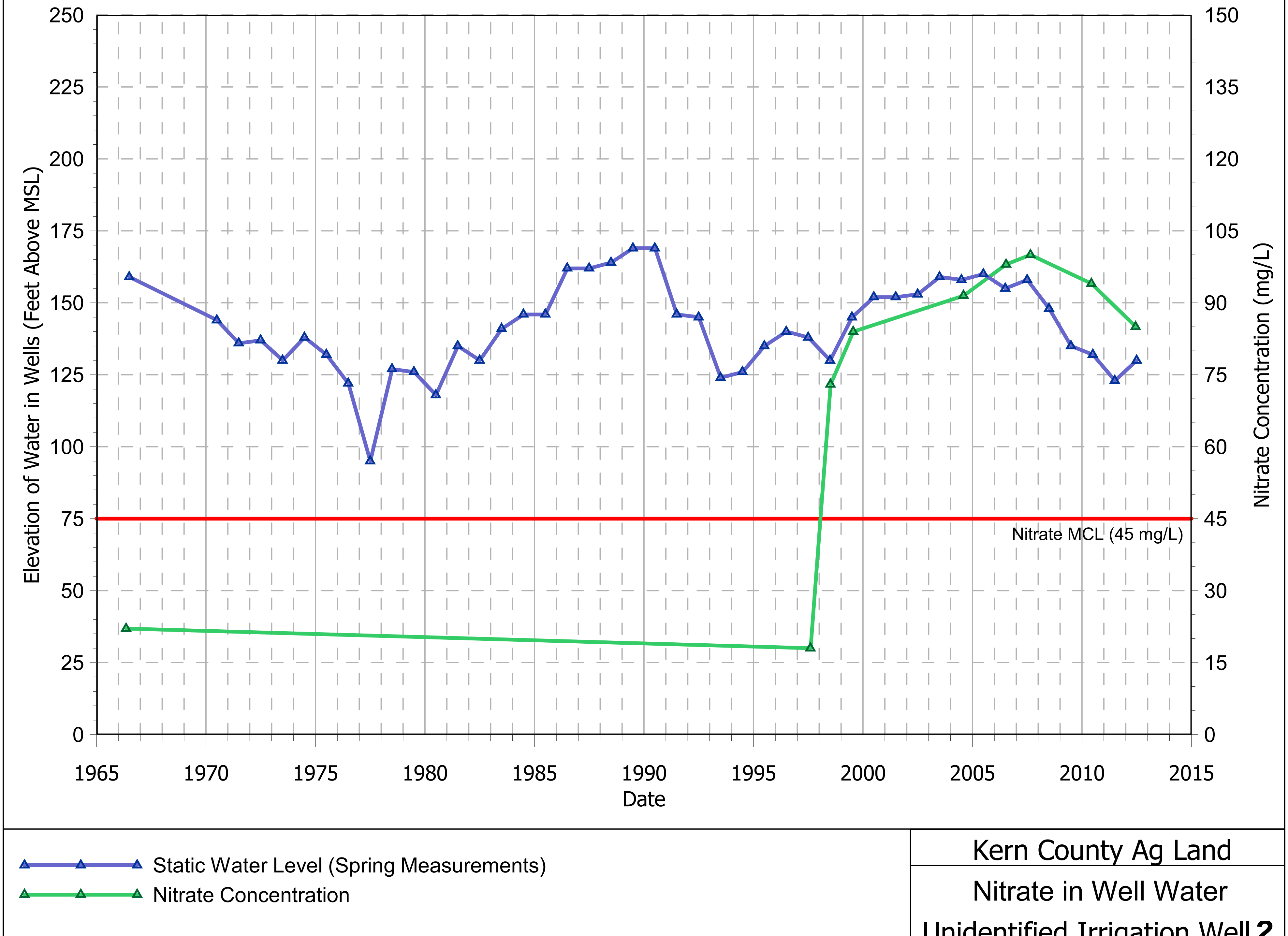
Figure 12



Kern County Ag Land
Nitrate in Well Water
Unidentified Irrigation Well **1**

DRAFT

Figure 13



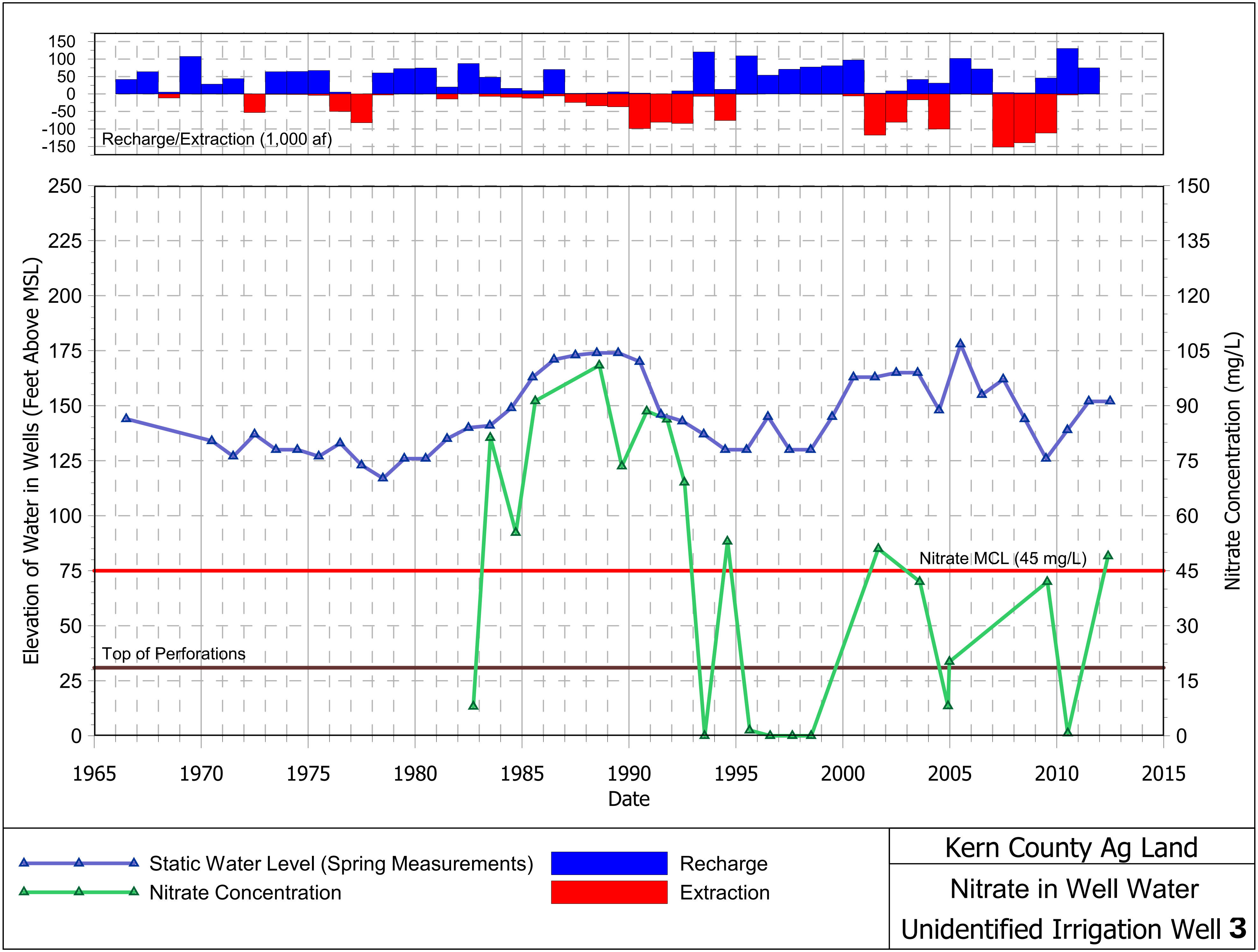
Kern County Ag Land

Nitrate in Well Water

Unidentified Irrigation Well **2**

DRAFT

Figure 14



Kern County Ag Land

Nitrate in Well Water

Unidentified Irrigation Well **3**

APPENDIX A

CURRICULUM VITAE FOR ROBERT M. GAILEY

Robert M. Gailey, P.G., C.HG.

Principal Hydrogeologist

Summary

Mr. Gailey has 28 years of experience on a wide range of projects in the field of hydrogeology. In the process of conducting projects throughout much of the United States, he has conducted site investigations ranging from preliminary site assessments to remedial investigations, negotiated with regulatory agencies for closure of contaminated sites as well as operation of municipal supply wells, provided critical review of technical documents, prepared written and verbal arguments for litigation and cost allocation, evaluated strategies for capture of groundwater solute plumes, designed and implemented remedial actions, assessed the effectiveness of ongoing groundwater remediation programs, mapped aquifers and assessed conditions for water supply development, performed water supply well siting evaluations, assessed water supply well conditions and performance, evaluated potential effects of well-field operations on water rights for adjacent parcels, and evaluated potential impacts on groundwater supplies related to groundwater contamination and proposed land development. This work has been conducted in accordance with local and state requirements, and federal requirements (CERCLA, RCRA, and SDWA) as administered by both state and federal agencies. Many of the hydrogeologic evaluations have been performed at scales that range up to basin-wide analysis.

For remediation and wastewater projects, Mr. Gailey has worked on both active and inactive industrial and commercial facilities where both organic constituents (petroleum, semi-volatile organic compounds [SVOCs], and volatile organic compounds [VOCs]) and inorganic constituents (heavy metals, nitrate, perchlorate, total dissolved solids [TDS], and tritium) have been present. The types of industries involved include agriculture (dairy and crop), airline, banking, barrel processing, chemical, defense, dry cleaning, electronics, food processing, flare manufacturing, insurance, machining, mining, petroleum (retail, storage, and refining), real estate, steel, trucking, waste disposal, and wood treatment. In addition, he has performed review and analysis for law firms and government agencies (Army Corps of Engineers [ACE], Department of Energy [DOE], Environmental Protection Agency [EPA], and Washington Department of Ecology). This work has involved hydrogeologic evaluation, modeling, statistical and other data analysis, and database management. The purposes of this work have included characterizing site conditions, predicting exposure point concentrations, developing remedial designs, evaluating ongoing remedial effectiveness, and performing comparative data analyses to meet various project needs.

For water supply projects, Mr. Gailey has worked on both municipal and rural facilities. The industries served include private and municipal water supply, agriculture, food processing, hospital, hotel, and mining. This work has involved hydrogeologic evaluation, well siting and performance evaluation (step discharge, pumping and wire-to-water tests), flow and concentration profiling (under pumping and static conditions using both spinner logs and the U.S. Geological Survey [USGS] dye tracer approach) water quality impact assessment (arsenic, bacteria, nitrate, pesticides, TDS, uranium and VOCs), feasibility testing for well modification, modeling, database management, economic and optimization analysis, and preparing construction and equipment specifications. The purposes of this work have been included developing and rehabilitating municipal and other water supplies, enhancing well field operations, and managing groundwater resources.

Project Experience

- Provides technical analysis related to hydrogeologic aspects of projects. Issues for analysis include hydraulic analysis for water supply and construction projects, water supply assessment, the distribution and migration of constituents of concern in groundwater, benefits of naturally occurring biodegradation, remediation system performance, and environmental impact assessment under the California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA).
- Provides testimony, technical counsel, and support for regulatory negotiations and litigation involving 1) groundwater/soil cleanup and cost allocation related to serial and adjacent tenancy of commercial, industrial, and retail parcels and 2) conflicts over water resources. Has prepared expert reports and material for interrogatories and declarations, participated in the meet-and-confer process and settlement discussion, developed case strategy under the client-attorney confidentiality umbrella, briefed expert witnesses on technical aspects of cases, and provided deposition testimony.

Water Supply Assessment and Service

- Serving as Technical Lead evaluating the source of PCE in a municipal water supply well located in the Central Valley of California. Vertical flow and concentration profiling (USGS dye tracer approach) under ambient (non-pumping) conditions has been performed and profiling under dynamic (pumping) conditions is planned. The goal of the project is to modify the well and improve water quality at the wellhead.

Project Experience – *Water Supply Assessment and Service (cont.)*

- Serving as Technical Lead for ongoing supply well water quality evaluations at various locations throughout California. At issue is whether pumping operations and the well screens can be modified to reduce constituent concentrations (i.e., arsenic, manganese, nitrate, TDS, uranium and VOCs) to below drinking water standards. Vertical flow and concentration profile data are often collected from the wells using miniaturized tools so that the pumps do not have to be removed (USGS dye tracer approach). Data collection plans are developed to, among other things, account for uncertainty in pump intake depths, maximize information value and minimize the impact of any data collection uncertainties. For projects where evaluation results indicate that modifications may improve water quality, feasibility testing is performed and, as appropriate, recommendations for final modification of operations and facilities are provided. Management, or support as appropriate, of fieldwork is provided throughout the projects.

- Serving as Technical Lead performing analysis and construction tasks related to rehabilitating and modifying a water supply well for a disadvantaged community located in the Central Valley of California. The goal of the project is to reduce nitrate concentrations at the wellhead. Project work includes preparing technical specifications as well as conducting construction inspection, vertical flow and concentration profiling (USGS dye tracer approach), feasibility testing data analysis.

- Providing technical support to a public utility district regarding data collection and analysis for establishing baseline hydrologic conditions in a small groundwater basin located on the Central Coast of California. The work is being performed to support interest in developing the water resource. Project work has included installing water level and barometric transducers, training district staff regarding transducer maintenance and data retrieval, and data analysis related to evaluating safe yield for the basin

- Serving as Technical Lead to provide technical specifications and construction inspection support for the rehabilitation of four municipal water supply wells located in the Central Valley of California. The work is being performed subsequent to an initial evaluation of ten wells (specific capacity testing, progressive-volume water quality sampling, and video inspection without removing the vertical turbine pumps). The wells have not been rehabilitated within the past 40 to 60 years, and the removal of significant amounts of calcium carbonate scaling is necessary to increase the specific capacities of the wells. Space and wastewater discharge limitations are particular challenges being addressed to successfully complete the project. Particular attention has been given to balancing the benefits of improving hydraulic performance of the wells against the potential costs of damaging the aged wells. Thus far, spinner log and specific capacity testing conducted before and after the rehabilitation work have quantified performance increases in specific capacity of as much as 30 percent.

- Serving as Technical Lead to provide technical specifications and construction inspection support for the rehabilitation of four municipal water supply wells and pumps located in the Central Valley of California. The wells have not been rehabilitated within the past 20 years, and the removal of calcium carbonate and iron oxide scaling as well as bacterial mass is necessary to increase the specific capacities of the wells. Because the municipality relies heavily on the groundwater portion of its water supply, the project is being phased so that the construction activity does not impede the municipality's ability to meet demand. Thus far, spinner log, specific capacity and wire to water testing conducted before and after the rehabilitation work have quantified performance increases in specific capacity of 16 percent and plant efficiency of 32 percent.

Project Experience – *Water Supply Assessment and Service (cont.)*

- Serving as Technical Lead for evaluating potential hydraulic manipulation evaluation of a municipal water supply well located in the Central Valley of California. The focus of the work is to reduce nitrate concentration at the wellhead by changing how the well draws from strata that contain varying concentrations of nitrate. Vertical flow and concentration profiling data from the well (USGS dye tracer approach) were considered in order to identify a design strategy that would allow the well to be brought back on-line without the use of expensive wellhead treatment. The design strategy entailed well screen modification. Field testing of the design concept entailed step-discharge testing, sequential discharge sampling and packer testing in order to evaluate the potential improvement to water quality and decrease in production capacity associated with the chosen well screen modification design. The testing results proved that well modification will be sufficient to address the water quality issue and no treatment system will be required. Current project activities involve finalizing the well modification.

- Provided technical consultation related to bringing a new municipal water supply well online in the Central Valley of California. At issue were bacterial concentrations (total coliform and heterotrophic place counts). Extended purging, chlorination and cycle testing resulted in approval from the Department of Public Health for bringing the well online.
- Served as Technical Lead to perform an analysis for a county water management agency in northeastern California that determined the applicability of alternative monitoring approaches for compliance with the California Statewide Groundwater Elevation Monitoring (CASGEM) program. Six basins were evaluated and a report consistent with California Water Code requirements was prepared within five weeks to meet a client deadline. The report, first in the state to be accepted by the California Department of Water Resources (DWR), was finalized with only minor revisions after review by the DWR.

- Provided technical review of a draft Environmental Impact Statement prepared in accordance with NEPA for a proposed shale gas hydraulic fracturing project to be performed in a western state. At issue were a variety of concerns related to impacts upon water quantity and quality.

- Served as Technical Lead for an expedited review of well and pumping system conditions for four municipal supply wells located in the Central Valley of California. Issues of interest were 1) reduced production rates over time and 2) potential improvements in water quality through well modification in order to avoid the use of treatment systems. Miniaturized equipment was used to video log the wells in order to perform an initial assessment of well and pumping system condition. The pumps in all four wells were further evaluated by performing wire-to-water testing. Three of the wells were further evaluated by performing flow and concentration profiling (USGS dye tracer approach). The constituents of potential concern were arsenic, uranium, manganese and TDS. The findings were that 1) reduced production rates had resulted from both pump wear and well screen fouling and 2) well modification likely would not significantly improve water quality. The field work and reporting was completed in just under four weeks to meet this client's schedule requirements.

- Provided consultation related to increasing the water supply for a medical facility in northern California. The initial task was to review water development efforts in a limited-access area that had been unsuccessful and to recommend additional efforts in the same area. After reviewing the available information and performing field reconnaissance of the subject area, an alternative course of action was identified. The alternative approach to water development was based upon making a connection, previously missed by others, between pieces of information related to the groundwater availability and pumping system capacity. Once limited pumping capacity was identified as the primary issue, additional work in the remote access area was avoided and a significant water supply was readily developed.

- Served as Technical Lead for evaluating potential hydraulic manipulation of a municipal water supply well located in southern California east of Los Angeles. The focus of the work was to reduce arsenic concentrations at the wellhead by changing how the well draws from strata that contain varying concentrations of arsenic. Vertical flow and concentration profiling data (USGS dye tracer approach) from the well were considered along with other water supply system information in order to identify a design strategy that would allow the well to be brought back on-line without the use of expensive wellhead treatment. The design strategy included a combination of well screen modification and blending of the well discharge with that from two other wells. Field testing of the design concept entailed step-discharge testing, sequential discharge sampling and packer testing in order to evaluate the potential improvement to water quality and decrease in production capacity associated with the chosen well screen modification design. In this case, it was established that the site hydrogeology did not support successful well modification.

Project Experience – *Water Supply Assessment and Service (cont.)*

- Served as Technical Lead for evaluating the potential to hydraulically manipulate a municipal water supply well located in the Central Valley of California. The constituent of concern was arsenic. Vertical flow and concentration profiling data (USGS dye tracer approach) were collected. No additional work related to well modification was performed since it was determined that the distribution of arsenic concentrations in strata located along the well screen was not conducive to well modification.
- Served as Technical Lead for a groundwater supply management analysis for a city in the Central Valley of California. The purpose of the project was to evaluate current production operations and suggest operational guidelines and facility modifications to both maintain required production and protect water quality from a variety of constituents (nitrate, uranium and VOCs).
- Served as Technical Lead for developing an irrigation supply well for an athletic park in a coastal area of northern California. Issues considered included well siting, design and yield, and potential water quality impacts from a nearby municipal wastewater treatment facility. An opinion on the potential affects on the groundwater system with respect to production potential and water quality was also prepared for use in a CEQA analysis.
- Served as Technical Lead for a water supply well source area contamination assessment in the Central Valley of California. The sources and migration pathways related to nitrate and other potential contaminants were evaluated through 1) property and well records review, 2) focused well sampling and 3) isotopic analysis to evaluate the age of water pumped from different screened intervals (USGS dye tracer approach) in the municipal well and fingerprint the source of contamination. The purposes of the assessment were to provide information for 1) designing a wellhead treatment system, 2) addressing groundwater cleanup needs and 3) negotiating with the responsible party (RP) and the Central Valley Regional Water Quality Control Board (RWQCB).
- Served as Technical Lead for a hydrogeologic evaluation of water supply development potential in a basin located near the Central Coast of California. Factors considered included geologic formation and structure of water-bearing strata, groundwater flow patterns, existing well yields, water quality distribution patterns and trends, and hydrogeologic conditions specific to the parcel considered for development. Because the basin was not in a state of overdraft, recommendations were made for site-specific investigation of the parcel.
- Served as Technical Lead for a water quality impact analysis in support of regulatory negotiations regarding plans for increased groundwater pumping by a growing community in the Central Valley of California. At issue was whether additional deep pumping would degrade water quality by causing shallow nitrate contamination to migrate downward in significant quantities. The available data were reviewed and historic conditions under which downward migration of nitrate had occurred were identified. This information suggested that the increased pumping would not cause water quality degradation. Technical negotiations with the State Water Board were conducted and a limited amount of additional hydrogeologic data was collected. The collected data corroborated the original findings and the plans for increased pumping were approved.
- Provided technical review for a hydrogeologic impact assessment of dewatering related to expansion of gravel mining operations in the Central Valley of California. The review entailed comparing the results of two different groundwater modeling studies, explaining differences in results of the two studies, and evaluating these differences within the context of potential impacts to the local groundwater system.
- Served as Senior Hydrogeologist for the preparation of a State loan application/workplan to conduct a feasibility study for supplementing a municipal groundwater-based drinking water supply in the Central Valley of California. The workplan included tasks related to modeling groundwater recharge and wellfield operations, and groundwater management planning under the Groundwater Management Act.
- Served as Senior Hydrogeologist and Project Manager on a water well rehabilitation and maintenance project for a water purveyor in northern California. The initial focus of the project was to develop and implement a course of action to rehabilitate under-performing wells. The second focus of the project was to develop and implement a long-term plan for preserving efficiency and extending the lives of satisfactorily-performing wells by considering the economic life expectancy of each well and specifying data collection requirements for tracking performance. This information was managed using database and economic analysis software.

Project Experience – *Water Supply Assessment and Service (cont.)*

- Served as Senior Hydrogeologist Project Manager for the rehabilitation of a municipal water supply well in northern California. Services included developing specifications for both chemical/mechanical rehabilitation of the well screen and installation of a new pumping system that was compatible with an existing variable-frequency drive.
- Served as Project Manager and Senior Hydrogeologist for a new well and reservoir siting study conducted for a municipality in northern California. The goal of the project was to identify viable sites for the new facilities from the list of surplus city-owned lands. Issues considered included aquifer characteristics, proximity to groundwater contamination, proximity to existing facilities, potential for well interference, site suitability for aboveground facilities, aesthetics, and other criteria.
- Served as Project Manager on the design of pumping and transmission facilities for two new municipal water supply wells on the Central Coast of California. Services included developing equipment and construction specifications, and providing construction and system startup inspection. Timely completion of the project allowed the client to apply for project cost reimbursement from Federal funds.
- Provided consultation regarding the rehabilitation needs of a municipal water supply well located in the Central Valley of California. Services provided included consulting with the client on issues that arose during field implementation of the rehabilitation measures.
- Served as Senior Hydrogeologist for an electronics manufacturing facility siting assessment in western Mexico. Issues related to the quality and reliability of the water supply for the proposed site were considered as part of the assessment.
- Served as Senior Hydrogeologist for assessing conditions for developing a groundwater supply for a fruit processing facility located in the northern Central Valley of California. The local groundwater quality was poor, and a well was designed to maintain efficiency and integrity under anticipated use scenarios. Requirements for the well installation and related water treatment system construction were specified in accordance with the California Department of Health Services Office of Drinking Water.
- Developed and installed groundwater and surface water level measurement instruments for a watershed monitoring project in southwestern Mexico. The work was part of a larger malaria control research project.
- Evaluated potential impacts on groundwater supplies related to a proposed land development project on the Central Coast of California. Available hydrogeologic data were reviewed within the context of plans for groundwater withdrawal related to the development. Potential reductions in water availability were identified, and recommendations were made to further assess the degree of impact.
- Performed data collection and interpretation for groundwater resource evaluations in eastern South Dakota. Glacially derived aquifers were delineated and characterized in support of agricultural water supply development.

Wastewater

- Serving as Technical Lead related to renegotiation of WDRs for a cheese plant in southern California east of San Diego. The project is driven by changes in the wastewater stream. Tasks performed include 1) characterization of the wastewater quantity and quality, 2) preparation of a Report of Waste Discharge and a Nutrient/Salt Management Plan, and 3) contribution of various types of information and insights to support infrastructure modifications at the facility. Negotiation with the Colorado River Basin RWQCB on the WDR modification is in-process.
- Serving as Technical Expert reviewing and commenting on draft language for a General Order and WDRs regarding the Irrigated Lands Regulatory Program that has been prepared by the Central Valley RWQCB.
- Served as Project Manager for an environmental site assessment conducted on a 150-acre mixed-use/agricultural parcel located in the Central Valley of California. The purpose of the assessment was to facilitate acquisition of the parcel for expansion of wastewater land application operations at a food processing facility. Accordingly, the list of details for the assessment was expanded to address the intended use of the parcel.

Project Experience – *Wastewater (cont.)*

- Served as Technical Lead for planning and analysis related to technical and regulatory aspects of performing surface and groundwater drainage in a coastal area of northern California. Issues considered include potential rates of drainage, surface water quality, septic discharges and permissible ocean discharges.
- Served as Technical Lead related to renegotiation of WDRs for a dairy in southern California east of San Diego. The project was driven by changes in both the wastewater stream and the lands to which the water would be discharged. Tasks performed include 1) completion of a water use audit that resulted in a 40% reduction in wastewater production, 2) preparation of a Nutrient Management Plan and an Engineered Wastewater Management Plan that were accepted by the RWQCB in initial form, 3) contribution of various types of information and insights that supported infrastructure modifications at the facility, and 4) expedited negotiation with the RWQCB on the WDR modification.

Groundwater Modeling and Optimization Analysis

- Served as Technical Lead for a prospective performance evaluation of a new wastewater storage pond liner technology proposed at a dairy in the Central Valley of California. Information on site conditions and planned pond design were used to construct a groundwater flow and transport model. A range of estimated seepage rates through the liner were simulated with the model in order to evaluate potential impacts to shallow groundwater quality. The evaluation was used to finalize construction requirements and permitting details for the new wastewater pond.
- Served as Technical Lead for a probabilistic cost analysis regarding the remediation of a commercial property in the Central Valley of California that was impacted by chlorinated volatile organic compounds. Site conditions were somewhat uncertainty because only preliminary characterization of soil, soil gas and groundwater had been performed. The set of tasks required to perform the cleanup were identified and cost ranges were estimated based upon the existing uncertainties. A Monte Carlo analysis was performed to evaluate the range in total project cost and the probabilities of occurrence for costs within the range. The results provided a cost-benefit basis for the potential purchaser of the property to make decisions regarding site management.
- Served as Technical Lead for sea water intrusion and groundwater/surface water interaction modeling studies. The work considered past and potential future effects of groundwater extraction for irrigation upon flow and water quality in a river and estuary on the Central Coast of California. Technical aspects of this work were assessing buried channel geometry and hydraulic properties from the wide range of available data, and evaluating the simultaneous effects of groundwater pumping and spring tide occurrence. Detailed transient models that included several river reaches and hourly tidal variations were created based upon previously available information and data collected for this project. The work was used to support negotiations with the California Department of Fish and Game and, ultimately, hearings at the State Water Resources Control Board.
- Served as Technical Lead for flow and transport modeling conducted to evaluate the source of nitrate contamination to a municipal water supply well located in the Central Valley of California. The model was calibrated using the results of 1) a 30-day pumping test and 2) flow and concentration profiling performed on the impacted municipal supply well. Important aspects of the modeling were 1) simulating the contaminant plume response to different historical pumping periods and 2) including the effects of a nearby improperly constructed water supply well that acted as a vertical conduit.
- Served as Technical Lead for hydrogeologic analysis and development of software for the prediction of groundwater quality impacts resulting from operations at a northern California facility. The software used historic and projected facility operations to predict sourcing and migration of tritium in groundwater. A flow and transport code was developed to simulate advection, dispersion, decay and other processes particular to the site that are not included in standard modeling packages (in-place constituent mass creation and rate-limited mass transfer at multiple spatial scales). Once calibrated, the model was used to evaluate the impacts of various future operations scenarios within the context of making facilities management and regulatory negotiation decisions.

Project Experience – *Groundwater Modeling and Optimization Analysis (cont.)*

- Served as Technical Advisor for modeling performed in support of a feasibility study regarding groundwater cleanup in the Central Valley of California. Flow and transport modeling were performed to evaluate contaminant plume movement under different remedial pumping scenarios. Of particular importance in this work were the effects of many water supply wells located near the plume and flows between vertically adjacent water-bearing zones.
- Served as Technical Lead for a study that developed conjunctive use strategies and wellfield operational rules related to meeting future municipal water supply requirements of a growing community in the Central Valley of California. The project entailed developing a groundwater flow model that included 1) the operations of wellfields run by two adjacent communities and 2) groundwater-surface water interactions. Once calibrated, the model was linked to optimization tools in order to cost effectively evaluate a range of operational scenarios. At issue was how to meet projected higher demands without mobilizing contaminants (naturally occurring total dissolved solids and two plumes containing VOCs and pesticides) that would result in increased future treatment costs. Results of the study included wellfield operations guidelines, suggested maximum extraction schedules, and proposed coordination of wellfield operations by the two adjacent communities. The model was extended in time and recalibrated four years later. Future plans are to use the model as part of water supply planning for city expansion.
- Served as Technical Lead on a groundwater management study performed to support remedial design for a landfill site in Arizona. Remedial designs necessary to accommodate Groundwater flows resulting from present and future water supply management practices were evaluated with a groundwater model developed for the project. The goal of the work was to develop designs that were both economically viable and able to contain the leachate plume as water supply pumping and basin recharge practices changed.
- Served as Senior Hydrogeologist for a feasibility study and remedial action at an industrial site in the Central Valley of California. The project was reviewed by the California Department of Toxic Substances Control (DTSC) and entailed hydrogeologic analysis and groundwater modeling to mitigate impacts to a water supply wellfield by VOCs. Evaluating and implementing wellhead treatment as the remedial approach entailed accounting for both seasonal variations in wellfield pumping demand and economic constraints on performance of the project. Use of automated/optimization techniques for assessment of design options streamlined the modeling process and reduced project expenditures. The work also included developing a cost-effective monitoring program for the remedial action.
- Served as Senior Hydrogeologist for a remedial action at a decommissioned research facility located in northern California. The project was reviewed by the EPA, DTSC, and the Central Valley RWQCB. It included hydrogeologic analysis and modeling to mitigate impacts to groundwater and nearby irrigation supply wells by VOCs, and litigation support. This work supported preparation of an Engineering Evaluation/Cost Analysis and an Interim Remedial Action, and favorable settlement of the litigation matter. The work also included an assessment of rehabilitation needs for injection wells used in the remedial action.
- Served as Technical Lead for an assessment of potential VOC, SVOC and metals concentrations in groundwater at an industrial facility located in northern California. The project, reviewed by the EPA, DTSC, and National Oceanic and Atmospheric Administration, entailed modeling groundwater transport of constituents of potential concern and mixing of the constituents with surface waters. The concentration predictions were used to support performance of ecological and human health risk assessments.
- Served as Technical Lead on a groundwater supply management study for a mining operation located in the western United States. The focus of the project was exploring options for both meeting water production requirements and capturing impacted water while accounting for restrictions related to water rights and well/transmission line capacity limits. Use of automated/optimization techniques for assessing options streamlined the process and allowed a more detailed study to be conducted with a limited budget.
- Served as Technical Lead for an evaluation of groundwater drainage rates and volumes resulting from a planned tunnel construction project in the Sierra Nevada of California. A spreadsheet model was constructed to simulate transient drainage from fractured host rock surrounding the planned tunnel construction. Best- and worst-case estimates of the drainage rates and volumes were prepared to support plans for removal of suspended solids from the water prior to discharge.

Project Experience – *Groundwater Modeling and Optimization Analysis (cont.)*

- Provided consultation regarding the feasibility of modeling groundwater flow and solute transport in an alluvial valley located in the western United States. Flow in the valley has been increasingly influenced by water supply pumping. Key elements for conducting the assessment were development of a complete conceptual model of how groundwater flow patterns have changed over time, and identifying a viable approach for model calibration.
- Served as Senior Hydrogeologist to develop a remedial approach for an industrial site in Nevada impacted by chlorinated VOCs. Groundwater modeling was used as a planning tool for phased implementation of a pumping system to address remediation requirements for the 7,000-foot-long plume. The plume was present throughout the saturated alluvium in a small valley, and viable remedial pumping designs are highly sensitive to available drawdowns and potential dewatering. Use of automated/optimization techniques for model calibration and design development streamlined the modeling process and reduced project expenditures.
- Supported development of technical strategy and provided senior review for groundwater modeling performed for remedial investigation/feasibility study and litigation tasks related to a site in Oregon impacted by chlorinated VOCs. Hydrogeologic analysis involved accounting for the effects of nearby water supply well pumping on VOC transport in the vicinity of the site. Automated/optimization techniques were developed and demonstrated to streamline the modeling process.
- Evaluated an optimization model for cost-effective disposal of dredging wastes for potential application to San Francisco Bay. The evaluation was performed for the ACE. Methods were developed for applying the model to problems that included constraints imposed by environmental regulations. A result of the evaluation was the determination that increased permitting fees might not change disposal patterns within the Bay.
- Analyzed transient hydraulic head data collected during soil boring to estimate the hydraulic conductivity and potential solute migration rates for a petroleum site in Oregon. The analysis entailed developing a mathematical model for assessing slug test data in a three-dimensional flow field. Performance of the analysis reduced project costs by providing migration rate information without installation of monitoring wells.
- Conducted a modeling study for the DOE to determine the effect of spatially variable solute adsorption on groundwater solute concentration predictions. This included use of statistical techniques to increase the reliability of the transport predictions. These techniques have recently been used on other projects to defend conclusions that are based upon model predictions.
- Developed pump-and-treat designs for capturing organic and heavy metal compounds at an impacted groundwater site in Canada. The design involved development of a site-specific model of groundwater flow and solute transport for prediction of exposure point concentrations and application of optimization techniques for developing designs. The designs involved minimum capital and recurring remediation costs. Reliability of concentration predictions upon which the designs were based was demonstrated through application of statistical techniques.

Modeling, statistical analysis, and database management tasks performed by Mr. Gailey on many of the above-referenced projects have entailed use of software including Groundwater Vistas, MODFLOW, MODPATH, MT3D, SEAWAT, RT3D, MOC, Bioscreen, Bioplume II/III, SUTRA, PEST, LINDO, STARPAC, GEOEAS, NPSOL, AQMAN, Visual MODFLOW, GMS, ModelCad and GIS/Key.

Groundwater Remediation

- Provided technical support on subsurface characterization, modeling and reporting for a solvent contamination site in southern California. Much of the work focused on addressing technical challenges posed by the hydrogeologic setting (structurally deformed, fractured sedimentary rock). The project included significant scientific contributions in the areas of field characterization and groundwater flow modeling.

Project Experience – *Groundwater Remediation (cont.)*

- Served as Principal Hydrogeologist for ongoing remedial action at an industrial site located in northern California. The project entailed conducting remedial activities (groundwater and soil vapor extraction) and monitoring progress toward cleanup for a multiparty, subregional plume of chlorinated VOCs. Reporting and interaction with the San Francisco Bay RWQCB involved completing semi-annual Self Monitoring Reports. Recent activity also included conducting a Five-Year Remedial Effectiveness Evaluation. Documenting and emphasizing the effects of impediments to pump-and-treat and naturally occurring biodegradation were important aspects of this project with respect to limiting future remedial requirements.
- Served as Principal Hydrogeologist for ongoing remedial action at an industrial site located in northern California. The project entailed conducting remedial activity (groundwater extraction) and monitoring progress toward cleanup for a plume of chlorinated VOCs. Reporting and interaction with the North Coast RWQCB involved completing semi-annual Self Monitoring Reports. Other project work also included reassessment of the hydrogeology and the approach to groundwater extraction with the goal of increasing project efficiency.
- Served as Principal Hydrogeologist for evaluating the results of shutting down a groundwater extraction system at an industrial site located in northern California. The San Francisco RWQCB approved remedial system shutdown on a temporary basis because (1) on-going pump-and-treat efforts had resulted in only limited progress toward attaining remedial goals and (2) there was evidence that naturally occurring biodegradation may have prevented plume migration. The project entailed evaluating the groundwater data (elevations as well as VOC and inorganic water chemistry) for pre- and post-shutdown periods. A convincing case for VOC degradation was made based on spatial data trends. A case for plume stabilization was also been made based on temporal data trends. Accounting for the effects of concentration rebound after pumping and plume migration from the source area was an important consideration for future site monitoring in order to assess whether the plume front was stable.
- Served as Principal Hydrogeologist for proposing monitored remedial system shutdown at an industrial site in northern California. The proposal to the North Coast RWQCB included a workplan for collecting the necessary groundwater data to demonstrate the effects of naturally occurring biodegradation of VOCs in groundwater.
- Served as Principal Hydrogeologist for ongoing remedial action at an industrial site located in northern California. The project entailed enhancing remedial activities (groundwater and soil vapor extraction) for a plume of chlorinated VOCs. Reporting and interaction with the DTSC involved conducting expedited conceptual and engineering design for expansion of a remedial system. Plans were also been developed for collecting data to document the potential effects of naturally occurring biodegradation in order to limit future remedial requirements. This work was conducted within the context of negotiating a Prospective Purchaser Agreement for an adjacent parcel that was impacted by the plume.
- Served as Principal Hydrogeologist for ongoing remedial action at an industrial site located in northern California. The project entailed conducting remedial activity (groundwater extraction) and monitoring progress toward cleanup for a specific site within a multiparty, subregional plume of chlorinated VOCs. Reporting and interaction with the EPA involved semi-annual Self Monitoring Reports. Recent activity also included reevaluating measures for maintaining a site-specific capture zone given that remedial activities were also occurring on adjacent sites.
- Served as Lead Hydrogeologist for remedial action design related to petroleum-impacted groundwater near residential water supply wells in central California. The constituents of concern included MTBE, and the Central Valley RWQCB conducted a detailed review of the Remedial Action Plan. The potential effects of residential well pumping were factored into the remedial pumping design so that containment of the constituents of concern was achieved and the water supplies were protected.
- Served as Senior Hydrogeologist for a fate and transport analysis related to petroleum-impacted groundwater near residential water supply wells in Alaska. The effects of naturally occurring biodegradation were incorporated into the analysis and supported the conclusion that risk to the water supplies was low.
- Served as Senior Hydrogeologist for a remedial investigation and action at an industrial facility in central California. The project was reviewed by the Central Valley RWQCB. It included hydrogeologic analysis, historical review, and negotiation to define remedial action requirements and allocate responsibility among responsible parties.

Project Experience – *Groundwater Remediation (cont.)*

- Served as Project Manager and Senior Hydrogeologist for a subsurface investigation of an air cargo facility at the San Francisco International Airport. The project was reviewed by the RWQCB and parties involved in cost allocation for cleanup of petroleum-impacted groundwater and soil. Evaluation of subsurface impacts and recommendation of future actions was conducted within the context of maintaining current business activities at the site and deferring any intrusive remedial activities until an appropriate time in the future.

- Served as Senior Hydrogeologist for a landfill closure in Mexico City, Mexico. Tasks performed included acquiring data on potential leachate production rates and recommending design parameters for a leachate collection system. Collection of the leachate was required to facilitate the next step of the closure, extraction of accumulated landfill gas.

- Served as Senior Hydrogeologist for a five-year review and remedial effectiveness evaluation of a groundwater cleanup operation in northern California. The project entailed evaluation of remedial performance data for six groundwater extraction systems installed in alluvial sediments and was reviewed by the San Francisco RWQCB. Key points considered during the evaluation were hydraulic containment of the chlorinated VOC groundwater plume, cumulative removal of groundwater and VOCs, VOC removal efficiency, offsite sources of VOCs, and the potential for attaining cleanup goals set by the RWQCB. Presentation of the project findings positioned the client well for negotiation on further remedial actions.

- Provided technical/economic analysis and technical review for remedial investigations/ feasibility studies involving three industrial sites owned by a single client in southern California. The work was performed under the review of the DTSC. Project findings were used to develop estimates of cleanup cost and facilitate completion of real estate transactions for the benzene-impacted properties. Detailed evidence of naturally occurring biodegradation was developed and used to limit the extent of cleanup measures that were considered.

- Served as Senior Hydrogeologist for a remedial investigation conducted at a commercial site in northern California. The investigation was performed under review of the San Francisco Bay RWQCB. Communication with the RWQCB on technical aspects of the investigation prior to commencing work positioned the client well for negotiations on further investigative requirements. The option for cost recovery was developed by maintaining consistency with the National Contingency Plan during the remedial investigation and interim remedial action, and by presenting arguments for the presence of off-site sources of chlorinated VOCs. Potential off-site source areas were identified, and arguments for requiring subsurface investigation by neighboring parties were supported through an analysis of site hydrogeology and migration potential. The arguments were presented and defended to the RWQCB. The ultimate goal of this effort is to identify other parties also responsible for the cleanup so that costs may be shared.

- Served as Project Manager and Senior Hydrogeologist for a soil and groundwater remedial investigation/feasibility study and an ecological river assessment conducted at a decommissioned wood treatment facility in Michigan. Creosote was present at the facility as a dense nonaqueous phase liquid. Negotiations with state regulatory agencies were key to successfully limiting the scopes of the investigations. Early data review allowed expeditious performance of the site characterization and development of a risk assessment strategy that both met regulatory requirements and was protective of client cleanup liability. The quality of the site characterization work contributed to the cooperative relationship between the client and regulatory agency, which reduced the potential for natural resource damage claims by the state.

- Performed remedial investigations and developed site closure arguments for petroleum sites in California, Florida, Massachusetts, and Rhode Island. The work in California was performed under the review of the Kern County Department of Environmental Health. Site closure arguments were accepted in all four states.

- Performed an emergency investigation, and designed, installed, and maintained a petroleum recovery system in response to a high-volume spill of diesel fuel into the subsurface at a commercial site in Massachusetts. Implementation of interim petroleum recovery measures minimized petroleum migration away from the source area. During the first year of recovery system operation, 25,000 gallons of fuel were recovered. System enhancements were then made to maintain recovery rates. Project costs were defrayed by reuse of the recovered fuel.

Project Experience – *Groundwater Remediation (cont.)*

- Designed, installed and maintained numerous petroleum and groundwater recovery systems in several states. This work also included evaluation of overall remedial effectiveness and the benefits of using groundwater infiltration systems to enhance petroleum recovery. Work in California was performed under review of the Central Valley RWQCB.
- Performed site assessments for real estate transactions involving retail petroleum, commercial, and industrial sites throughout California and Massachusetts. The assessment findings were used to facilitate completion of the transactions.

Litigation Support

- Recent cases in which Mr. Gailey has been declared as an expert:
  - RF Land Inc. v. City of Ripon (California) 2010
  - Raymond Coldani v. Jack Hamm and Patricia Hamm (Federal 2009)
  - NCH Corporation v. Hartford Accident and Indemnity Company, et al. (New Jersey) Deposition testimony in 2007
  - Union Bank of California v. Rheem Corp. (California), 2006
  - Pinal Creek Group v. Newmont Mining Corp., et al. (Federal – Arizona) Deposition testimony in 2003 and 2006
- Serving as a Technical Consultant regarding responsibility for VOC contamination of a municipal water supply well. The case is being heard in the California courts.
- Served as an expert witness regarding financial responsibility for nitrate contamination of a municipal supply well from an industrial facility in northern California. Contributions included planning both data collection from the impacted well and inspection of the industrial facility, as well as presenting findings during mediation. The case, filed in the California state court system, ultimately settled.

Project Experience – *Litigation Support (cont.)*

- Served as an expert witness regarding responsibility for nitrate contamination of groundwater in the vicinity of a dairy in northern California. Work on the case, filed under the Clean Water Act in the California state court system, involved field investigation and analysis, mediation support and presentations, and preparing a technical declaration in support of a motion for recovery of attorney/expert fees and costs. The case was ultimately rescinded.
- Served as an expert witness regarding cost recovery and future apportionment among RPs for cleanup of a large acid mine drainage site in Arizona. The case involved several RPs active over almost a century and located throughout a mining complex, had been filed under CERCLA, and was heard in the federal court system. Expert analysis included a comprehensive consideration of the site hydrogeology and historic mining activities, and flow calculations (water budgets and mass balance assessments on surface water and groundwater flows, and three-dimensional groundwater flow modeling) to assess the relative contributions to the acid plume by various RPs. Video taped deposition testimony was given twice.
- Served as an expert witness regarding insurance coverage claims related to cleanup of a Superfund site. The case was filed under CERCLA and heard in the New Jersey state court system. Analysis and opinion development focused on hydrogeologic and regulatory factors that would influence the ultimate cost of the cleanup. Methods for incorporating uncertainty into the cost estimates was also addressed. Deposition testimony was given. Issues related to the above-referenced opinions were subsequently dropped from the case.
- Served as an expert witness regarding cost recovery for a former electronics manufacturing facility. The case was filed under CERCLA and heard in the California state court system. Analysis and opinion development focused on hydrogeologic factors that controlled both the duration of release to groundwater and the extent of subsequent off-site migration. The case settled before any testimony was given.

Project Experience – *Litigation Support (cont.)*

- Served as a consultant regarding a CERCLA claim for damages related to a release of contamination into a San Francisco Bay Area aquifer that serves a large population of individual well owners (residential and agricultural). The case, filed by a class of plaintiffs, involves releases from a single industrial parcel where multiple RPs operated over time and was heard in the federal court system. Consultation has included document review, quantitative analysis related to the extent of contamination and potential cleanup timeframe, mediation brief preparation, development of computer animation visual aids for mediation discussions, and presentation at mediation.
- Provided consultation for mediation of cleanup cost allocation for petroleum-impacted groundwater and soil at the San Francisco International Airport. The project involved research and strategy development focused on supporting negotiations with some twenty responsible parties.
- Provided consultation for legal defense against a claim concerning financial responsibility for contamination of residential and agricultural water supplies and soil. The case involved two adjacent parcels in northern California, was filed under CERCLA, and heard in the federal court system. Data analysis and discussions with attorneys focused on the plausibility of claims made by the plaintiff with respect to source area locations, site hydrogeology and migration potential of the constituents, and differences in signature assemblages of constituents present at each of the two sites. The case settled before any testimony was given.
- Provided consultation for legal defense against a claim concerning financial responsibility for petroleum and heavy metals present in soil and groundwater. The case involved two adjacent industrial parcels in northern California, was filed under CERCLA and heard in the federal court system. Data analysis and development of arguments focused on the plausibility of claims made by the plaintiff with respect to source area locations, site hydrogeology and migration potential of the constituents, and differences in signature assemblages of constituents present at each of the two sites. The arguments prepared supported successful opposition to motions made by the plaintiff for widespread inspection of the defendant's property, settlement discussions, and the defendant's motion for summary judgment. Prior to a settlement being reached, Mr. Gailey participated in settlement discussions and preparing the expert witness for trial.
- Provided consultation for legal defense against a claim concerning financial responsibility for petroleum contamination at two adjacent retail/industrial parcels in northern California. Data analysis and development of arguments focused upon the adequacy of previously implemented remedial actions for which the plaintiff sought compensation. The technical merits of written arguments developed for the defense resulted in the plaintiff's claim being rescinded prior to the case being heard in court.
- Served as an expert witness for a defendant regarding a cost recovery claim concerning petroleum and chlorinated VOCs present in soil and groundwater. The case was filed under CERCLA and heard in the federal court system. It involved a single property in northern California, an initial owner-operator (the plaintiff), and a subsequent series of occupants (the codefendants). Data analysis and development of written arguments focused on both changes in the chemical composition of materials used for automotive fueling and repair between the 1940s and the 1980s, and the appropriate allocation of cost for site cleanup among the involved parties. Estimation of total cost for the cleanup was also performed. 1,2-Dichloroethane (DCA) was identified as a signature compound for releases to the environment that occurred before the codefendants occupied the site. Data collected by the plaintiff demonstrated that DCA was present across the property and supported arguments that the plaintiff was also responsible for the cleanup. The case settled before any testimony was given.
- Provided consultation in support of a class action suit against the state of California concerning a levee failure. Three-dimensional transient groundwater flow and soil mechanical processes were modeled to show that departure from guidelines for levee maintenance could have caused the failure. Mr. Gailey defended the modeling work in deposition. This work supported testimony of the expert witness.

Insurance Analysis Support

- Conducted a comprehensive assessment and estimation of future remediation costs in support of insurance premium pricing for a cost cap policy on two sites. Annual costs over the life of the policy were developed for three possible scenarios (high, medium, and low costs) based on detailed review and consideration of project characteristics. These characteristics included technical (engineering and science), regulatory and logistical issues. The results were presented and discussed during negotiations between the insurance company and insurance brokers over premium price.

Project Experience – *Insurance Analysis Support (cont.)*

- Conducted several assessments of remediation projects in support of insurance claims analyses. The overall approach and effectiveness of remedial actions were evaluated. In addition, costs incurred were identified and categorized with respect to policy coverage and exclusion categories. General projections of future costs and timelines were also prepared.

Education

MBA, University of California, Berkeley, 2003.
MS, Applied Hydrogeology, Stanford University , 1991.
BS, Geology/Biology, Brown University, 1985.

Professional Certifications and Registrations

Professional Geologist, California No. 5338
Certified Hydrogeologist, California No. 259
40-Hour OSHA HAZWOPER Safety Training
8-Hour OSHA HAZWOPER Refresher/Respirator Fit Test
8-Hour OSHA Site Supervisor Certification
First Aid/CPR Training

Continued Education

Isotope Methods for Groundwater Investigation, Groundwater Resources Association of California, 2007
Endangered Species Acts: Meeting the Challenges, Association of California Water Agencies, 1999
Groundwater Use and Management, University of California at Berkeley Extension, 1998
Drinking Water Regulation, University of California at Berkeley Extension, 1998
Water Supply and Fish in the Sacramento-San Joaquin Delta, University of California at Berkeley Extension, 1997
Managing Groundwater into the 21st Century, Association of California Water Agencies, 1997
Watershed Management and Source Water Protection: The First Barrier, American Water Works Association, 1997
Aquifer Storage and Recovery, American Water Works Association, 1997
Graduate Study in Environmental Engineering, Stanford University, 1990
Surveying, Wentworth Institute of Technology, 1986

Professional Memberships and Activities

Association of Ground Water Scientists and Engineers
Groundwater Resources Association of California
Technical reviewer for various journals

Publications

Gailey, R.M. 2000. Application of Mixed-Integer Linear Programming Techniques for Water Supply Wellfield Management and Plume Containment at a California EPA Site. Proceedings of the International Symposium On Integrated Water Resources Management, International Association of Hydrological Sciences.

Gailey, R.M. 1999. Application of Mixed-Integer Linear Programming Techniques for Water Supply Wellfield Management and Plume Containment at a California EPA site. Proceedings of the 26th Annual Conference on Water Resources Planning and Management, American Society of Civil Engineers. (Published on compact disc.)

Gailey, R.M. and M. Eisen. 1997. An Optimization-based Evaluation for Groundwater Plume Containment and Water Supply Management at a California EPA Site. p. 138. In: proceedings of XXVIIth IAHR Congress, Water for a Changing Global Community, Theme C: Groundwater An Endangered Resource.

Brogan, S.D. and R.M. Gailey. 1995. A method for estimating field-scale mass transfer rate parameters and assessing aquifer clean-up times. Ground Water 33 (6) 997-1009.

Gailey, R.M. and S.M. Gorelick. 1993. Optimal, reliable plume capture schemes: application to The Gloucester Landfill groundwater contamination problem. Ground Water 31 (1) 107-114.

Gailey, R.M., A.S. Crowe, and S.M. Gorelick. 1991. Coupled process parameter estimation and prediction uncertainty using hydraulic head and concentration data. Advances in Water Resources 14 (5) 301-314.

Publications (cont.)

Gailey, R.M. and D.E. Jones. 1987. The use of sediment permeability variations in the performance of petroleum recovery from glacial sediments. p. 515. In: Proc. of the Focus on Eastern Regional Groundwater Issues, National Water Well Association.

Presentations

A Case for Alternative Groundwater Monitoring under CASGEM in Northeastern California. Session Speaker, Groundwater Resources Association of California, 21st Annual Meeting and Conference, California Groundwater: Data, Planning and Opportunities, October 4 and 5, 2012, Rohnert Park, California.

Water Supply Well Rehabilitation Methods: Alternatives and Successes. Invited Speaker, Groundwater Resources Association of California Managing Wells in California and Protecting Groundwater Resources Symposium, August 22 and 29, 2012, Sacramento, California.

Factors Affecting Nitrate Concentrations in Water Supply Wells. 28th Biennial Groundwater Conference and 20th Annual Meeting of the Groundwater Resources Association of California, California's Water's Future Goes Underground, October 5-6, 2011, Sacramento, California.

Identifying the Sources of Nitrate to a Deep Municipal Water Supply Well Using Stable Isotopes of Nitrate, Groundwater Age Dating and Depth-Specific Sampling. Copresenter with Brad Esser, Groundwater Resources Association of California Environmental Forensics Symposium, April 12, 2011, Irvine, California.

Reducing Arsenic Concentrations from a Municipal Supply Well through Well Screen Modification. Invited Speaker, Arsenic Symposium: Treatment Alternatives and Case Studies, December 8-10, 2009, Bakersfield, Barstow and Ontario, California.

Simulating Flow and Transport Uncertainty Associated with Water Supply Well Modification Based upon Well Profiling and Pumping Test Data. Coauthor with Grace Su, 2010 National Groundwater Association Groundwater Summit, April 12-14, 2010, Denver, Colorado.

Reducing Arsenic Concentrations from a Municipal Supply Well through Well Screen Modification. Invited Speaker, Arsenic Symposium: Treatment Alternatives and Case Studies, December 8-10, 2009, Bakersfield, Barstow and Ontario, California.

Considering the Consumption of Energy and Other Resources during Pumping at the Well and Wellfield Scales. Invited Speaker, 27th Biennial Groundwater Conference and 18th Annual Meeting of the Groundwater Resources Association of California, Water Crisis and Uncertainty: Shaping Groundwater's Future, October 6-7, 2009, Sacramento, California.

Planning Combined Municipal Use of Groundwater and Surface Water: Technical and General Results from a Case Study. Session Speaker, Groundwater Protection Council Annual Forum 2009, Water/Energy Sustainability Symposium – Water and Energy Policy in the 21st Century, September 13-16, 2009, Salt Lake City, Utah.

Optimal Conjunctive Use of Surface Water and Groundwater Resources: A Tale of Two Cities. Session Speaker and Symposium Co-Chair, Applications of Optimization Techniques to Groundwater, a Groundwater Resources Association of California Symposium, October 16, 2008, Sacramento, California.

Details of Optimization and Applications to Groundwater Projects. Course Instructor and Co-Chair, a Groundwater Resources Association of California Short Course, October 15, 2008, Sacramento, California.

Application of a Simulation-Optimization Approach for Water Supply Wellfield Management and Plume Containment. Session Speaker, Groundwater Resources Association of California, 13th Annual Meeting and Conference, Managing Aquifers for Sustainability – Protection, Restoration, Replenishment, and Water Reuse, September 23-24, 2004, Rohnert Park, California.

Application of Mixed-Integer Linear Programming Techniques for Water Supply Wellfield Management and Plume Containment at a California EPA site. Session Speaker, International Association of Hydrological Sciences, International Symposium On Integrated Water Resources Management, April 9-12, 2000, Davis, California.

Application of Mixed-Integer Linear Programming Techniques for Water Supply Well Fixed Management and Plume Containment at a California EPA site. Session Moderator and Speaker, American Society of Civil Engineers Water Resources Planning and Management Division Annual Conference, June 6-9, 1999, Tempe, Arizona.

Presentations (cont.)

Wellfield Optimization: A Case Study. Session speaker, American Water Works Association, California-Nevada Section, Fall Conference, October 6-9, 1998, Reno, Nevada.

A Linear Programming Application for Water Resource Management at a Mining Operation. Session speaker, 25th Annual Conference on Water Resources Planning and Management, American Society of Civil Engineers, June 7-10, 1998, Chicago, Illinois.

Water Disposal Concerns with a Well Rehabilitation Project. Invited Speaker, American Water Works Association, California-Nevada Section, Water Well Monitoring and Rehabilitation Seminar, May 20-21, 1998, Stockton, California.

Quantifying Rate-Limited Mass Transfer Effects in the Field: Challenges Faced by Environmental Science Practitioners. Session speaker, American Geophysical Union Fall Meeting, December 8-12, 1997, San Francisco, California.

An optimization-based evaluation for groundwater plume containment and water supply management at a California EPA site. Session speaker, American Water Resources Association Annual Conference and Symposium on Conjunctive Use of Water Resources: Aquifer Storage and Recovery, October 19-23, 1997, Long Beach, California.

An optimization-based evaluation for groundwater plume containment and water supply management at a California EPA site. Session speaker, XXVII in IAHR Congress, Water For A Changing Global Community, August 10-15, 1997, San Francisco, California.

A method for estimating field-scale mass transfer rate parameters and predicting aquifer clean-up times. Session speaker, 1994 Groundwater Modeling Conference, August 10-12, 1994, Fort Collins, Colorado.

Design of optimal, reliable groundwater capture schemes. Session speaker, solving Ground Water Problems with Models, February 11-13, 1992, Dallas, Texas.

Design of optimal, reliable groundwater capture schemes. Lecturer, National Research and Development Conference on the Control of Hazardous Materials, February 4-6, 1992, San Francisco, California.

Design of optimal, reliable plume capture schemes: application to the Gloucester Landfill. Invited speaker, American Geophysical Union Fall Meeting, December 9-13, 1991, San Francisco, California.

The use of sediment permeability variations in the performance of petroleum recovery from glacial sediments. Session speaker, Focus on Eastern Regional Groundwater Issues, July 14-16, 1987, Burlington, Vermont.

Presentations on aspects of quantitative hydrogeology at the U.S. Geological Survey, Lawrence Berkeley National Laboratory, California Department of Water Resources, and universities (California State University at Sacramento, Harvard, Stanford, and the University of Illinois).

APPENDIX B

CALCULATIONS ON UNSATURATED ZONE TRANSIT TIME AND WATER QUALITY IMPACTS TO FIRST-ENCOUNTERED GROUNDWATER

APPENDIX B

CALCULATIONS ON UNSATURATED ZONE TRANSIT TIME AND WATER QUALITY IMPACTS TO FIRST ENCOUNTERED GROUNDWATER

Unsaturated zone transit time calculations were performed for representative locations within the KRWCA area. This work was accomplished in collaboration with a soil and agricultural scientist hired by the KRWCA (Joel Kimmelshue). From a larger evaluation conducted by Mr. Kimmelshue, entitled Kern River Watershed Coalition Authority Agricultural Return Flow and Nitrogen Transport Estimates and Comparisons, three locations were selected for evaluation (Figure B1). The salient details of each location are presented below.

- Location 1
  - Crop: citrus
  - Irrigation method: drip/micro
  - Soil: medium-grained
  - Return flow: 2.3 inches per year
  - Nitrogen lost below root zone: 15 pounds per acre per year
  - Unsaturated zone stratigraphy: loam in shallow subsurface transitioning to clay at depth
  - Depth to first-encountered groundwater: 500 feet
- Location 2
  - Crop: almonds
  - Irrigation method: drip/micro (90%) & flood (10%)
  - Soil: coarse-grained
  - Return flow: 5.0 inches per year
  - Nitrogen lost below root zone: 15 pounds per acre per year
  - Unsaturated zone stratigraphy: interlayered sand and clay
  - Depth to first-encountered groundwater: 330 feet
- Location 3
  - Crop: cotton/wheat
  - Irrigation method: furrow/border
  - Soil: coarse-grained
  - Return flow: 16.4 inches per year
  - Nitrogen lost below root zone: 55 pounds per acre per year
  - Unsaturated zone stratigraphy: interlayered sand and clay
  - Depth to first-encountered groundwater: 150 feet

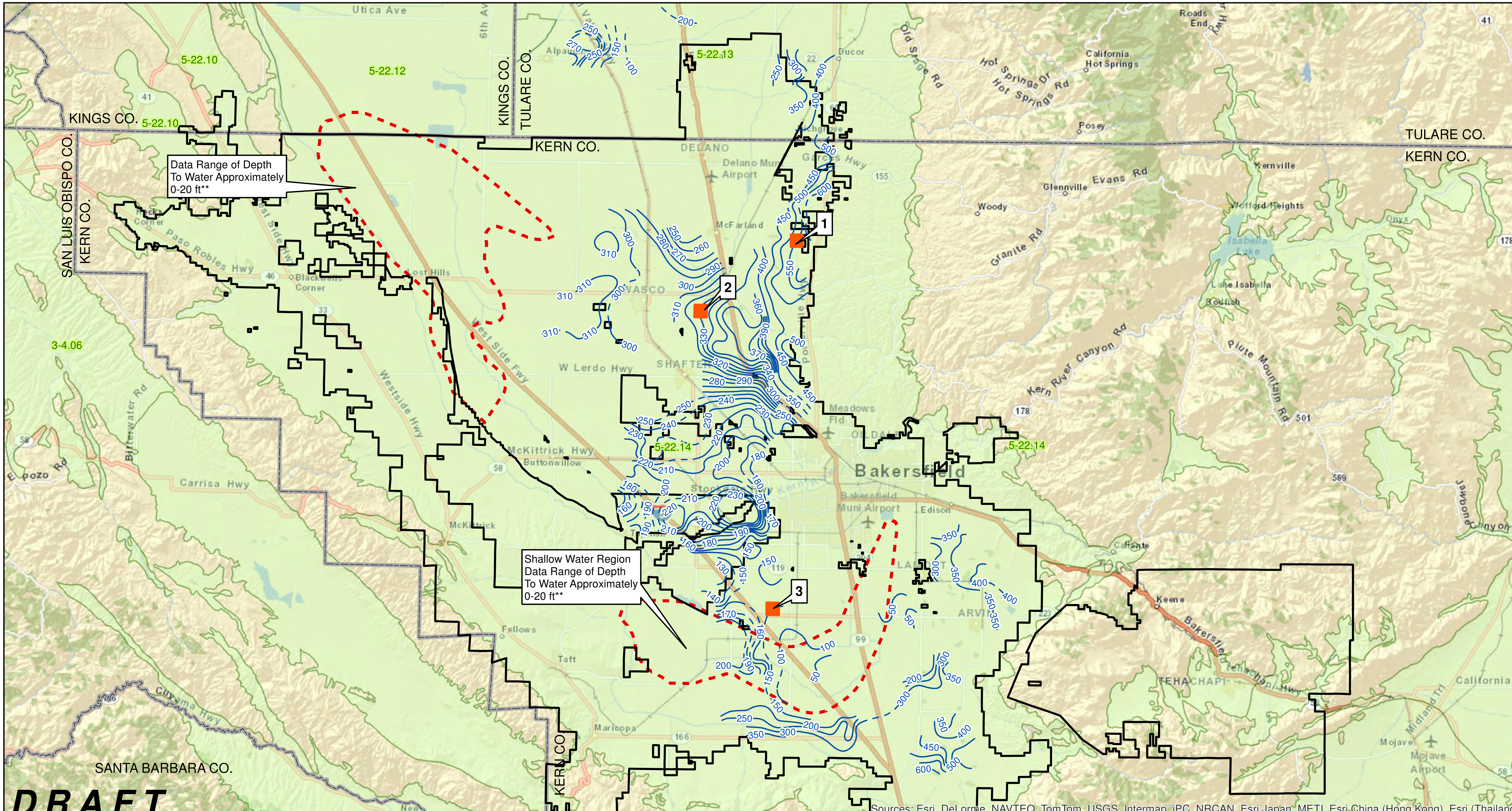
Unsaturated flow and nitrogen transport was simulated using the Hydrus 1D software. Estimates of monthly return flows and annual nitrogen losses below the root zone were obtained from Mr. Kimmelshue and used to specify upper boundary conditions for the flow and transport simulations (variable flux for flow and constant concentration for transport). Depth to first encountered groundwater was obtained from Department of Water Resources data (Figure 2a) and used to develop lower boundary conditions for the flow and transport simulations (constant head for flow and zero gradient for transport). Stratigraphy was included for each of the three locations based upon information from well completion reports obtained from KRWCA members, and physical properties were assigned based upon database values provided through the Hydrus 1D software. Initial conditions for flow were developed by running the flow model once before the flow and transport simulation was performed[15]. It was assumed that 1) all nitrogen occurred as nitrate, 2) no attenuation occurred by denitrification, diffusion or other processes and 3) no acceleration or deceleration occurred by anion exclusion, physical interaction with the sediments or other processes. This approach appears to be similar to that taken as part of the UC Davis nitrate study (Boyle et al., 2012); however, the two approaches differ in one important aspect. The present work included stratigraphic variability based upon field information instead of assuming a homogeneous soil column. This information adds a site-specific element to the results.

Transit times were calculated for transport from the bottom of the root zone to the bottom of the unsaturated zone. First arrival was considered as the simulated elapsed time when the nitrate concentration reached 1 mg/l at the bottom of the unsaturated zone[16]. Arrival of the 9 mg/l nitrate concentration, considered to be background (Boyle et al., 2012), was also considered. The results indicated a range in transport times[17]. For Location 1 where the depth to groundwater was greatest (Figure B1), arrival times were the greatest ranging from approximately 600 to 700 years (Figure B2). For Location 2 where the depth to groundwater was intermediate (Figure B1), arrival times were intermediate ranging from approximately 45 to 55 years (Figure B3). For Location 3 where the depth to groundwater was least (Figure B1), arrival times were the least ranging from approximately 10 to 15 years (Figure B4).

[15] The durations of the initial flow simulations were long enough to include the elapsed times for the transport simulations.

[16] Transport as nitrogen was simulated and the predicted nitrogen concentrations were then converted to nitrate concentrations.

[17] Transport mass balance errors were less than 0.5 percent.



0 5 10 Miles

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(559) 636-1166

- Locations of Bulk Unsaturated Flow Estimates
- DWR Groundwater Basin/Subbasin (ID Label)
- County
- KRWCA Boundary
- Shallow Water Region - Approximate**

Depth To Water - Unconfined Aquifer***

- High Degree of Confidence
- Inferred

Data References:

**Areas digitized from CA DWR "Present and Potential Drainage Problem Areas" survey map, 2010
http://www.water.ca.gov/pubs/drainage/2010_shallow_groundwater_map__san_joaquin_valley/sgw10.pdf

***Isopleth lines from CA DWR "Lines of Equal Depth to Water in Wells, Unconfined Aquifer, San Joaquin Valley, Spring 2010"
http://www.water.ca.gov/groundwater/data_and_monitoring/south_central_region/images/groundwater/sjv2010spr_unc_depth.pdf

Kern County Irrigated Lands Program
Kern Sub-Watershed

Locations For Unsaturated Flow Estimation

FIGURE B1

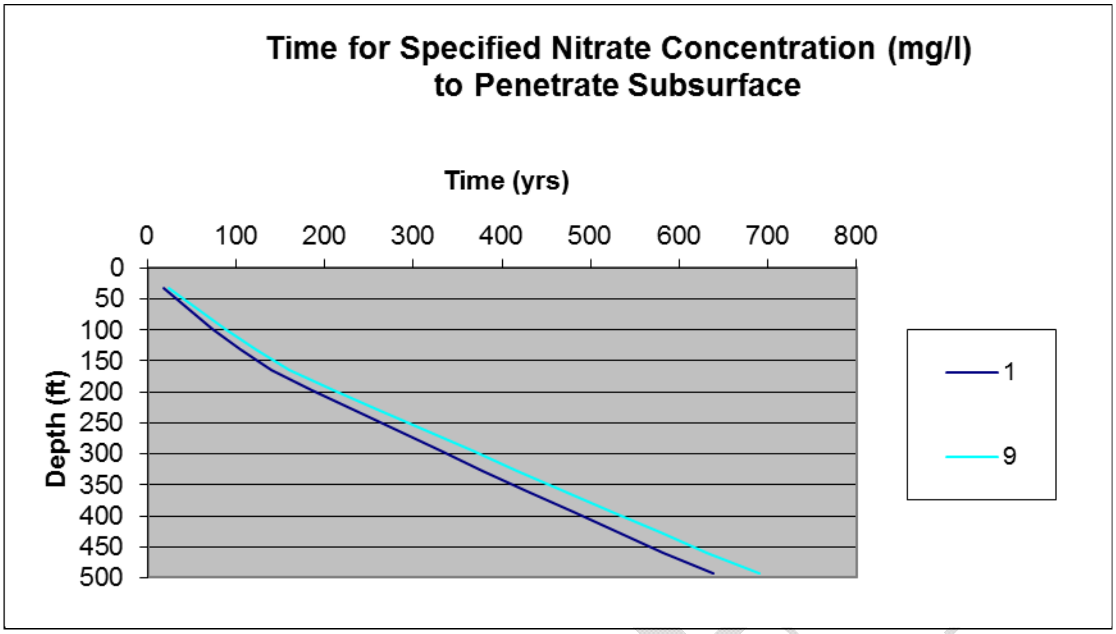

Figure B2: Nitrate Arrival Times for Location 1

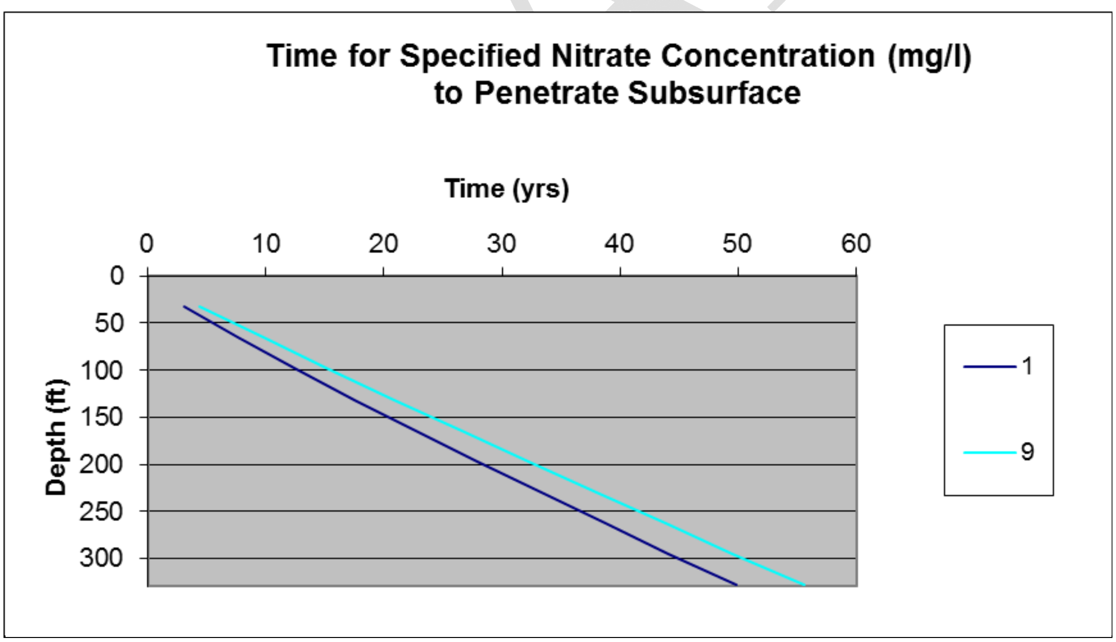

Figure B3: Nitrate Arrival Times for Location 2

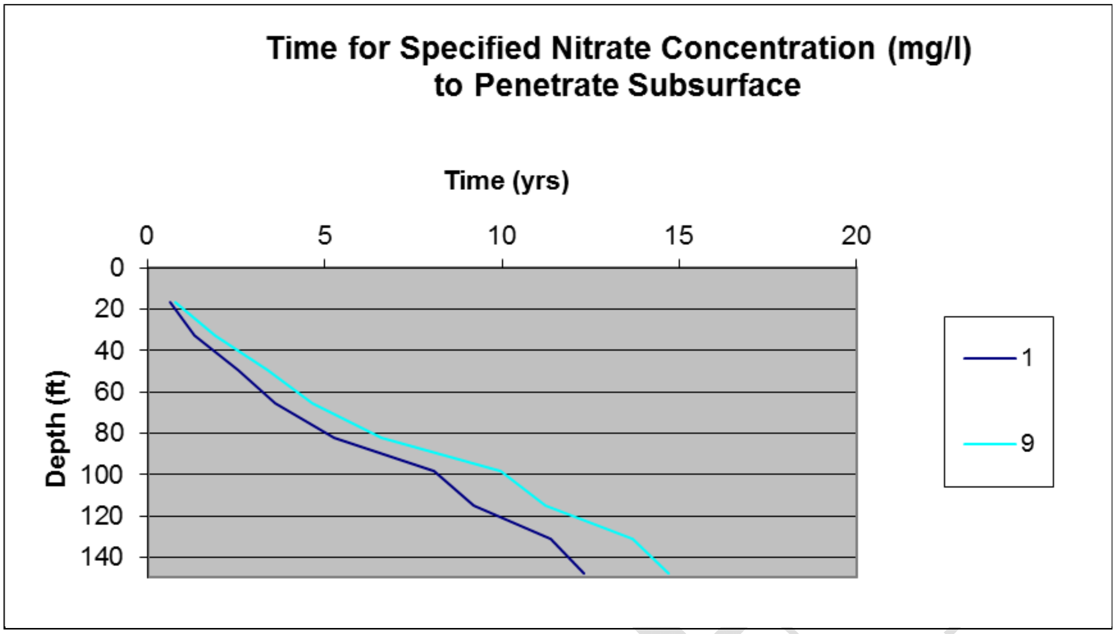

Figure B4: Nitrate Arrival Times for Location 3

Brown, Kimberly

From: Brown, Kimberly
Sent: Friday, February 15, 2013 5:10 PM
To: 'jcostantino@waterboards.ca.gov'
Cc: Brown, Kimberly; eaverett@rrbwsd.com; Phillimore, Bill
Subject: Background for February 20th Meeting
Attachments: 2-14 KRWCA Letter.pdf; Kimmelshue Draft Report.pdf; Gailey Draft Report.pdf

Mr. Costantino,

We look forward to our upcoming meeting at your office on Wednesday, February 20th. In preparation, we wanted to provide you the attached which was transmitted to Pamela Creedon yesterday. It provides background, analysis and research related to Kern County. We plan to bring additional summary information to aide in our discussion, but wanted to provide this to you in advance.

Again, we appreciate your time and look forward to our meeting.

Best Regards,

Kimberly M. Brown
Resource Manager

Paramount Farming Company
33141 E. Lerdo Highway
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