**BASELINE GROUNDWATER COMPOSITION AND QUALITY BELOW
IRRIGATED ALMOND AND WALNUT ORCHARDS IN DURHAM, CA, USA.**

A Thesis

presented to

the Faculty of California Polytechnic State University

San Luis Obispo

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Agriculture

with a Specialization in Soil Science

by

Candace A. Gallion

May 2012

COMMITTEE MEMBERSHIP

TITLE: BASELINE GROUNDWATER COMPOSITION AND
QUALITY BELOW IRRIGATED ALMOND AND
WALNUT ORCHARDS IN DURHAM, CA, USA.

AUTHOR: Candace A. Gallion

DATE SUBMITTED: MAY 2012

COMMITTEE CHAIR: Dr. Brent G. Hallock, Professor of Soil Science

COMMITTEE MEMBER: Dr. Terry L. Smith, Professor of Soil Science

COMMITTEE MEMBER: Dr. Thomas J. Rice, Professor of Soil Science

ABSTRACT

BASELINE GROUNDWATER COMPOSITION AND QUALITY BELOW IRRIGATED ALMOND AND WALNUT ORCHARDS IN DURHAM, CA, USA.

Candace A. Gallion

This study investigated groundwater quality in the Durham, California, USA area. The goal of the study was to determine baseline groundwater quality for the study area, whether crop type or time of year influenced groundwater quality, whether groundwater quality was significantly different among sample sites, and if groundwater quality test factors were correlated, and if any limiting factors for irrigation were present. Groundwater samples were collected and analyzed from eleven wells in almond (A2, A4, A5, A6, A7 and A8) and walnut (W1, W2, W3, W4 and W5) orchards and samples were sent to a laboratory to be analyzed for calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), sulfate (SO_4), bicarbonate (HCO_3), iron (Fe), chloride (Cl), and nitrate (NO_3) concentrations, total dissolved solids (TDS), hardness, pH, electrical conductivity (EC), and sodium adsorption ratio (S.A.R.). Groundwater samples were collected in September 2008, March 2009, May 2009 and September 2009. Results were analyzed using One-Way ANOVA testing and a correlation analysis, both at alpha levels equal to 0.05. Not many differences were discovered among sampling times or between tree types. Potassium was the only factor significantly different between the almond (0.98 ppm) and walnut (0.73 ppm) sites, a trend possibly resulting from greater usage of potassium fertilizer in almond orchards as compared to walnut orchards. Sodium adsorption ratio was greater in March 2009 (0.35) and May 2009 (0.34) than either

September sample (both 0.26) due to leaching of sodium into groundwater following rain events. Mean potassium concentration was greater in March 2009 (1.49 ppm) than in May 2009 (0.69 ppm), September 2008 (0.75 ppm) or September 2009 (0.63 ppm), also due to leaching of potassium into groundwater during the rainy winter months. Many differences were found among the sampling sites. In general, W1, W3, W5, A2, A4, A6 and A8 had lower concentrations of the test factors, and therefore purer groundwater, than W2, W4, A5 and A7. The majority of the test factors had significant, positive correlations with other test factors, with the exception of pH; pH had primarily significant negative correlations with the other test factors. Test factors were not present in groundwater at levels to cause any severe irrigation restrictions. Slight-to-moderate limitation levels were found for HCO_3 (all sample sites), TDS and EC (W2, W4, A5, and A7), and NO_3 (W1, W2, W3, W4, A4, A5, and A7). Overall, groundwater at the sampled sites was suitable for use as irrigation water, not many tree type or temporal differences in groundwater quality were discovered, many differences were found among sample sites, and many correlations were present among test factors. The information gathered and interpreted in this study will be useful for making management decisions regarding use of the tested groundwater for irrigation.

Keywords: groundwater quality, irrigation suitability

TABLE OF CONTENTS

LIST OF TABLES	VII
LIST OF FIGURES	VII
CHAPTER 1: INTRODUCTION	1
<i>Background Information and Problem Statement.....</i>	<i>1</i>
<i>Statement of the Overall Goal.....</i>	<i>1</i>
<i>Statement of Subgoal to be Investigated</i>	<i>2</i>
<i>Importance of the Project</i>	<i>2</i>
<i>General Approach</i>	<i>2</i>
SCOPE.....	3
<i>Sampling Times.....</i>	<i>3</i>
<i>Location.....</i>	<i>3</i>
<i>Constraints.....</i>	<i>3</i>
<i>Key Factors and Variables</i>	<i>3</i>
<i>Handling of Variables.....</i>	<i>4</i>
<i>Not Included.....</i>	<i>4</i>
OBJECTIVES AND HYPOTHESES	5
<i>Objectives</i>	<i>5</i>
<i>Hypotheses.....</i>	<i>5</i>
ASSUMPTIONS	6
CHAPTER 2: LITERATURE REVIEW	7
<i>Introduction</i>	<i>7</i>
<i>Sources of Groundwater Ions</i>	<i>7</i>
<i>Problematic Ions.....</i>	<i>9</i>
<i>Seasonal Differences in Groundwater Quality</i>	<i>11</i>
<i>Spatial Differences in Groundwater Quality</i>	<i>14</i>
<i>Ion Correlations.....</i>	<i>15</i>
<i>Northern California Groundwater Resources</i>	<i>16</i>
<i>Conclusions.....</i>	<i>17</i>
CHAPTER 3: METHODS AND MATERIALS	19
<i>Location</i>	<i>19</i>
<i>Field Collections.....</i>	<i>22</i>
<i>Laboratory Analysis.....</i>	<i>22</i>
<i>Statistical Design</i>	<i>22</i>
<i>Methods of Analyzing Data and Interpreting Results</i>	<i>23</i>
CHAPTER 4: RESULTS AND DISCUSSION	24
<i>Differences between Almond and Walnut Blocks.....</i>	<i>24</i>
<i>Differences Among Sampling Times</i>	<i>25</i>
<i>Differences Among Sample Sites</i>	<i>27</i>
<i>Correlations Among Water Constituents</i>	<i>32</i>
<i>Irrigation Suitability</i>	<i>33</i>
CHAPTER 5: CONCLUSIONS.....	34
CHAPTER 6: REFERENCES	36
APPENDIX A	38
<i>Official Soil Series Descriptions.....</i>	<i>38</i>
APPENDIX B	ERROR! BOOKMARK NOT DEFINED.
<i>Groundwater Analysis Data</i>	<i>Error! Bookmark not defined.</i>

LIST OF TABLES

TABLE 1.	GROUNDWATER COMPONENTS AND LEVELS OF USE RESTRICTION	10
TABLE 2.	GROUNDWATER SAMPLE SITE INFORMATION	19

LIST OF FIGURES

FIGURE 1.	MAP OF THE STUDY LOCATION AND SAMPLE SITES	20
FIGURE 2.	SOIL MAP OF THE STUDY LOCATION	21
FIGURE 3.	MEAN GROUNDWATER POTASSIUM (K) CONCENTRATIONS IN WALNUT AND ALMOND BLOCKS	25
FIGURE 4.	MEAN GROUNDWATER POTASSIUM (K) CONCENTRATIONS FOR SEPTEMBER 2008, MARCH 2009, MAY 2009 AND SEPTEMBER 2009	26
FIGURE 5.	MEAN GROUNDWATER SODIUM ADSORPTION RATIO (S.A.R.) VALUES FOR SEPTEMBER 2008, MARCH 2009, MAY 2009 AND SEPTEMBER 2009	27
FIGURE 6.	MEAN GROUNDWATER CONCENTRATIONS OF CALCIUM (CA), MAGNESIUM (MG) AND SULFATE (SO ₄) FOR ALL SAMPLE SITES	29
FIGURE 7.	MEAN GROUNDWATER CONCENTRATIONS OF SODIUM (NA), CHLORIDE (CL) AND NITRATE (NO ₃) FOR ALL SAMPLE SITES	30
FIGURE 8.	MEAN GROUNDWATER CONCENTRATIONS OF BICARBONATE (HCO ₃), TOTAL DISSOLVED SOLIDS (TDS) AND HARDNESS FOR ALL SAMPLE SITES	31
FIGURE 9.	MEAN PH VALUES FOR ALL GROUNDWATER SAMPLE SITES	31

CHAPTER 1: INTRODUCTION

Background Information and Problem Statement

Groundwater is an important source of irrigation water in many areas of the world. The quality of groundwater is important since it can have a large impact on crop health. Ions such as sodium and bicarbonate can cause problems in cropping systems if present in excessive levels. Groundwater quality can vary on a seasonal basis and by well location (Reddy et al., 2009). The problem, then, is knowing whether or not groundwater quality is poor, where it is poor, and if it is poor year-round. Monitoring groundwater quality is essential to determining if any measures need to be taken to remediate groundwater quality issues.

Statement of the Overall Goal

The overall goal of my research was assess groundwater quality. More specifically, groundwater quality will be investigated in Durham, California, USA, which is in the northern Sacramento Valley of California, below established almond and walnut orchards. Since groundwater is a primary source for crop irrigation water for many farmers in this area, the quality of groundwater can have a large impact on agricultural production.

Statement of Subgoal to be Investigated

The subgoals investigated were ascertaining the baseline groundwater quality for the Durham, California area, whether groundwater quality was different from well to well, whether crop type played a role in groundwater quality, and whether groundwater quality changed significantly depending upon time of year.

Importance of the Project

This research established baseline concentrations for impurities in groundwater in the Durham, California area and how ion levels change depending upon the season, location, and crop type. Currently, no groundwater quality information pertaining to irrigation could be found for the Durham, California area. Groundwater quality information gathered during this research can be used by farmers in the area to make management decisions to counteract possible poor groundwater quality conditions.

General Approach

This was an empirical, applied research study. Groundwater samples were collected out in the field and sent to a professional laboratory for analysis. Data from groundwater analysis were statistically interpreted to find any significant relationships and/or trends.

Scope

Sampling Times

Samples were collected over the course of one year (2008-2009) in:

- September 2008
- March 2009
- May 2009
- September 2009

Location

- Property farmed by Kimmelshue Orchards
- Durham, California, USA (Northern Sacramento Valley, California)

Constraints

Groundwater samples will only be taken when the farmer is running water for farming (irrigation or frost protection) purposes.

Key Factors and Variables

The independent key factors this study will include are site characteristics, climate, and land management. The topography, soils, and climate for the entire study area are very similar, so these factors will not be investigated within this study. The crop grown at each sampling site (almonds or walnuts) will be compared to the respective water quality of each site to determine if tree crops impact water quality differently. Almonds and walnuts are managed differently, but within each crop type management is

similar, so irrigation methods and fertilization practices will be assumed to be generally similar within all almond or all walnut orchards.

The dependent key factor this study investigated was the chemical properties of groundwater. The variables included in groundwater chemical properties were Ca, Mg, K, Na, SO_4 , HCO_3 , Fe, Cl, and NO_3 concentrations, total dissolved solids (TDS), hardness, pH, electrical conductivity (EC), and sodium adsorption ratio (S.A.R.).

Handling of Variables

- Land management practices will be standardized because the same farmer (Kimmelshue Orchards) manages all the sampling sites.
- Site characteristics and climate will be standardized since all sampling sites are within 2 mi^2 and have similar topography, geology, and climate.
- Differences in crop type will be statistically analyzed to determine if differences (if any) are significant.

Not Included

- This study did not include investigation of any aquifer differences. It will be assumed that the sample sites are representative of the aquifer characteristics of the area.
- This study did not compare the groundwater quality of the Durham, California area to that of any other location.
- This study did not compare sample sites based upon orchard age.

Objectives and Hypotheses

Objectives

The objective of this research is to determine the baseline concentrations and seasonal variations, crop differences and site differences of Ca, Mg, K, Na, SO₄, HCO₃, Fe, Cl, NO₃ concentrations, TDS, hardness, pH, EC, and S.A.R. in the groundwater at eleven well locations in Durham, California.

Hypotheses

- Ion baseline concentrations in groundwater are within tolerable levels for irrigation use.
- Groundwater quality improves after the winter due to precipitation recharging aquifers.
- The worst groundwater quality is during the late summer/early fall prior to significant precipitation events.
- Different sample locations are not significantly different in groundwater quality.
- Crop type does not result in differences in groundwater quality.

Assumptions

- The professional laboratory (Kinsey Agricultural Services, Inc.) conducts sound water analysis tests.
- Storing groundwater in a refrigerated environment (4°C) for a period of time before samples are analyzed will not significantly change the concentration of compounds of interest.
- Polyethylene bottles used to collect and store samples will not significantly change the concentration of compounds of interest.
- The sampling sites are representative of the groundwater of the area.
- Irrigation lines will not contaminate groundwater samples.

CHAPTER 2: LITERATURE REVIEW

Introduction

Groundwater is an important source of irrigation water. Groundwater supplies 39% of the agricultural irrigation water in the United States (Criss, 1996). The quality of groundwater for irrigation is important because it can adversely impact plant and soil health if groundwater quality is poor. Recharge water quality, inland surface water, atmospheric precipitation, and subsurface geochemical processes are the main factors impacting groundwater quality (Tizro and Voudouris, 2008). Soluble salts (EC, Mg, Ca, Na, K, Cl, SO₄ and HCO₃) are some of the main contributors to groundwater quality (de Andrade et al., 2008).

Sources of Groundwater Ions

Ions in groundwater generally originate either from the parent material of an aquifer or from leaching of materials from aboveground. Both natural (lithology, interaction with other aquifers, quality of recharge water, and groundwater velocity) and anthropogenic (agricultural, urban, industrial activities and usage) processes determine groundwater quality (de Andrade et al., 2008). An example of a natural influence on groundwater quality was in the Peddavanka watershed, India where a major source of dissolved solids in groundwater was host rocks (Gowd, 2005). The chemistry of recharge areas and subsurface geochemical processes can also have a large influence on groundwater geochemical properties (Kumar et al., 2006).

Calcium and magnesium bicarbonate are often present as the result of carbonate mineral (calcite, dolomite, and aragonite) dissolution (Al-Agha, 2005; Tizro and

Voudouris, 2008). Carbonate lithology leads to high groundwater bicarbonate content since bicarbonate in groundwater results from calcite dissolution (Tizro and Voudouris, 2008). Similarly, sodium can originate from sodium feldspar and/or halite dissolution, and a source of sulfur is pyrite dissolution (Tizro and Voudouris, 2008).

Dissolution of different parent materials leads to distinct relationships among ions. If cations originate from carbonate dissolution only, then $\frac{(Ca + Mg)}{HCO_3^-} \approx 0.5$

fertilizers is a major contributor to groundwater contamination in agricultural systems (Kumar et al., 2007; McMahon, 2008; Vengosh et al., 2002). Sulfur is also added to groundwater through leaching. High groundwater sulfate levels result from gypsum and sulfur usage in cropping systems (Vengosh et al., 2002). Sodium in groundwater can originate from various sources. Salinity of groundwater increases due to salt concentration from evapotranspiration and fertilizer applications (Schmidt, 1987). Saline characteristics also come from seawater intrusion, non-marine saline water, and/or agricultural return flow (Vengosh et al., 2002).

The quality of recharge water influences groundwater quality (de Andrade et al., 2008). Irrigation water can have a substantial impact on groundwater quality because it can comprise a large percentage of aquifer recharge. For example, water return to groundwater is 5-20% from irrigation in the Chahardouly basin, West Iran, and in the western Sacramento Valley, California groundwater recharge is greater than 80% from irrigation water (Criss, 1996; Tizro and Voudouris, 2008). Natural aquifer recharge from meteoric sources tends to result in purer groundwater, whereas recharge from agricultural irrigation leads to higher salt and nitrate content in groundwater (Vengosh et al., 2002). Rainfall recharge causes the water table to rise, and the rising water table impacts groundwater chemical properties by resulting in groundwater contacting more of the soil strata and collecting substances from the soil (Ödemiş et al., 2006).

Problematic Ions

The substances added to groundwater through leaching, cation exchange and dissolution can adversely impact groundwater quality (Table 1). A gross excess of any

ion in groundwater can be problematic, but prominent factors that are of concern in groundwater are sodium, bicarbonate, and nitrate.

Table 1. Groundwater components and levels of use restriction for irrigation.

Water Component	Units	Degree of Use Restriction		
		None	Slight to Moderate	Severe
EC	mmhos/cm	< 0.7	0.7 - 3.0	> 3.0
TDS	ppm	< 450	450 - 2000	> 2000
Na	ppm	< 69	> 69	
Cl	ppm	< 106.5	> 106.5	
NO ₃	ppm	< 5	5 - 30	> 30
HCO ₃	ppm	< 91.5	91.5 - 518.5	> 518.5
S.A.R.	n/a	< 0.3	0.3 - 2.0	> 2.0

Adapted from Ayers and Westcot, 1994 and Tizro and Voudouris, 2008.

Sodium is important with regard to irrigation water because it can decrease soil permeability (Tizro and Voudouris, 2008). There are multiple indices to determine if sodium levels are within tolerable limits for growing crops. Sodium percentages less than 35% are considered suitable for irrigation (Tizro and Voudouris, 2008). Sodium adsorption ratios less than 0.3 are suitable for irrigation, 0.3-0.5 are permissible suitability, 0.5 to 2.0 are doubtful suitability, and an S.A.R. greater than 2.0 is unsuitable for irrigation (Tizro and Voudouris, 2008). Problems arise with high sodium because a high sodium adsorption ratio indicates a decrease in the water infiltration rate into soil. Decreased infiltration occurs due to sodium degrading soil structure through clay particle dispersion (Raihan and Alam, 2008). Soil permeability is similarly reduced when sodium concentration is excessive compared to calcium and magnesium or when sodium and magnesium are present together in high levels. Low soil permeability can lead to less available water for plants because water will run off the soil surface rather than penetrating into the rooting zone (Kumar et al., 2007). Excess NaHCO₃ and Na₂CO₃ also

causes dissolution of soil organic matter, which is detrimental to soil health (Kumar et al., 2007).

The bicarbonate concentration in groundwater is an important factor determining irrigation water quality (Raihan and Alam, 2008). Bicarbonate can adversely affect plant growth by decreasing the solubility of some nutrients in alkaline conditions (Beletse et al., 2008). Bicarbonate bonds to cations such as calcium and makes insoluble precipitates when the pH is alkaline. High concentrations of ions such as calcium and bicarbonate will encourage this precipitation. The saturation index in the Gaza Strip, Palestine showed groundwater was supersaturated with calcite and dolomite; this resulted in some of the minerals precipitating out of solution (Al-Agha, 2005). High bicarbonate in groundwater can also cause scorching on tender plant tissue when water contacts the leaf surfaces and then dries, leaving a salty crust. Bicarbonate poses a risk with micro-sprinkler and drip emitter plugging, by forming precipitates that block emitters. Emitter plugging can result in decreased irrigation distribution uniformity. This means water will not be distributed evenly across a field, causing some plants to suffer from water shortage and resulting in decreased performance (California Plant Health Association, 2002).

High nitrate in groundwater can cause excessive vegetative growth and quality problems in some crops (Jang et al., 2008). High groundwater nitrate is particularly a problem near harvest, because excess nitrate can delay plant reproductive maturity and stimulate vegetative growth (Ayers and Westcot, 1985).

Seasonal Differences in Groundwater Quality

Seasonal and spatial differences in groundwater quality are determined by subsurface geochemical processes and recharge area chemistry (Kumar et al., 2006).

Depending upon the area, groundwater can either increase or decrease in quality from before to after the season when meteoric precipitation occurs (Kumar et al., 2007). The characteristics of groundwater can also change over multiple years. This is due to mineral dissolution over time, leaching, and, in arid regions, concentration of ions in groundwater due to evaporative losses. The general trend is older groundwater tends to be more mineralized than younger groundwater (Tizro and Voudouris, 2008).

Ions in groundwater will concentrate when water is removed through evapotranspiration and ions will dilute in groundwater when pure water from meteoric precipitation recharge is added. Rainwater dilution can cause a decrease in ion concentrations from before to after the rainy season. For example, rainwater dilution caused a decrease of Na, K, Cl, hardness, TDS, EC and NO_3 from the pre- to post-monsoon season in India (Reddy et al., 2009). By the same token, ions will concentrate in groundwater leading up to the rainy season due to evapotranspiration (Reddy et al., 2009). Concentration of ions in semi-arid regions is high due to high evaporation (Tizro and Voudouris, 2008).

Total hardness was also lower in India in the post-monsoon season than pre-monsoon season due to dilution and flushing, and coastal Turkey also had slightly higher mean EC, Ca, and Mg in the irrigated versus the non-irrigated season (Kumar et al., 2007; Ödemiş et al., 2006). Electrical conductivity values were an average of 1.4 dS/m in the irrigation season and 1.2 dS/m in the non-irrigation season in coastal Turkey (Ödemiş et al., 2006). The irrigation season also had a slightly higher mean pHs than the non-irrigation season (Ödemiş et al., 2006). The pH in Pradesh, India was 8.36 in the post-monsoon season and 8.45 in the pre-monsoon season (Gowd, 2005).

Conversely, ion concentrations can also increase following rains due to leaching and mineral dissolution from water contact with soil. A rising water table resulted in groundwater contact with the tilled soil in the rainy season, but groundwater did not come into contact with tilled soil in the irrigation season in coastal Turkey. Increased groundwater contact with soil resulted in the ion concentration in shallow groundwater increasing in the non-irrigation season and decreasing at the end of the irrigation season; the increase in ion concentrations was caused by leaching of soils by rain and water table contact with the soil. The irrigation season had low sodium adsorption ratio values (Ödemiş et al., 2006). Leaching and salt dissolution can cause higher EC in the post-monsoon compared to the pre-monsoon season (Kumar et al., 2007). The EC in Pradesh, India was an average of 1075 $\mu\text{mhos/cm}$ in the post-monsoon season and 778.02 $\mu\text{mhos/cm}$ in the pre-monsoon season (Gowd, 2005). The average chloride concentration was higher in the post-monsoon season than in the pre-monsoon season due to increased salt dissolution resulting from a raised water table in Delhi, India (Kumar et al., 2006). In Punjab, India, a slight pH increase occurred from the pre- to post-monsoon season (7.3 to 7.6) due to increased soil and rainwater contact which caused an increase in carbonate dissolution. Bicarbonate content was also slightly higher in the post-monsoon season due to carbonate weathering by rainwater. Sulfate increased in the post-monsoon season due to leaching from organic matter breakdown and sulfur soil amendments; and nitrate content was higher in the post-monsoon season due to leaching (Kumar et al., 2007). The TDS in Pradesh, India averaged 638 mg/L in the post-monsoon season and 530 mg/L in the pre-monsoon season; both of these values are within the acceptable range for irrigation water (Gowd, 2005).

Sometimes, no significant difference in water quality traits occurs from before to after the rainy season. The total dissolved solids concentration in coastal Turkey was consistent between the irrigation and non-irrigation seasons (Ödemiş et al., 2006). Not all ions follow the same concentration patterns throughout a year. In the non-irrigation season, Na, K, Cl, and SO₄ concentrations were high, while in the irrigation season CO₃ and HCO₃ were high in coastal Turkey (Ödemiş et al., 2006). Location also plays a role in ion concentration trends. Some temporal variation in groundwater quality was present in downland regions of Brazil, but not in upland regions (de Andrade et al., 2008).

Depending upon location, groundwater quality can change or remain consistent over multiple years. Reduced rainfall and aquifer recharge during 2001-2002 did not significantly impact water quality in the Guadalupe Valley, Baja California (Daesslé et al., 2006). In the Fresno, California area, salinity of groundwater did not change significantly from 1950-1967 (Schmidt, 1987). However, groundwater supply and quality have decreased over time due to domestic and agricultural usage in the Sacramento Valley, California (Criss, 1996).

Spatial Differences in Groundwater Quality

Seasonal and spatial differences in groundwater quality are determined by subsurface geochemical processes and recharge area chemistry (Kumar et al., 2006). Groundwater quality is not necessarily influenced solely by land practices and characteristics directly above and around a well; areas up-gradient from a well can impact the groundwater characteristics (Johnson, 2009). Electrical conductivity and TDS values increased the greater the distance from the recharge site in West Iran (Tizro and Voudouris, 2008).

Ion Correlations

Ions concentrations most often are correlated when the ions are derived from the same sources. Correlations vary depending upon location characteristics. In Gaza Strip, Palestine, a high calcium-magnesium correlation resulted from the dissolution of dolomite, calcite, and high magnesium-calcite. Sodium had significant correlations with K, Cl, Mg and SO_4 , with the highest correlation being with Cl because of halite dissolution, sea water intrusion and/or dissolution of Na from saline soil. Potassium had a significant positive correlation with flouride, calcium, alkalinity, total dissolved solids, electrical conductivity, magnesium, sodium, chloride, bicarbonate, and sulfate, but not with nitrate; all these factors except nitrate were derived from clay lenses in the aquifer interacting with groundwater (Al-Agha, 2005). Seawater intrusion resulted in positive correlations between potassium, magnesium, and calcium, and also between sodium and chloride (Al-Agha, 2005). In West Iran, significant high positive correlations (>0.80) existed between: sodium and chloride, sulfate, magnesium, bicarbonate; bicarbonate and potassium, calcium; magnesium and chloride, sulfate, bicarbonate; and chloride and sulfate, bicarbonate (Tizro and Voudouris, 2008). In Gaza Strip, Palestine there were positive correlations between calcium, magnesium and alkalinity, total dissolved solids, electrical conductivity, potassim, nitrate, and bicarbonate (Al-Agha, 2005). Increased salinity did not coenside with increased calcium and magnesium concentrations in Delhi, India (Kumar et al., 2006). Whereas in Gaza Strip, Palestine, Mg had a significant correlation between Cl and Na, but Ca did not have similar correlation with Cl and Na (Al-Agha, 2005). No correlation was present between phosphate and any other ion in Baja California; therefore, phosphate concentration was due to independent

hydrogeologic processes such as adsorption/desorption of phosphate from sediments in the aquifer (Daesslé et al., 2006).

Northern California Groundwater Resources

The Sacramento Valley is the northern 1/3 of the central valley of California. The Sacramento Valley has a Mediterranean climate type with hot, dry summers and mild, wet winters, and rainfall ranging from 43-69 cm (16.9 to 27.2 inches) per year (Milby Dawson, 2001). The western Sacramento Valley has groundwater recharge that is over 80% from irrigation water (Criss, 1996). The Sacramento Valley aquifer system is heterogeneous in nature with no continuous confining layers. The aquifer of the Sacramento Valley resides in a trough created by the surrounding mountain ranges—the Sierra Nevada, Coast, and Cascade ranges. The aquifer in the Sacramento Valley is thousands of meters thick and made up of sediment which has eroded from the surrounding mountain ranges (Milby Dawson, 2001). The Tuscan formation is within an accumulation of alluvial fan deposits at the base of the Coastal Range; it is made up of black volcanic gravels and sands, with layers of tuff breccia and clay interbedded between the sands and gravels (Criss, 1996; Ferriz, 2001). Fresh water is present to a depth around 600m (1500-3500 feet) below sea level in the Sacramento Valley; below 600m, saline connate water is present. The general flow of groundwater in the Sacramento Valley is toward the center of the valley from the sides, then in a southerly direction (Milby Dawson, 2001). Water from the Sacramento Valley aquifers discharges at the the Sacramento River Delta (Ferriz, 2001). Recharge into the aquifer of the Sacramento Valley is mainly from the upper ends of rivers in the valley, from irrigated areas, and somewhat from precipitation (Milby Dawson, 2001). The aquifer in the

Sacramento Valley yields fresh water to wells in large quantities, from 900 to 3,000 gal/min; the groundwater often originates from tuffaceous-bed confined aquifers (Ferriz, 2001). The major water types in the Sacramento Valley are magnesium- and calcium-bicarbonate water (in the eastern alluvial plane), sodium-sulfate water (in the western valley), and groundwater that is intermediate between the two water types (in the central portion of the valley) (Milby Dawson, 2001). There is a lower TDS in the eastern Sacramento Valley basin because of recharge from the Sierra Nevada mountains; whereas the western basin is more saline (Ferriz, 2001). Geology differences based on location determine variances in ion concentrations in the Sacramento Valley (Milby Dawson, 2001).

Conclusions

Sources of groundwater components include parent material mineral dissolution, cation exchange, and leaching. Any ion can be problematic for irrigation if it is present in excess in groundwater, but some major ions of concern in groundwater are sodium, bicarbonate and nitrate. Sodium can contribute to decreases in soil water penetration and infiltration. Bicarbonate can lead to decreases in availability of nutrients and nitrate can lead to excessive plant vegetative growth. Concentrations of different ions are generally correlated if they originate from similar or the same sources.

Seasonal variances in ion concentrations occur due to dilution by rainwater and concentration by evapotranspiration. An increase in rainfall can also lead to increased leaching and mineral dissolution. The quality of recharge water quality influences groundwater quality. Groundwater characteristics change by location due to local and upstream characteristics. In Northern California's Sacramento Valley a large portion of

recharge comes from irrigation water. The aquifer of the Sacramento Valley is heterogeneous and puts out a substantial amount of water to wells. The major water types in the Sacramento Valley are magnesium- and calcium-bicarbonate, sodium-sulfate, and a combination of the two. Groundwater is used to a great extent for irrigation, causing groundwater quality to be an important issue in agriculture.

CHAPTER 3: METHODS AND MATERIALS

Location

The study area is the property farmed by Kimmelshue Orchards in Durham, California (Figure 1). All groundwater samples were collected from wells pumped by electric pumps (Table 2). The drawing depth of the wells is 80-100 feet. The climate of the area is Mediterranean with hot, dry summers, and mild, wet winters. The average annual rainfall for the area is between 25 and 30 inches (NOAA).

Table 2. Groundwater sample site information

Well/Parcel #	Longitude	Latitude	Plant Date	Crop Type
W1	N 39° 37.039'	W 121° 49.256'	2003	WALNUT
W2	N 39° 37.245'	W 121° 49.482'	1998	WALNUT
W3	N 39° 37.589'	W 121° 48.793'	2007	WALNUT
W4	N 39° 36.759'	W 121° 49.537'	1978	WALNUT
W5	N 39° 36.661'	W 121° 49.240'	2007	WALNUT
A2	N 39° 36.903'	W 121° 49.240'	1996	ALMOND
A4	N 39° 36.915'	W 121° 49.471'	1983	ALMOND
A5	N 39° 36.802'	W 121° 49.352'	1988	ALMOND
A6	N 39° 37.575'	W 121° 49.102'	1995	ALMOND
A7	N 39° 37.808'	W 121° 49.259'	2006	ALMOND
A8	N 39° 37.096'	W 121° 49.376'	1985	ALMOND

The three major soil series for the sampling area are Busacca clay loam, Conejo clay loam, and Edjobe silty clay (Figure 2). All slopes are less than one percent. The parent materials for all soils are alluvial (Appendix A).

The crops grown on the sampling area are almonds, walnuts, and some beans intercropped in orchards less than three years old. Typical management practices include fertilization (nitrogen, phosphorus, potassium and micronutrients), herbicide, insecticide and fungicide spraying, mowing and dragging between tree rows, and irrigation during the summer months.

Figure 1. Map of the study location and sample sites.

Figure 2. Soil map of the study location.

Field Collections

Groundwater samples were taken from sprinkler heads in orchards undergoing irrigation. Samples were taken no sooner than thirty minutes after the pump was started to ensure all irrigation lines were adequately flushed. Polyethylene bottles were used to collect groundwater samples. Bottles were flushed with sample water at least two times prior to sample collection. Samples were stored in an ice chest right after sampling until they were transferred to a refrigerator (4° C) for storage prior to shipping (Kumar et al., 2007; Tizro and Voudouris, 2008; Ödemiş et al., 2006). Groundwater samples were collected in September 2008, March 2009, May 2009 and September 2009.

Laboratory Analysis

Samples were shipped to Kinsey Agricultural Services, Inc. (Charleston, MO) for analysis. This lab was chosen because it was used by B & B Ag Consulting, Inc. for the first set of groundwater samples collected when the researcher was employed with B & B Ag Consulting, Inc. For consistency, the same laboratory was used for all groundwater analyses. Samples were analyzed for concentrations of calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), sulfate (SO₄), bicarbonate (HCO₃), iron (Fe), chloride (Cl), nitrate (NO₃), total dissolved solids (TDS), hardness, pH, electrical conductivity (EC) and sodium adsorption ratio (S.A.R.).

Statistical Design

A One-Way ANOVA was used to determine if any significant differences were present among the ion concentrations of each sampling time, tree type and sampling location. An alpha level of 0.05 was used for all ANOVA analyses. A correlation analysis

was also run for Ca, Mg, K, Na, SO₄, HCO₃, Fe, Cl, NO₃, TDS, hardness, pH, conductivity and S.A.R. at alpha level equal to 0.05.

Methods of Analyzing Data and Interpreting Results

Groundwater data will be analyzed and interpreted by determining

- Whether current ion concentrations are hazardous to plants
- Differences in ion concentrations throughout the year
- Differences in ion concentrations among sampling sites
- Differences in ion concentrations between almonds and walnuts
- Correlations among test factors

CHAPTER 4: RESULTS AND DISCUSSION

Differences between Almond and Walnut Blocks

Most factors were not significantly different between almond and walnut sites; potassium was the exception. The mean potassium concentration was significantly greater in almond sites (0.98 ppm) than in walnut sites (0.73 ppm) at $p=0.05$ (Figure 3). Almonds are considered to be high potassium users; so in general, more potassium fertilizer is applied to almonds compared to what is applied to walnuts, which are not considered to be high potassium users. Historically, at the study sites, almond orchards had high rates of potassium applied once every few years (e.g. 1500 pounds per acre of potassium sulfate applied once every three years), whereas walnut orchards received little to no applied potassium. Almond and walnut orchards have been receiving comparable amounts of potassium fertilizer every year from 2006 to present (250 pounds per acre of potassium sulfate and 30 gallons per acre potassium thiosulfate). Almonds use a great deal of potassium from the soil and applied fertilizer, as compared to walnuts, and much of the potassium is removed from the orchard in the almond hulls and kernels. Even though much of the potassium is removed from the orchard, an excess still remains due to historic application of more potassium fertilizer than is required by the trees in order to account for a non-100% efficient uptake of applied potassium. The excess potassium then leaches into the groundwater during precipitation events.

Nitrate in groundwater also can originate from applied fertilizer. Walnuts generally have more nitrogen fertilizer applied (300-350 pounds per acre) than almonds (225-250 pounds per acre). Surprisingly, no significant difference in groundwater nitrate

concentration was detected between almond and walnut blocks. This indicates that the amount of nitrogen fertilizer applied to walnuts is not in such excess that higher levels of nitrate are detected in groundwater as compared to almonds.

Figure 3. Mean groundwater potassium (K) concentrations in walnut and almond sample sites.

Differences Among Sampling Times

Not many differences were present among the different sampling times.

Potassium and sodium adsorption ratio were the only factors that expressed significant differences at $p=0.05$ among sampling times. Mean potassium concentration in March 2009 (1.49 ppm) was significantly greater than May 2009 (0.69 ppm), September 2008 (0.75 ppm) and September 2009 (0.63 ppm) (Figure 4). This difference likely occurred due to leaching and dissolution of potassium during the rainy winter months. Similarly, mean S.A.R. values in March 2009 (0.35) and May 2009 (0.34) were significantly greater

than September 2008 (0.26) and September 2009 (0.26) (Figure 5). The difference in S.A.R. values was also likely due to leaching. Sodium leaching into groundwater during winter rain events, while calcium and magnesium remained relatively constant, caused S.A.R. to be greater in the months following the rainy season versus the months just before significant precipitation occurred. Since only potassium and S.A.R. concentrations changed significantly among the sample times, groundwater quality remained relatively consistent throughout the study period.

Figure 4. Mean groundwater potassium (K) concentrations for September 2008, March 2009, May 2009 and September 2009.

Figure 5. Mean groundwater sodium adsorption ratio (S.A.R.) values for September 2008, March 2009, May 2009 and September 2009.

Differences Among Sample Sites

All of the sample sites were significantly different at $p=0.05$ from at least one of the other sample sites for multiple factors (Figures 6 - 9). The general trend was that W1, W3, W5, A2, A4, A6, and A8 had significantly lower mean values for their differing factors than the other sites, whereas W2, W4, A5, and A7 had significantly greater mean values for the factors in which they differed from the other sites. Potassium, sodium adsorption ratio, iron and electrical conductivity were not significantly different among the sample sites.

Three soil types were present in the study area: Busacca clay loam, Conejo clay loam and Edjobe silty clay (Figure 2). Site A6 is located within Busacca clay loam. Sites

A2, A4, A5, W1, W2, W3 and W5 are in the boundaries of Conejo clay loam, and sites W4 and A7 are in Edjobe silty clay. W4 and A7 are also in the group of sites with significantly higher levels of groundwater constituents; soil type could contribute toward these two sites having high ion concentrations. However, W2 and A5 are also sites with high concentrations of groundwater constituents, but they are within the same soil type as most of the sites with low ion concentrations. Soil types among the sites are relatively similar, so it is not likely a major factor in determining the groundwater quality of each site.

Spatial proximity appears to have a relationship to the relative abundance of groundwater constituents. The sites with the highest ion concentrations were paired spatially, with W2 and A7 close together and W4 and A5 adjacent to one another (Figure 1). These pairs of sites are likely drawing groundwater from the same aquifer strata, giving them similar groundwater characteristics.

The sites with the highest mean calcium levels were W4 (104.17 ppm) and A5 (103.13 ppm). Sites W5 (24.59 ppm), A2 (25.00 ppm), A6 (21.25 ppm) and A8 (20.63 ppm) had the lowest mean calcium concentrations. Site A5 had the highest mean magnesium concentration (83.34 ppm), while W5 (15.83 ppm), A2 (18.54 ppm), A6 (13.75 ppm) and A8 (16.67 ppm) had the lowest mean magnesium concentrations. Sulfate concentrations were highest in A5 (262.50 ppm), mid-range in W4 (107.00 ppm) and lowest in all other sites (Figure 6).

Figure 6. Mean groundwater concentrations of calcium (Ca), magnesium (Mg) and sulfate (SO₄) for all sample sites. Different letter designations indicate significantly different values.

Sodium concentrations were highest in A5 (17.29 ppm) and lowest in W5 (7.71 ppm), A6 (7.71 ppm) and A8 (8.55 ppm). The site with the highest chloride concentration was A7 (51.75 ppm). The sites with the lowest chloride concentrations were W1 (12.72 ppm), W5 (11.73 ppm), A2 (10.11 ppm), A4 (14.15 ppm), A6 (10.51 ppm), and A8 (10.51 ppm). Nitrate concentrations were highest in A5 (19.07 ppm) and lowest in W5 (1.42 ppm), A2 (1.42 ppm), A6 (1.12 ppm) and A8 (1.35 ppm) (Figure 7).

Figure 7. Mean groundwater concentrations of sodium (Na), chloride (Cl) and nitrate (NO₃) for all sample sites. Different letter designations indicate significantly different values.

Bicarbonate concentrations were highest in W4 (473.36 ppm), while A6 (133.39 ppm) and A8 (136.64 ppm) had the lowest bicarbonate concentrations. The site with the highest TDS value was A5 (830.5 ppm) and A6 had the lowest TDS value (156.9 ppm). Hardness was highest in A5 (600.1 ppm) and lowest in A6 (109.6 ppm) and A8 120.0 ppm) (Figure 8). The sites with the highest pH were A8 (7.77), W5 (7.73), A4 (7.73) and A2 (7.73). Site W2 had the lowest pH value (7.25) (Figure 9).

Figure 8. Mean groundwater concentrations of bicarbonate (HCO_3), total dissolved solids (TDS) and hardness for all sample sites. Different letter designations indicate significantly different values.

Figure 9. Mean pH values for all groundwater sample sites. Different letter designations indicate significantly different values.

Correlations Among Water Constituents

Many correlations were present among the test factors in groundwater samples. Calcium had positive correlations with Mg, Na, SO_4 , HCO_3 , Cl, TDS, hardness, EC, and NO_3 and negative correlations with S.A.R. and pH. pH also had negative correlations with Mg, Na, SO_4 , HCO_3 , Cl, hardness, EC and NO_3 . This relationship is surprising, since the expected trend would be that as Ca, Mg, HCO_3 and hardness go up, so would pH. Conversely, pH had a positive correlation with S.A.R. Potassium had a positive correlation with TDS only. Magnesium had positive correlations with Na, SO_4 , HCO_3 , Cl, TDS, hardness, EC and NO_3 . Sodium had positive correlations with SO_4 , HCO_3 , Cl, TDS, hardness, EC and NO_3 ; and sulfate had positive correlations with HCO_3 , Cl, TDS, hardness, EC and NO_3 . Bicarbonate had positive correlations with Cl, TDS, hardness and NO_3 ; and chloride had positive correlations with TDS, hardness and NO_3 . Hardness also had positive correlations with EC and NO_3 , and NO_3 was also positively correlated with EC. Iron had no correlations with any other groundwater test factors. The positive correlations among Ca, Mg, Na, SO_4 , HCO_3 , Cl and NO_3 were likely due to these ions originating from the parent material of the aquifer and dissolving into groundwater over time. Hardness, TDS and EC had positive correlations with many of the ions because the ions these measurements were correlated with are ones that contribute to the measurements (e.g. Ca and Mg contribute to hardness). Therefore, as the contributing ion concentrations go up, so do the levels of hardness, TDS and EC.

Irrigation Suitability

All factors tested in the groundwater samples were present at levels permissible for irrigation. Some locations had test values in the slight-to-moderate limitation range for use as irrigation water (Table 1). All sites fell into the slight-to-moderate limitation range for HCO_3 (91.5 – 518.5 ppm). W2, W4, A5 and A7 were in the slight-to-moderate limitation range for TDS (450 – 2000 ppm) and EC (0.7 – 3.0 mmhos/cm). Sites that fell into the slight-to-moderate limitation range for NO_3 (5 – 30 ppm) were W1, W2, W3, W4, A4, A5 and A7 (Ayers and Westcot, 1985). Sodium adsorption ratio was in the slight-to-moderate limitation range (0.3 – 2.0) in all locations except W2 and W3 (Tizro and Voudouris, 2008). These groundwater quality values can be used as a reference when diagnosing crop health issues. Even though some factors fell into the slight-to-moderate limitation range, tree health and yields have not appeared to be significantly impacted.

Some ions present in the groundwater may prove to be beneficial. Levels of ions such as nitrate in groundwater can be accounted for when planning fertilizer application. The amount of applied nitrate from the irrigation water can be calculated and included when developing a nitrogen fertilizer application schedule, and less additional applied nitrogen may be required compared to what was budgeted. Similar calculations can be made for other ions such as potassium and sulfate.

CHAPTER 5: CONCLUSIONS

The data collected in this study gives a baseline for groundwater quality in the south Durham, California area. This information will be beneficial both to farmers for making management decisions based on groundwater quality for irrigation and the data will be beneficial for future research to track groundwater quality over time. Not many differences in groundwater composition were present with regard to tree type or sampling time. The lack of tree type differences was to be expected since management of almonds and walnuts is relatively similar, but the lack of sampling time differences was contrary to what was expected. Many differences were detected among sampling locations, which were not expected because of similar soil types, crops, and the relatively close proximity of all the sample locations. Many correlations were observed among the groundwater test factors. Only one significant difference in groundwater quality was present between almond and walnut blocks. The potassium concentration was significantly greater in almond block groundwater samples than in walnut block samples. The difference between potassium in almonds and walnuts was likely due to fertilization differences. Potassium was also significantly different among the sampling times, as was sodium adsorption ratio. Potassium and sodium adsorption ratio were highest in the sample times following the rainy winter months and lowest just before the rains began. Leaching of potassium and sodium into groundwater created this trend.

Numerous variations in groundwater composition were detected among sample sites. Many factors could have led to the variations, including differences in soil chemical properties, past management practices, characteristics of the aquifer directly around the wells and upstream aquifer characteristics. In general, the sites with lower concentrations

of components—and therefore more pure water—were W1, W3, W5, A2, A4 and A6; whereas W2, W4, A5 and A7 had higher component concentrations.

Many correlations among the test factors were also discovered. An interesting trend was that pH had negative correlations with most other test factors. A high acidity would coincide with high levels of mineral dissolution, and therefore high concentrations of ions in groundwater, leading to a negative correlation between pH and ion concentrations. In general, most other factors had positive correlations with one another.

No indication was present that any groundwater from the sample sites was unsuitable for use as irrigation water. This was to be expected since crops have been grown with the tested groundwater for many years. Slight-to-moderate limitation levels were found for HCO_3 (all sample sites), TDS and EC (W2, W4, A5, and A7), and NO_3 (W1, W2, W3, W4, A4, A5, and A7), but no test factors were present in groundwater at levels that would be severely limiting for irrigation.

This study met its objective by establishing a baseline for water quality in the Durham, California study area. Temporal, crop, and site differences were also established. Future research can expand upon this study by including more sample sites and sampling over multiple years to establish long-term trends in groundwater quality. The information from this and any future studies will be a helpful tool for making management decisions regarding the use and treatment of groundwater for irrigation.

CHAPTER 6: REFERENCES

- Al-Agha M.R. (2005) Hydrochemistry and carbonate saturation model of groundwater, Khayounis Governorate, Gaza Strip, Palestine, Springer International : Berlin, Federal Republic of Germany, Federal Republic of Germany. pp. 898-906.
- Ayers R.S., Westcot D.W. (1985) Water quality for agriculture, Food and Agriculture Organization of the United Nations, Rome.
- Beletse Y.G., Annandale J.G., Steyn J.M., Hall I., Aken M.E. (2008) Can crops be irrigated with sodium bicarbonate rich CBM deep aquifer water? Theoretical and field evaluation. *Ecological Engineering* 33:26-36. DOI: 10.1016/j.ecoleng.2007.12.011.
- California Plant Health Association S.I.C. (2002) Western Fertilizer Handbook. Ninth ed. Interstate Publishers, Inc., Danville, IL.
- Criss R.E. (1996) Isotopic imaging of surface water/groundwater interactions, Sacramento Valley, California, in: M. L. Davisson (Ed.), Elsevier : Amsterdam, Netherlands, Netherlands. pp. 205-222.
- Daesslé L.W., Lugo-Ibarra K.C., Dorst L.V., Rodríguez-Pinal A., Quintanilla-Montoya A.L., Camacho-Ibar V.F., Mendoza-Espinosa L.G., Morton O., Rozier W. (2006) The hydrogeochemistry of a heavily used aquifer in the Mexican wine-producing Guadalupe Valley, Baja California [electronic resource]. *Environmental geology* 51:151-159. DOI: <http://dx.doi.org/10.1007/s00254-006-0318-x>.
- de Andrade E.M., Palacio H.A.Q., Souza I.H., Leao R.A.D., Guerreiro M.J. (2008) Land use effects in groundwater composition of an alluvial aquifer (Trussu River, Brazil) by multivariate techniques. *Environmental Research* 106:170-177. DOI: 10.1016/j.envres.2007.10.008.
- Ferriz H. (2001) Groundwater resources of Northern California; an overview, Ken Johnson, Canada, Canada. pp. 19-44.
- Gowd S.S. (2005) Assessment of groundwater quality for drinking and irrigation purposes; a case study of Peddavanka watershed, Anantapur District, Andhra Pradesh, India, Springer International : Berlin, Federal Republic of Germany, Federal Republic of Germany. pp. 702-712.
- Jang C.S., Chen S.K., Ching-Chieh L. (2008) Using multiple-variable indicator kriging to assess groundwater quality for irrigation in the aquifers of the Choushui River alluvial fan. *Hydrological Processes* 22:4477-4489. DOI: 10.1002/hyp.7037.
- Johnson T.D. (2009) Assigning land use to supply wells for the statistical characterization of regional groundwater quality; correlating urban land use and VOC occurrence, in: K. Belitz (Ed.), Elsevier : Amsterdam, Netherlands, Netherlands. pp. 100-108.
- Kumar M., Kumari K., Ramanathan A., Saxena R. (2007) A comparative evaluation of groundwater suitability for irrigation and drinking purposes in two intensively cultivated districts of Punjab, India. *Environmental Geology* 53:553-574. DOI: 10.1007/s00254-007-0672-3.
- Kumar M., Ramanathan A.L., Rao M.S., Kumar B. (2006) Identification and evaluation of hydrogeochemical processes in the groundwater environment of Delhi, India. *Environmental Geology* 50:1025-1039. DOI: 10.1007/s00254-006-0275-4.

- McMahon P.B. (2008) Simulated response of water quality in public supply wells to land use change, in: K. R. Burow, et al. (Eds.), American Geophysical Union : Washington, DC, United States, United States. pp. @Citation W00A06.
- Milby Dawson B.J. (2001) Water-Resources Investigations - U. S. Geological Survey Shallow ground-water quality beneath rice areas in the Sacramento Valley, California, 1997, U. S. Geological Survey : [Reston, VA], United States, United States.
- NOAA. Average Annual Northern California Precipitation.
- Ödemiş B., Bozkurt S., Ağca N., Yalçın M. (2006) Quality of Shallow Groundwater and Drainage Water in Irrigated Agricultural Lands in A Mediterranean Coastal Region of Turkey. *Environmental Monitoring & Assessment* 115:361-379. DOI: 10.1007/s10661-006-7085-8.
- Raihan F., Alam J.B. (2008) Assessment of groundwater quality in Sunamganj of Bangladesh. *Iranian Journal of Environmental Health Science & Engineering* 5:155-166.
- Reddy A.G.S., Kumar K., Rao D., Rao S. (2009) Assessment of nitrate contamination due to groundwater pollution in north eastern part of Anantapur District, A. P. India. *Environmental Monitoring and Assessment* 148:463-476. DOI: 10.1007/s10661-008-0176-y.
- Schmidt K.D. (1987) Effect of irrigation on groundwater quality in California, in: I. Sherman (Ed.), American Society of Civil Engineers : New York, NY, United States, United States. pp. 16-29.
- Tizro A.T., Voudouris K.S. (2008) Groundwater quality in the semi-arid region of the Chahardouly basin, West Iran. *Hydrological Processes* 22:3066-3078. DOI: 10.1002/hyp.6893.
- Vengosh A., J. Gill, M.L. Davisson, G.B. Hudson. (2002) A multi-isotope (B, Sr, O, H, and C) and age dating (^3H - ^3He and ^{14}C) study of groundwater from Salinas Valley, California. *Water Resources Research* 38:(9-1) - (9-17).

Appendix A

Official Soil Series Descriptions

LOCATION BUSACCA
Established Series
IRD: AEC/JJJ/SBS
10/2006

CA

BUSACCA SERIES

The Busacca series consists of very deep, moderately well drained soils that formed in alluvium from mixed rocks. Busacca soils are on distal alluvial fans. Slopes range from 0 to 1 percent. The mean annual precipitation is about 24 inches, (610 mm) and the mean annual temperature is about 62 degrees F, (17 degrees C).

TAXONOMIC CLASS: Fine, mixed, superactive, thermic Pachic Haploxerolls

TYPICAL PEDON: Busacca clay loam, on a less than one percent slope under a cover of irrigated pasture grasses at an elevation of 157 feet, (48 m). When described on 7/20/93, the soil was slightly moist to 72 inches, (183 cm). (Colors are for dry soil unless otherwise noted)

Ap--0 to 3 inches, (0 to 8 cm); dark grayish brown (10YR 4/2) clay loam, very dark grayish brown (10YR 3/2) moist; 35 percent clay; moderate medium platy structure; extremely hard, slightly rigid, moderately sticky and very plastic; common very fine and few fine and medium roots; common very fine and fine tubular pores; slightly acid, pH 6.5 by Hellige-Truog; clear smooth boundary. (3 to 10 inches, (8 to 25 cm) thick)

A--3 to 8 inches, (8 to 20 cm); dark grayish brown (10YR 4/2) clay loam, very dark grayish brown (10YR 3/2) moist; 35 percent clay; strong coarse prismatic structure parting to strong fine and medium granular; extremely hard, slightly rigid, moderately sticky and very plastic; common very fine and few fine and medium roots; common very fine and fine tubular pores; slightly acid, pH 6.5 by Hellige-Truog; clear smooth boundary. (5 to 10 inches, (13 to 25 cm) thick)

Bw1--8 to 16 inches, (20 to 41 cm); brown (10YR 4/3) clay loam, dark brown (10YR 3/3) moist; 35 percent clay; strong coarse prismatic structure parting to strong fine angular blocky; extremely hard, slightly rigid, moderately sticky and very plastic; common very fine and few fine and medium roots; few very fine and fine tubular pores; neutral, pH 7.0 by Hellige-Truog; abrupt smooth boundary.

Bw2--16 to 28 inches, (41 to 71 cm); brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) moist; 37 percent clay; moderate medium prismatic structure parting to strong fine angular blocky; hard, very firm, moderately sticky and very plastic; common very fine roots; common very fine and few fine tubular pores; neutral, pH 7.0 by Hellige-Truog; abrupt smooth boundary.

Bw3--28 to 43 inches, (71 to 109 cm); brown (10YR 5/3) silty clay loam, dark brown (10YR 3/3) moist; 35 percent clay; moderate fine angular blocky structure; very hard, extremely firm, moderately sticky and very plastic; few very fine roots; few fine and common very fine tubular pores; slightly alkaline, pH 7.5 by Hellige-Truog; gradual smooth boundary.

Bw4--43 to 60 inches, (109 to 152 cm); brown (10YR 5/3) clay loam, dark brown (10YR 3/3) moist; 33 percent clay; weak fine angular blocky structure; moderately hard, firm, slightly sticky and moderately plastic; few very fine roots; few very fine tubular pores; few fine round black (N 2/0) moist, iron-manganese concretions throughout; slightly alkaline, pH 7.5 by Hellige-Truog; gradual smooth boundary.

Bw5--60 to 72 inches, (152 to 183 cm); brown (10YR 5/3) clay loam, brown (10YR 4/3) moist; 29 percent clay; weak fine subangular blocky structure; moderately hard, firm, slightly sticky and moderately plastic; few very fine roots; common very fine and fine tubular pores; few fine round black (N 2/0) moist, iron-manganese concretions with sharp boundaries throughout; slightly alkaline, pH 7.5 by Hellige-Truog. (Combined thickness of the Bw horizon is 60 to 72 inches, (152 to 183 cm) thick)

TYPE LOCATION: Butte County, California; about 2.5 miles east of Durham, approximately 2800 feet east and 100 feet south of the intersection of the Durham Highway and Esquon Road; Township 21 N., Range 2 E.,; in an unsectionized area in the Esquon Land Grant; 39 degrees, 38 minutes, 44 seconds North latitude, 121 degrees, 45 minutes, 12 seconds West longitude, NAD27. U.S.G.S. Quad: Chico, California.

RANGE IN CHARACTERISTICS: Thickness of the mollic epipedon is 20 to 35 inches, (51 to 89 cm). The mean annual soil temperature is 60 to 62 degrees F, (16 to 17 degrees C). The soil moisture control section is dry from July to November (120 to 125 days). The particle-size control section averages 35 to 40 percent clay. Mineralogy is mixed. Surface-initiated reversible cracks 1/8 to 1/2 inch wide extend to a depth of 28 inches, (71 cm) from about May 15 to October 15 (140 to 160 days) when the soil is not irrigated. A fluctuating water table can occur between 30 and greater than 80 inches, (76 to 203 cm) below

the surface of the soil from December through April. In some pedons lime is present below 28 inches, (71 cm).

The A horizon dry color is 10YR 4/1, 4/2, 4/3, 5/2 or 5/3. Moist color is 10YR 3/1, 3/2 or 3/3. Clay content ranges from 30 to 40 percent. Organic matter ranges from 2 to 5 percent. Reaction ranges from slightly acid to slightly alkaline.

The upper Bw horizon dry color is 10YR 4/3, 5/2, 5/3, 6/2 or 6/3. Moist color is 10YR 3/2, 3/3, 4/2 or 4/3. Texture is clay loam, silty clay loam or clay. Clay content ranges from 35 percent to 42 percent. Organic matter ranges from .2 to 2 percent. Reaction ranges from neutral to slightly alkaline.

The lower Bw horizon dry color is 10YR 5/3, 6/3, 6/4, 7/3 or 7/4. Moist color is 10YR 3/3, 4/2, 4/3, 4/4, 5/3, 5/4, 7.5YR 4/3 or 4/4. Texture is clay loam or loam. Clay content ranges from 25 percent to 35 percent. Redoximorphic features such as oxidized iron masses and iron manganese concentrations occur. Organic matter ranges from .1 percent to 1 percent. Reaction ranges from neutral to strongly alkaline.

COMPETING SERIES: These are the [Archerdale](#) and [Finrod](#) soils. Archerdale soils are well drained and are on fan terraces. Finrod soils have a duripan between 40 and 60 inches, (102 to 152 cm).

GEOGRAPHIC SETTING: Busacca soils are on distal alluvial fans. Slopes range from 0 to 1 percent and have been leveled. These soils formed in alluvium weathered from mixed rocks. Elevation is 120 to 245 feet, (37 to 75 m). Mean annual precipitation is 20 to 27 inches, (508 to 686 mm). The mean annual temperature is 60 to 62 degrees F, (16 to 17 degrees C). Frost free season is 245 to 255 days.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the [Conejo](#), [Edjobe](#), [Bosquejo](#) and [Farwell](#) soils. Conejo soils average less than 35 percent clay in the particle-size control section. Edjobe soils have a duripan between 60 and 80 inches, (152 to 203 cm), have smectitic mineralogy and are on basin rims. Bosquejo soils have 40 to 50 percent clay in the particle-size control section, are smectitic and are in interfan basins. Farwell soils are fine-loamy and are on flood plain margins.

DRAINAGE AND PERMEABILITY: Moderately well drained; negligible runoff; moderately slow saturated hydraulic conductivity in the A horizon, moderately slow to slow in the upper Bw horizon and moderate to moderately slow in the lower Bw horizon. Occasionally ponded up to 3 inches, (8 cm) above the surface for brief duration from December through March. A fluctuating water table can occur between 30 and greater than 80 inches, (76 to 203 cm) below the surface of the soil from December through April.

USE AND VEGETATION: This soil is used for pasture, row crops and some orchards.

DISTRIBUTION AND EXTENT: Butte County, California. The soils are moderately extensive. MLRA 17 - Sacramento Valley.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Davis, California

SERIES ESTABLISHED: Butte County, California 2005. Source of name is coined.

REMARKS: Diagnostic horizons and features recognized in this pedon are:

Mollic epipedon zone from 0 to 28 inches, (0 to 71 cm). (Ap, A1, Bw1, Bw2)

Cambic horizon zone from 28 to 72 inches, (71 to 183 cm). (Bw3, Bc1, Bc2)

Particle-size control section zone from 0 to 40 inches, (0 to 102 cm).

Moisture control section zone from 5 to 14 inches, (13 to 36 cm) is dry from July to November (120 to 125 days).

LEP based on estimated LE was calculated to be 5.4 (to 100cm)

Assumed mixed mineralogy.

ADDITIONAL DATA: Characterization data from nearby lab pedon number: 89P0067, NSSL, Lincoln, NE.

LOCATION CONEJO
Established Series
Rev. SBJ/DJL/DJE/SBS/DWB
03/2006

CA

CONEJO SERIES

The Conejo series consists of very deep, well drained soils that formed in alluvium from basic igneous or sedimentary rocks. Conejo soils are on alluvial fans and stream terraces. Slopes range from 0 to 9 percent. The mean annual precipitation is about 20 inches, (508 mm) and the mean annual air temperature is about 62 degrees F, (17 degrees C).

TAXONOMIC CLASS: Fine-loamy, mixed, superactive, thermic Pachic Haploxerolls

TYPICAL PEDON: Conejo clay loam under a cover of milo at an elevation of 135 feet, (41 m). Redescribed on 7/20/1993. (Colors are for dry soil unless otherwise noted).

Ap--0 to 5 inches, (0 to 13 cm); dark gray (10YR 4/1) clay loam, very dark gray (10YR 3/1) moist; 31 percent clay, moderate medium and coarse subangular blocky and strong medium granular structure; very hard, friable, moderately sticky and moderately plastic; many fine and medium irregular pores; slightly alkaline, pH 7.5 by Hellige-Truog; abrupt wavy boundary. (3 to 8 inches, (8 to 20 cm) thick)

A1--5 to 19 inches, (13 to 48 cm); very dark grayish brown (10YR 3/2) clay loam, very dark brown (10YR 2/2) moist; 31 percent clay, moderate coarse subangular blocky structure; very hard, friable, moderately sticky and moderately plastic; common very fine roots; many very fine and fine tubular and many fine irregular pores; slightly alkaline, pH 7.5 by Hellige-Truog; clear wavy boundary. (10 to 17 inches, (25 to 43 cm) thick)

A2--19 to 30 inches, (48 to 76 cm); very dark grayish brown (10YR 3/2) clay loam, very dark grayish brown (10YR 3/2) moist; 31 percent clay, moderate medium subangular blocky structure; very hard, friable, moderately sticky and moderately plastic; common very fine roots; many very fine and few fine tubular pores; few pressure faces; common fine iron-manganese nodules about 1 mm diameter; 1 percent gravel; slightly alkaline, pH 7.5 by Hellige-Truog; gradual wavy boundary. (10 to 15 inches, (25 to 38 cm) thick)

Bw1--30 to 48 inches, (76 to 122 cm); dark grayish brown (10YR 4/2) clay loam, very dark grayish brown (10YR 3/2) moist; 29 percent clay; moderate coarse subangular blocky structure; very hard, friable, moderately sticky and moderately plastic; common very fine roots; many very fine and fine tubular and many fine irregular pores; many pressure faces; few fine iron-manganese nodules about 1 mm diameter; 2 percent gravel; slightly alkaline, pH 7.5 by Hellige-Truog; clear wavy boundary. (13 to 20 inches, (33 to 51 cm) thick)

Bw2--48 to 70 inches, (122 to 178 cm); brown (10YR 5/3) loam, dark yellowish brown (10YR 4/4) moist; 19 percent clay, weak fine and medium subangular blocky structure; slightly hard, weakly brittle but friable, nonsticky and slightly plastic; common very fine roots; many very fine and few fine and medium tubular pores; slightly effervescent in seams; common medium oxidized iron masses; 1 percent gravel; moderately alkaline, pH 8.0 by Hellige-Truog.

TYPE LOCATION: Butte County, California; about 6 miles south of Chico on west side of Aquas Frias Road; 800 feet south of northeast corner of Section 33, Township 21 N., Range 1 E., 39 degrees, 38 minutes, 10 seconds North latitude; 121 degrees, 51 minutes, 40 seconds West longitude, NAD27 - U.S.G.S. Quad: Chico, California.

RANGE IN CHARACTERISTICS: Depth is greater than 80 inches, (203 cm). The mean annual soil temperature is 59 to 66 degrees F, (15 to 19 degrees C). The soil moisture control section is dry in all parts from about May through October (about 140 to 160 days). The particle-size control section has about 20 to 35 percent clay and some gravel is present.

Some pedons have fine sandy loam or loam overwash less than 20 inches (51cm) thick. These pedons have clay loam or loam Ab and upper Bw horizons, have 0 to 5 percent gravel and average 18 to 35 percent clay in the particle-size control section. The extent of this overwash phase is 600 to 700 acres and is the result of hydraulic mine deposits splaying out of the early levees on Butte Creek, north of Durham.

The Ap and A horizons have dry colors of 10YR 3/2, 4/1, 4/2, 4/3, 4/4, 5/2 or 5/3. Moist color is 10YR 3/1, 3/2, 2/2, 3/3, 4/2 or 7.5YR 3/2. In some pedons, it has weak to strong granular structure; in others, all or part has moderate to strong subangular blocky structure. Texture is clay loam. Clay content ranges from 27 to 35 percent. Organic matter ranges from 1.5 to 6 percent. Rock fragments range from 0 to 2 percent gravel. Reaction ranges from slightly acid to slightly alkaline.

The upper Bw horizon has dry colors of 10YR 4/2, 4/3, 4/4, 5/2, 5/3, 5/4, 6/2, 6/3, 6/4, 7/3, 7.5YR 4/2, 4/4, 5/4 or 6/4. Moist color is 10YR 2/2, 3/2, 3/3, 3/4, 4/2, 4/3, 4/4, 5/2, 7.5YR 3/2, 3/4, 4/2 or 4/4. Texture is loam or clay loam. Clay content ranges from 27 to 35 percent. Rock fragments range from 0 to 2 percent gravel. Reaction ranges from slightly acid to slightly alkaline.

The lower Bw horizon has dry colors of 10YR 3/4, 4/2, 4/3, 4/4, 5/3, 5/4, 6/2, 6/3, 6/4, 7.5YR 4/2, 4/4, 5/2 or 5/4. Moist color is 10YR 4/2, 4/3, 4/4, 5/3 or 5/4. Texture is sandy loam, fine sandy loam, loam or clay loam. Clay content ranges from 15 to 35 percent. Rock fragments range from 0 to 2 percent gravel. Reaction ranges from neutral to moderately alkaline, but some pedons are slightly acid. Segregated or secondary lime is in some pedons at depths greater than 48 inches, (76 cm). Some pedons have redoximorphic features within 40 inches, (102 cm) of the surface, a few pedons have redoximorphic features within 30 inches, (76 cm) of the surface. Some pedons have siltstone at depths of 40 to 60 inches, (102 to 152 cm).

COMPETING SERIES: These are the [Agueda](#), [Almendra](#), [Anaheim](#), [Carranza](#), [Gazos](#), [Reward](#), [Salinas](#) and [Westfan](#) series. Agueda soils are calcareous throughout. Almendra soils have 18 to 27 percent clay in the particle-size control section. Anaheim soils are moderately deep to a paralithic contact. Gazos soils have a lithic contact within 40 inches, (102 cm) of the surface. Carranza soils have extremely gravelly sandy clay loam C horizons within a depth of 40 inches, (102 cm). Reward soils are effervescent and have a lithic contact at 40 to 60 inches, (102 to 152 cm). Salinas soils have secondary carbonate accumulations in the C horizons. Westfan soils have Btk and Ck horizons that are strongly effervescent and have disseminated carbonates or concretions, have solum thickness of 25 to 60 inches, (64 to 152 cm), and have a water table between 36 to 60 inches, (91 to 152 cm) from November through April.

GEOGRAPHIC SETTING: Conejo soils are on alluvial fans and stream terraces at elevations of 30 to 2,000 feet, (9 to 610 m). Slopes range from 0 to 9 percent. The soil formed in alluvium from basic igneous and sedimentary rocks. The climate has hot dry summers and cool moist winters. Mean annual precipitation is 14 to 26 inches, (356 to 660 mm). Mean annual temperature is about 59 to 64 degrees F, (15 to 18 degrees C), average January temperature varies from 45 to 50 degrees F, (7 to 10 degrees C), and average July temperature varies from 70 to 80 degrees F, (21 to 26 degrees C). Frost free period is about 260 to 330 days.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the [Cibo](#), [Clear Lake](#) and [Trimmer](#) soils. Cibo and Trimmer soils occur on upland areas and have lithic and paralithic contacts respectively. Clear Lake soils are of clay texture and occupy basins.

DRAINAGE AND PERMEABILITY: Well drained; slow to medium runoff, moderately slow saturated hydraulic conductivity in the A and upper Bw horizons and moderately slow to moderately rapid in the lower Bw horizon. Some areas are subject to occasional flooding.

USE AND VEGETATION: Used for irrigated row crops, orchard, hay and pasture and grain. Vegetation is annual grasses and forbs with few scattered oaks.

DISTRIBUTION AND EXTENT: Valley areas in northern and central California and the Coast Range of California. The soils are of small extent

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Davis, California

SERIES ESTABLISHED: Siskiyou County (Shasta Valley Area, California 1919).

REMARKS: The Conejo series was established in Siskiyou County in 1919. The type location was moved to Butte County some time prior to 1989. It is mapped in multiple MLRA's in Butte, Contra Costa, Los Angeles, San Benito, Santa Cruz, Solano, Sutter and Yuba Counties.

The official description from Butte County was written prior to modern soil survey mapping and does not adequately represent conditions in Butte County. The type location was revisited on 7/93 and the description revised. The range of characteristics has been left as is. The use of Conejo in other areas should be reviewed during MLRA updates. In Butte County, to reflect actual conditions, the range of characteristics in the taxonomic unit description is narrowed down. (Average clay in the particle-size control section is 27 to 35 percent).

Additional Data: Clay determined by particle-size analysis at local survey office.

LOCATION EDJOBE
Established Series
IRD: AEC/JJJ/SBS
10/2006

CA

EDJOBE SERIES

The Edjobe series consists of very deep, poorly drained soils that formed in alluvium from mixed rocks. Edjobe soils are on basin rims. Slopes range from 0 to 1 percent. The mean annual precipitation is about 21 inches, (533 mm) and the mean annual temperature is about 61 degrees F, (16 degrees C).

TAXONOMIC CLASS: Fine, smectitic, thermic Xeric Epiaquerts

TYPICAL PEDON: Edjobe silty clay on a less than 1 percent slope under a cover of weeds in a fallow field at an elevation of 122 feet, (37 m). When described on 7/15/1993, the soil was slightly moist throughout. (Colors are for dry soil unless otherwise stated).

Ap--0 to 8 inches, (0 to 20 cm); very dark gray (10YR 3/1) silty clay, black (10YR 2/1) moist; 55 percent clay; strong medium angular blocky structure parting to strong fine granular; extremely hard, firm, very sticky and very plastic; common fine roots; common fine irregular pores; slightly alkaline, pH 7.5 pH by Hellige-Truog; abrupt smooth boundary. (4 to 10 inches, (10 to 25 cm) thick)

Bssg--8 to 25 inches, (20 to 64 cm); dark gray (10YR 4/1) silty clay, very dark gray (10YR 3/1) moist; 55 percent clay; strong very coarse prismatic structure parting to strong medium angular blocky; extremely hard, firm, very sticky and very plastic; few very fine and fine roots; few very fine tubular pores; many slickensides; slightly alkaline, pH 7.5 pH by Hellige-Truog; clear wavy boundary. (6 to 15 inches, (15 to 38 cm) thick)

Bkssg--25 to 32 inches, (64 to 81 cm); dark gray (10YR 4/1) silty clay, very dark gray (10YR 3/1) moist; 42 percent clay; strong medium angular blocky structure; extremely hard, firm, very sticky and very plastic; few very fine roots; common very fine tubular pores; many slickensides; few fine round carbonate concretions; common fine spherical and irregular soft masses of carbonates throughout; moderately alkaline, pH 8.0 pH by Hellige-Truog; gradual wavy boundary. (0 to 21 inches, (0 to 53 cm) thick)

Bw1--32 to 48 inches, (81 to 122 cm); dark gray (10YR 4/1) silty clay loam, dark grayish brown (10YR 4/2) moist; 37 percent clay; moderate fine and medium angular blocky structure; very hard, firm; sticky and plastic; few very fine roots; common very fine and few medium tubular pores; slightly effervescent throughout; moderately alkaline, pH 8.0 pH by Hellige-Truog; gradual smooth boundary. (0 to 16 inches, (0 to 41 cm) thick)

2Bw2--48 to 60 inches, (122 to 152 cm); light brownish gray (10YR 6/2) clay loam, grayish brown (10YR 5/2) moist; 30 percent clay; weak fine and medium angular blocky structure; hard, firm, moderately sticky and moderately plastic; few very fine roots; common very fine and fine, few medium tubular pores; many fine faint brown (10YR 4/3) moist, irregular soft oxidized iron masses throughout and few fine patchy prominent black (N 2/0) moist, manganese masses on ped faces; slightly effervescent; moderately alkaline, pH 8.0 pH by Hellige-Truog; gradual smooth boundary. (0 to 15 inches, (0 to 38 cm) thick)

2Bq--60 to 69 inches, (152 to 175 cm); pale brown (10YR 6/3) clay loam, brown (10YR 5/3) moist; 28 percent clay; massive; hard, firm, slightly sticky and slightly plastic; few very fine roots; common fine and very fine, few medium tubular pores; many fine distinct brown (7.5YR 4/4) moist, irregular soft oxidized iron masses throughout; 5 percent weakly cemented durinodes; slightly effervescent throughout; moderately alkaline, pH 8.0 pH by Hellige-Truog; abrupt smooth boundary. (0 to 12 inches, (0 to 30 cm) thick)

2Bkqm--69 to 75 inches, (175 to 190 cm); moderately cemented duripan ; pale brown (10YR 6/3) brown (7.5YR 4/4) moist; indurated capping with continuous silica cementation; weak fine platy structure; very rigid, nonsticky and nonplastic; common fine and medium carbonate threads; moderately alkaline, pH 8.0 pH by Hellige-Truog.

TYPE LOCATION: Butte County, California; about 3 miles south of Durham, approximately 5050 feet west and 4950 feet south of the intersection of Grainland Road and Durham Nelson Road; in an unsectionized area in the Aquas Frias Land Grant; 39 degrees, 35 minutes, 48 seconds North latitude and 121 degrees, 49 minutes, 2 seconds West longitude, NAD27. U.S.G.S. Quad: Nelson, California.

RANGE IN CHARACTERISTICS: Depth to duripan is 60 to 80 inches, (152 to 203 cm). The mean annual soil temperature is 60 to 62 degrees F, (16 to 17 degrees C). The soil moisture control section is dry from July to November (120 to 125 days). The particle-size control section averages 40 to 50 percent clay. Mineralogy is smectitic. The soil is calcareous from 25 to 72 inches, (64 to 183 cm). Surface-initiated

reversible cracks 1 to 2 inches, (2.54 to 5 cm) wide extend to a depth of 31 inches, (79 cm) from about May 15 to October 15 (140 to 160 days) when the soil is not irrigated. Intersecting slickensides range from common to many in the Bssg and Bsskg horizons from 8 to 50 inches, (20 to 127 cm). A fluctuating water table can occur between the top of the duripan and 10 inches, (25 cm) below the surface of the soil from December through May. Redoximorphic features such as reduced matrix occur in the overlying basin material and oxidized iron masses and manganese masses occur in the underlying loamy material. Some pedons lack gleyed matrix colors. In some pedons oxidized iron masses, manganese masses and/or iron-manganese concretions occur in the overlying basin material and iron-manganese concretions occur in the underlying loamy material. Some pedons lack calcium carbonate accumulation.

The Ap horizon dry color is 10YR 3/1, 4/1, 4/2, 5/1 or 5/2. Moist color is 10YR 2/1, 3/1 or 3/2. Clay content ranges from 40 to 55 percent. Reaction ranges from slightly acid to slightly alkaline.

The Bssg horizon dry color is 10YR 4/1, 5/1, 5/2 or 4/2. Moist color is 10YR 3/1, 4/1 or 4/2. Texture is silty clay or clay. Clay content ranges from 40 to 55 percent. Reaction ranges from neutral to moderately alkaline.

The Bkssg horizon dry color is 10YR 4/1, 5/1, 5/2 or 4/2. Moist color is 10YR 3/1, 4/1 or 4/2. Texture is silty clay or clay. Clay content ranges from 40 to 50 percent. Reaction ranges from slightly alkaline to moderately alkaline.

The Bw horizon dry color is 10YR 4/1, 5/1, 5/2 or 4/2. Moist color is 10YR 3/1, 4/1 or 4/2. Texture is silty clay loam or clay loam. Clay content is 27 to 40 percent. Reaction ranges from slightly alkaline to moderately alkaline.

The 2Bw horizon dry color is 10YR 6/2 or 4/2. Moist color is 10YR 5/2 or 4/2. Texture is clay loam or loam. Clay content ranges from 25 to 40 percent. Redoximorphic features such as oxidized iron masses (10YR 4/4, 7.5YR 3/4, 4/4, 4/6) moist, manganese masses (N 2/0) moist, and/or iron-manganese concretions (N 2/0) moist, occur on ped faces, in pores and throughout. Reaction ranges from slightly alkaline to moderately alkaline.

The 2Bq horizon dry color is 10YR 6/3 or 5/3. Moist color is 10YR 4/3 or 5/3. Texture is clay loam or loam. Clay content ranges from 25 to 35 percent. Redoximorphic features such as masses of oxidized iron masses (10YR 4/4, 7.5YR 3/4, 4/4, 4/6) moist, manganese masses (N 2/0) moist, and/or iron manganese concretions (N 2/0) moist, occur on ped faces, in pores and throughout. Rupture resistance ranges from weakly to moderately cemented. Reaction ranges from slightly alkaline to moderately alkaline.

The 2Bkqm horizon dry color is 10YR 6/3 or 6/4. Moist color is 10YR 4/3, 4/4 or 7.5YR 4/4. Rupture resistance ranges from indurated to strongly cemented with alternating weak and moderately cemented layers cemented with silica and carbonates. Reaction is moderately alkaline.

COMPETING SERIES: These are the [Stockton](#) and [Subaco](#) series. Stockton soils are deep. Subaco soils are moderately deep.

GEOGRAPHIC SETTING: Edjobe soils are on basin rims. Slopes range from 0 to 1 percent and have been leveled. These soils formed in alluvium from mixed rocks. Elevation is 115 to 150 feet, (35 to 46 m). Mean annual precipitation is 20 to 22 inches, (508 to 550 mm). The mean annual temperature is 60 to 62 degrees F, (16 to 17 degrees C). Frost free season is 240 to 250 days.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the [Busacca](#), [Conejo](#), [Govstanford](#), [Esquon](#) and [Neerdobe](#) soils. Busacca soils average 35 to 40 percent clay in the particle-size control section and are on distal fans. Conejo soils average 27 to 35 percent clay in the particle-size control section and are on distal fans. Govstanford soils have a mantle of coarser material in the upper profile and are on flood plains. Neerdobe soils have a duripan at 20 to 40 inches, (51 to 102 cm).

DRAINAGE AND PERMEABILITY: Poorly drained; high runoff; slow saturated hydraulic conductivity in the Ap, Bssg and Bkssg horizons, moderately slow in the Bw horizon, moderate to moderate slow in the 2Bw and 2Bq horizons and impermeable to very slow in the 2Bkqm horizon. Ponding frequently occurs for long durations up to 6 inches, (15 cm) from December through March. A fluctuating water table can occur between the top of the duripan and 10 inches, (25 cm) below the surface of the soil from December through May.

USE AND VEGETATION: This soil is used for rice, sugar beets, sorghum, safflower, wheat, pasture, almonds, prunes and walnuts.

DISTRIBUTION AND EXTENT: Butte County, California. MLRA 17 - Sacramento Valley. The soils are not extensive.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Davis, California

SERIES ESTABLISHED: Butte County, California 2005. Source of name is coined.

REMARKS: Diagnostic horizons and features recognized in this pedon are:

Ochric epipedon - 0 to 8 inches, (0 to 20 cm) (Ap)

Cambic horizon - 8 to 69 inches, (20 to 125 cm) (Bssg, Bkssg, Bw1, 2Bw2, 2Bq)

Lithologic discontinuity at 48 inches, (122 cm).

Duripan - the zone from 69 to 75 inches, (175 to 190 cm) (2Bkqm)

Particle-size control section- 10 to 40 inches, (25 to 102 cm)

Soil moisture control section- 7 to 18 inches, (18 to 46 cm)

National Cooperative Soil Survey

U.S.A.

Appendix B

Groundwater Analysis Data

SEPTEMBER 12, 2008

WATER REPORT

KINSEY AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **B & B AG CONSULTING**

SAMPLE: KIMMELSHUE ORCH.-W1-WATER-8069

Lab No.: 438		Parts per million - p.p.m.			
			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	56.88	2.844	13	
Magnesium	Mg	36.88	3.073	8	
Potassium	K	0.63	0.016	0	
Sodium	Na	8.13	0.353	2	
Sulfate	SO4	87.00	1.813	20	
Carbonate	CO3				
Bicarbonate	HCO3	219.60	3.600	51	
Iron	Fe	0.01	0.001	0	
Chloride	Cl	12.13	0.342	3	
Salt Concentration (TDS)		379.27			
Hardness		293.58	5.917	68	
pH		7.50			SPARINGLY
Conductivity (mmhos/cm)		0.59			
Boron	B				
Nitrate	NO3-N	16.20	1.157	4	
S.A.R.		0.21			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				
TOTAL CHLORINE		mg/L			
TOTAL SUSPENDED SOLIDS		mg/L			
Equivalent lbs of lime per 12" of irrigated water				496	

SEPTEMBER 12, 2008

WATER REPORT

KINSEY AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **B & B AG CONSULTING**

SAMPLE: KIMMELSHUE ORCH.-W2-WATER-8070

Lab No.: 439 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	70.63	3.531	16	UNSUITABLE
Magnesium	Mg	64.38	5.365	15	
Potassium	K	0.63	0.016	0	
Sodium	Na	11.25	0.489	3	
Sulfate	SO4	90.00	1.875	21	
Carbonate	CO3				
Bicarbonate	HCO3	336.72	5.520	77	
Iron	Fe	0.01	0.001	0	
Chloride	Cl	30.33	0.855	7	
Salt Concentration (TDS)		549.29			
Hardness		441.04	8.896	101	
pH		7.20			SPARINGLY
Conductivity (mmhos/cm)		0.86			SPARINGLY
Boron	B				
Nitrate	NO3-N	16.80	1.200	4	
S.A.R.		0.23			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 761

SEPTEMBER 12, 2008

WATER REPORT

KINSEY AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **B & B AG CONSULTING**

SAMPLE: KIMMELSHUE ORCH.-W3-WATER-8071

Lab No.: 440		Parts per million - p.p.m.			
			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	45.63	2.281	10	
Magnesium	Mg	33.75	2.813	8	
Potassium	K	0.63	0.016	0	
Sodium	Na	8.75	0.380	2	
Sulfate	SO4	30.00	0.625	7	
Carbonate	CO3				
Bicarbonate	HCO3	214.72	3.520	49	
Iron	Fe	0.01	0.001	0	
Chloride	Cl	21.83	0.616	5	
Salt Concentration (TDS)		326.96			
Hardness		252.67	5.094	58	
pH		7.60			SPARINGLY
Conductivity (mmhos/cm)		0.51			
Boron	B				
Nitrate	NO3-N	8.20	0.586	2	
S.A.R.		0.24			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				
TOTAL CHLORINE mg/L					
TOTAL SUSPENDED SOLIDS mg/L					
Equivalent lbs of lime per 12" of irrigated water				485	

SEPTEMBER 12, 2008

WATER REPORT

KINSEY AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **B & B AG CONSULTING**

SAMPLE: KIMMELSHUE ORCH.-W4-WATER-8072

Lab No.: 441 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	115.00	5.750	26	UNSUITABLE
Magnesium	Mg	80.63	6.719	19	UNSUITABLE
Potassium	K	1.25	0.032	0	
Sodium	Na	17.50	0.761	4	
Sulfate	SO4	139.50	2.906	32	
Carbonate	CO3				
Bicarbonate	HCO3	531.92	8.720	122	
Iron	Fe	0.07	0.004	0	
Chloride	Cl	25.47	0.719	6	
Salt Concentration (TDS)		771.62			
Hardness		618.57	12.473	142	
pH		7.60			SPARINGLY
Conductivity (mmhos/cm)		1.21			SPARINGLY
Boron	B				
Nitrate	NO3-N	22.40	1.600	5	
S.A.R.		0.31			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 1202

SEPTEMBER 12, 2008

WATER REPORT

KINSEY AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **B & B AG CONSULTING**

SAMPLE: KIMMELSHUE ORCH.-WS-WATER-8073

Lab No.: 442		Parts per million - p.p.m.			
			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	20.63	1.031	5	
Magnesium	Mg	15.00	1.250	3	
Potassium	K	0.63	0.016	0	
Sodium	Na	8.13	0.353	2	
Sulfate	SO4	7.50	0.156	2	
Carbonate	CO3				
Bicarbonate	HCO3	151.28	2.480	35	
Iron	Fe	0.03	0.002	0	
Chloride	Cl	8.49	0.240	2	
Salt Concentration (TDS)		163.48			
Hardness		113.16	2.283	26	
pH		7.80			SPARINGLY
Conductivity (mmhos/cm)		0.26			
Boron	B				
Nitrate	NO3-N	1.81	0.130	0	
S.A.R.		0.33			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				
TOTAL CHLORINE mg/L					
TOTAL SUSPENDED SOLIDS mg/L					
Equivalent lbs of lime per 12" of irrigated water				342	

MARCH 20, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: W1 WATER

Lab No.: 887 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	13.75	0.688	3	
Magnesium	Mg	13.75	1.146	3	
Potassium	K	1.25	0.032	0	
Sodium	Na	8.13	0.353	2	
Sulfate	SO4	12.00	0.250	3	
Carbonate	CO3				
Bicarbonate	HCO3	87.84	1.440	20	
Iron	Fe	0.04	0.002	0	
Chloride	Cl	15.77	0.445	4	
Salt Concentration (TDS)		170.02			
Hardness		90.87	1.835	21	
pH		7.40			SPARINGLY
Conductivity (mmhos/cm)		0.27			
Boron	B				
Nitrate	NO3-N	1.90	0.136	0	
S.A.R.		0.37			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 199

MARCH 20, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: W2 WATER

Lab No.: 888 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	77.50	3.875	18	UNSUITABLE
Magnesium	Mg	65.00	5.417	15	
Potassium	K	1.25	0.032	0	
Sodium	Na	13.13	0.571	3	
Sulfate	SO4	102.00	2.125	23	
Carbonate	CO3				
Bicarbonate	HCO3	341.60	5.600	79	
Iron	Fe	0.07	0.004	0	
Chloride	Cl	38.82	1.095	9	
Salt Concentration (TDS)		653.91			
Hardness		460.76	9.295	106	
pH		7.30			SPARINGLY
Conductivity (mmhos/cm)		1.02			SPARINGLY
Boron	B				
Nitrate	NO3-N	14.93	1.067	3	
S.A.R.		0.27			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 772

MARCH 20, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: 2 WATER

Lab No.: 889 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	19.38	0.969	4	
Magnesium	Mg	17.50	1.458	4	
Potassium	K	1.25	0.032	0	
Sodium	Na	9.38	0.408	2	
Sulfate	SO4	10.50	0.219	2	
Carbonate	CO3				
Bicarbonate	HCO3	131.76	2.160	30	
Iron	Fe	0.01	0.001	0	
Chloride	Cl	13.34	0.376	3	
Salt Concentration (TDS)		189.63			
Hardness		120.33	2.428	28	
pH		7.70			SPARINGLY
Conductivity (mmhos/cm)		0.30			
Boron	B				
Nitrate	NO3-N	1.89	0.135	0	
S.A.R.		0.37			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 298

MARCH 20, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: 4 WATER

Lab No.: 890 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	30.00	1.500	7	
Magnesium	Mg	25.00	2.083	6	
Potassium	K	1.25	0.032	0	
Sodium	Na	10.00	0.435	2	
Sulfate	SO4	25.50	0.531	6	
Carbonate	CO3				
Bicarbonate	HCO3	165.92	2.720	38	
Iron	Fe	0.04	0.002	0	
Chloride	Cl	16.98	0.479	4	
Salt Concentration (TDS)		261.57			
Hardness		177.69	3.585	41	
pH		7.80			SPARINGLY
Conductivity (mmhos/cm)		0.41			
Boron	B				
Nitrate	NO3-N	4.51	0.322	1	
S.A.R.		0.33			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 375

MARCH 20, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: 5 WATER

Lab No.: 891 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	40.00	2.000	9	SPARINGLY
Magnesium	Mg	52.50	4.375	12	
Potassium	K	1.88	0.048	0	
Sodium	Na	10.00	0.435	2	
Sulfate	SO4	141.00	2.938	32	
Carbonate	CO3				SPARINGLY
Bicarbonate	HCO3	156.16	2.560	36	
Iron	Fe	0.01	0.001	0	
Chloride	Cl	21.83	0.616	5	
Salt Concentration (TDS)		438.12			
Hardness		315.80	6.376	73	SPARINGLY
pH		7.50			
Conductivity (mmhos/cm)		0.68			
Boron	B				
Nitrate	NO3-N	10.87	0.776	2	
S.A.R.		0.25			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 353

MARCH 20, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: 6 WATER

Lab No.: 892 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	10.00	0.500	2	
Magnesium	Mg	13.75	1.146	3	
Potassium	K	1.25	0.032	0	
Sodium	Na	8.75	0.380	2	
Sulfate	SO4	9.00	0.188	2	
Carbonate	CO3				
Bicarbonate	HCO3	131.76	2.160	30	
Iron	Fe	0.02	0.001	0	
Chloride	Cl	10.92	0.308	3	
Salt Concentration (TDS)		143.86			
Hardness		81.52	1.647	19	
pH		7.70			SPARINGLY
Conductivity (mmhos/cm)		0.22			
Boron	B				
Nitrate	NO3-N	1.60	0.114	0	
S.A.R.		0.42			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 298

MARCH 20, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: 7 WATER

Lab No.: 893 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	70.00	3.500	16	UNSUITABLE
Magnesium	Mg	70.63	5.885	16	
Potassium	K	2.50	0.064	1	
Sodium	Na	15.00	0.652	3	
Sulfate	SO4	90.00	1.875	21	
Carbonate	CO3				
Bicarbonate	HCO3	322.08	5.280	74	
Iron	Fe	0.02	0.001	0	
Chloride	Cl	53.37	1.506	12	
Salt Concentration (TDS)		640.83			
Hardness		465.20	9.386	107	
pH		7.40			SPARINGLY
Conductivity (mmhos/cm)		1.00			SPARINGLY
Boron	B				
Nitrate	NO3-N	20.20	1.443	5	
S.A.R.		0.30			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 728

MARCH 20, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: 8 WATER

Lab No.: 894 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	4.38	0.219	1	
Magnesium	Mg	16.88	1.406	4	
Potassium	K	1.25	0.032	0	
Sodium	Na	9.38	0.408	2	
Sulfate	SO4	9.00	0.188	2	
Carbonate	CO3				
Bicarbonate	HCO3	87.84	1.440	20	
Iron	Fe	0.03	0.002	0	
Chloride	Cl	10.92	0.308	3	
Salt Concentration (TDS)		170.02			
Hardness		80.35	1.627	18	
pH		7.80			
Conductivity (mmhos/cm)		0.27			
Boron	B				
Nitrate	NO3-N	1.83	0.130	0	
S.A.R.		0.46			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

SPARINGLY

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 199

JUNE 5, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON MO, 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: W1

Lab No.: 492 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	16.88	0.844	4	
Magnesium	Mg	11.88	0.990	3	
Potassium	K	0.63	0.016	0	
Sodium	Na	8.13	0.353	2	
Sulfate	SO4	4.50	0.094	1	
Carbonate	CO3				
Bicarbonate	HCO3	136.64	2.240	31	
Iron	Fe	0.03	0.002	0	
Chloride	Cl	10.92	0.308	3	
Salt Concentration (TDS)		163.48			
Hardness		90.95	1.835	21	
pH		7.70			SPARINGLY
Conductivity (mmhos/cm)		0.26			
Boron	B				
Nitrate	NO3-N	0.76	0.054	0	
S.A.R.		0.37			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 309

JUNE 5, 2009

WATER REPORT

KINSEY AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: W2

Lab No.: 493		Parts per million - p.p.m.			
			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	93.13	4.656	21	UNSUITABLE
Magnesium	Mg	75.00	6.250	17	
Potassium	K	0.63	0.016	0	
Sodium	Na			0	
Sulfate	SO4	79.50	1.656	18	
Carbonate	CO3				
Bicarbonate	HCO3	434.32	7.120	100	
Iron	Fe	0.02	0.001	0	
Chloride	Cl	40.03	1.129	9	
Salt Concentration (TDS)		640.83			
Hardness		540.87	10.907	124	
pH		7.30			SPARINGLY
Conductivity (mmhos/cm)		1.00			SPARINGLY
Boron	B				
Nitrate	NO3-N	14.07	1.005	3	
S.A.R.					
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				
TOTAL CHLORINE mg/L					
TOTAL SUSPENDED SOLIDS mg/L					
Equivalent lbs of lime per 12" of irrigated water				982	

JUNE 5, 2009

WATER REPORT

KINSEY AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: W3

Lab No.: 494		Parts per million - p.p.m.			Irrigation Use
			meq/L	lbs/acre-inch	
Calcium	Ca	27.50	1.375	6	SPARINGLY
Magnesium	Mg	18.13	1.510	4	
Potassium	K	0.63	0.016	0	
Sodium	Na	9.38	0.408	2	
Sulfate	SO4	6.00	0.125	1	
Carbonate	CO3				
Bicarbonate	HCO3	185.44	3.040	43	
Iron	Fe	0.05	0.003	0	
Chloride	Cl	13.34	0.376	3	
Salt Concentration (TDS)		209.25			
Hardness		143.17	2.888	33	SPARINGLY
pH		7.70			
Conductivity (mmhos/cm)		0.33			
Boron	B				
Nitrate	NO3-N	1.39	0.099	0	
S.A.R.		0.34			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				
TOTAL CHLORINE mg/L					
TOTAL SUSPENDED SOLIDS mg/L					
Equivalent lbs of lime per 12" of irrigated water				419	

JUNE 5, 2009

WATER REPORT

KINSEYS AGRICUTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: W4 - ID7082

Lab No.: 495		Parts per million - p.p.m.			Irrigation Use
			meq/L	lbs/acre-inch	
Calcium	Ca	73.13	3.656	17	SPARINGLY
Magnesium	Mg	47.50	3.958	11	
Potassium	K	0.63	0.016	0	
Sodium	Na	16.25	0.707	4	
Sulfate	SO4	45.00	0.938	10	
Carbonate	CO3				
Bicarbonate	HCO3	346.48	5.680	80	
Iron	Fe	0.09	0.005	0	
Chloride	Cl	19.41	0.547	4	
Salt Concentration (TDS)		470.82			
Hardness		377.83	7.619	87	SPARINGLY
pH		7.70			
Conductivity (mmhos/cm)		0.74			
Boron	B				
Nitrate	NO3-N	9.20	0.657	2	
S.A.R.		0.37			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				
TOTAL CHLORINE mg/L					
TOTAL SUSPENDED SOLIDS mg/L					
Equivalent lbs of lime per 12" of irrigated water				783	

JUNE 5, 2009

WATER REPORT

KINSEY AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: W5 - ID7083

Lab No.: 496		Parts per million - p.p.m.			
			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	20.63	1.031	5	
Magnesium	Mg	11.25	0.938	3	
Potassium	K	0.63	0.016	0	
Sodium	Na	7.50	0.326	2	
Sulfate	SO4	3.00	0.063	1	
Carbonate	CO3				
Bicarbonate	HCO3	131.76	2.160	30	
Iron	Fe	0.06	0.003	0	
Chloride	Cl	14.56	0.411	3	
Salt Concentration (TDS)		143.86			
Hardness		97.73	1.972	22	
pH		7.70			SPARINGLY
Conductivity (mmhos/cm)		0.22			
Boron	B				
Nitrate	NO3-N	0.61	0.044	0	
S.A.R.		0.33			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				
TOTAL CHLORINE mg/L					
TOTAL SUSPENDED SOLIDS mg/L					
Equivalent lbs of lime per 12" of irrigated water				298	

MAY 29, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON MO, 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: 2

Lab No.: 486 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	23.13	1.156	5	
Magnesium	Mg	16.25	1.354	4	
Potassium	K	0.63	0.016	0	
Sodium	Na	8.75	0.380	2	
Sulfate	SO4	4.50	0.094	1	
Carbonate	CO3				
Bicarbonate	HCO3	175.68	2.880	40	
Iron	Fe	0.04	0.002	0	
Chloride	Cl	9.70	0.274	2	
Salt Concentration (TDS)		189.63			
Hardness		124.54	2.513	29	
pH		7.70			SPARINGLY
Conductivity (mmhos/cm)		0.30			
Boron	B				
Nitrate	NO3-N	0.75	0.053	0	
S.A.R.		0.34			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 397

JUNE 5, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON MO, 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: 4

Lab No.: 487 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	45.00	2.250	10	
Magnesium	Mg	26.25	2.188	6	
Potassium	K	0.63	0.016	0	
Sodium	Na	11.25	0.489	3	
Sulfate	SO4	18.00	0.375	4	
Carbonate	CO3				
Bicarbonate	HCO3	175.68	2.880	40	
Iron	Fe	0.05	0.003	0	
Chloride	Cl	14.56	0.411	3	
Salt Concentration (TDS)		287.72			
Hardness		220.24	4.440	51	
pH		7.70			SPARINGLY
Conductivity (mmhos/cm)		0.45			
Boron	B				
Nitrate	NO3-N	4.66	0.333	1	
S.A.R.		0.33			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 397

JUNE 5, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON MO, 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: 5

Lab No.: 488 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	111.25	5.563	26	UNSUITABLE
Magnesium	Mg	79.38	6.615	18	UNSUITABLE
Potassium	K	0.63	0.016	0	
Sodium	Na	19.38	0.842	4	
Sulfate	SO4	211.50	4.406	49	
Carbonate	CO3				
Bicarbonate	HCO3	375.76	6.160	86	
Iron	Fe	0.02	0.001	0	
Chloride	Cl	27.90	0.787	6	
Salt Concentration (TDS)		745.46			
Hardness		604.08	12.178	139	
pH		7.50			SPARINGLY
Conductivity (mmhos/cm)		1.16			SPARINGLY
Boron	B				
Nitrate	NO3-N	19.93	1.424	5	
S.A.R.		0.34			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 849

JUNE 5, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON MO, 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: 6

Lab No.: 489 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	29.38	1.469	7	
Magnesium	Mg	10.63	0.885	2	
Potassium	K	0.63	0.016	0	
Sodium	Na	7.50	0.326	2	
Sulfate	SO4	4.50	0.094	1	
Carbonate	CO3				
Bicarbonate	HCO3	126.88	2.080	29	
Iron	Fe	0.04	0.002	0	
Chloride	Cl	13.34	0.376	3	
Salt Concentration (TDS)		143.86			
Hardness		116.98	2.356	27	
pH		7.70			SPARINGLY
Conductivity (mmhos/cm)		0.22			
Boron	B				
Nitrate	NO3-N	0.59	0.042	0	
S.A.R.		0.30			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 287

JUNE 5, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON MO, 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: 7

Lab No.: 490 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	85.00	4.250	20	UNSUITABLE
Magnesium	Mg	64.38	5.365	15	
Potassium	K	1.25	0.032	0	
Sodium	Na	18.13	0.788	4	
Sulfate	SO4	63.00	1.313	14	
Carbonate	CO3				
Bicarbonate	HCO3	356.24	5.840	82	
Iron	Fe	0.04	0.002	0	
Chloride	Cl	55.80	1.574	13	
Salt Concentration (TDS)		627.76			
Hardness		476.89	9.617	110	
pH		7.30			SPARINGLY
Conductivity (mmhos/cm)		0.98			SPARINGLY
Boron	B				
Nitrate	NO3-N	18.47	1.319	4	
S.A.R.		0.36			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 805

JUNE 5, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON MO, 63834

SUBMITTED FOR: **KIMMELSHUE ORCHARDS**

SAMPLE: 8

Lab No.: 491 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	22.50	1.125	5	
Magnesium	Mg	13.75	1.146	3	
Potassium	K	0.63	0.016	0	
Sodium	Na	8.13	0.353	2	
Sulfate	SO4	4.50	0.094	1	
Carbonate	CO3				
Bicarbonate	HCO3	156.16	2.560	36	
Iron	Fe	0.03	0.002	0	
Chloride	Cl	12.13	0.342	3	
Salt Concentration (TDS)		176.56			
Hardness		112.69	2.272	26	
pH		7.70			SPARINGLY
Conductivity (mmhos/cm)		0.28			
Boron	B				
Nitrate	NO3-N	0.82	0.059	0	
S.A.R.		0.33			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 353

SEPTEMBER 14, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KAS KIMMELSHUE ORCHARDS**

SAMPLE: W1- 8795

Lab No.: 355 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	91.25	4.563	21	UNSUITABLE
Magnesium	Mg	70.63	5.885	16	
Potassium	K	0.63	0.016	0	
Sodium	Na	12.50	0.543	3	
Sulfate	SO4	195.00	4.063	45	
Carbonate	CO3				
Bicarbonate	HCO3	307.44	5.040	71	
Iron	Fe	0.05	0.003	0	
Chloride	Cl	23.05	0.650	5	
Salt Concentration (TDS)		640.83			
Hardness		518.19	10.451	119	
pH		7.30			SPARINGLY
Conductivity (mmhos/cm)		1.00			SPARINGLY
Boron	B				
Nitrate	NO3-N	17.93	1.281	4	
S.A.R.		0.24			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				
TOTAL CHLORINE mg/L					
TOTAL SUSPENDED SOLIDS mg/L					
Equivalent lbs of lime per 12" of irrigated water				695	

SEPTEMBER 14, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
 297 COUNTY HIGHWAY 357
 CHARLESTON, MO 63834

SUBMITTED FOR: **KAS- KIMMELSHUE ORCHARDS**

SAMPLE: W2- 8796

Lab No.: 356		Parts per million - p.p.m.			
			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	106.25	5.313	24	UNSUITABLE
Magnesium	Mg	83.75	6.979	19	UNSUITABLE
Potassium	K	0.63	0.016	0	
Sodium	Na	13.75	0.598	3	
Sulfate	SO4	135.00	2.813	31	
Carbonate	CO3				
Bicarbonate	HCO3	448.96	7.360	103	
Iron	Fe	0.04	0.002	0	
Chloride	Cl	37.60	1.061	9	
Salt Concentration (TDS)		693.15			
Hardness		609.61	12.294	140	
pH		7.20			SPARINGLY
Conductivity (mmhos/cm)		1.08			SPARINGLY
Boron	B				
Nitrate	NO3-N	14.20	1.014	3	
S.A.R.		0.24			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				
TOTAL CHLORINE mg/L					
TOTAL SUSPENDED SOLIDS mg/L					
Equivalent lbs of lime per 12" of irrigated water				1015	

SEPTEMBER 14, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KAS- KIMMELSHUE ORCHARDS**

SAMPLE: W3- 8798

Lab No.: 357 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	60.00	3.000	14	
Magnesium	Mg	41.88	3.490	10	
Potassium	K	0.63	0.016	0	
Sodium	Na	9.38	0.408	2	
Sulfate	SO4	49.50	1.031	11	
Carbonate	CO3				
Bicarbonate	HCO3	234.24	3.840	54	
Iron	Fe	0.08	0.004	0	
Chloride	Cl	36.39	1.027	8	
Salt Concentration (TDS)		444.66			
Hardness		321.95	6.494	74	
pH		7.40			SPARINGLY
Conductivity (mmhos/cm)		0.69			
Boron	B				
Nitrate	NO3-N	7.40	0.529	2	
S.A.R.		0.23			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 529

SEPTEMBER 14, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KAS- KIMMELSHUE ORCHARDS**

SAMPLE: W4- 8799

Lab No.: 358		Parts per million - p.p.m.			
			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	124.38	6.219	29	SPARINGLY-DO NOT ADD P FERT UNSUITABLE
Magnesium	Mg	91.25	7.604	21	
Potassium	K	0.63	0.016	0	
Sodium	Na	15.63	0.679	4	
Sulfate	SO4	136.50	2.844	31	
Carbonate	CO3				
Bicarbonate	HCO3	541.68	8.880	125	
Iron	Fe	0.01	0.001	0	
Chloride	Cl	25.47	0.719	6	
Salt Concentration (TDS)		771.62			
Hardness		685.68	13.823	158	
pH		7.40			SPARINGLY
Conductivity (mmhos/cm)		1.21			SPARINGLY
Boron	B				
Nitrate	NO3-N	19.00	1.357	4	
S.A.R.		0.26			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				
TOTAL CHLORINE mg/L					
TOTAL SUSPENDED SOLIDS mg/L					
Equivalent lbs of lime per 12" of irrigated water				1224	

SEPTEMBER 14, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KAS- KIMMELSHUE ORCHARDS**

SAMPLE: W5- 8800

Lab No.: 359 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	32.50	1.625	7	
Magnesium	Mg	21.25	1.771	5	
Potassium	K	0.63	0.016	0	
Sodium	Na	7.50	0.326	2	
Sulfate	SO4	15.00	0.313	3	
Carbonate	CO3				
Bicarbonate	HCO3	200.08	3.280	46	
Iron	Fe	0.01	0.001	0	
Chloride	Cl	12.13	0.342	3	
Salt Concentration (TDS)		215.79			
Hardness		168.50	3.396	39	
pH		7.70			SPARINGLY
Conductivity (mmhos/cm)		0.34			
Boron	B				
Nitrate	NO3-N	1.83	0.131	0	
S.A.R.		0.25			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 452

SEPTEMBER 14, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KAS- KIMMELSHUE ORCHARDS**

SAMPLE: A2- 8801

Lab No.: 360		Parts per million - p.p.m.			
			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	32.50	1.625	7	
Magnesium	Mg	21.88	1.823	5	
Potassium	K	0.63	0.016	0	
Sodium	Na	8.75	0.380	2	
Sulfate	SO4	10.50	0.219	2	
Carbonate	CO3				
Bicarbonate	HCO3	200.08	3.280	46	
Iron	Fe	0.01	0.001	0	
Chloride	Cl	7.28	0.205	2	
Salt Concentration (TDS)		215.79			
Hardness		171.07	3.448	39	
pH		7.80			
Conductivity (mmhos/cm)		0.34			
Boron	B				
Nitrate	NO3-N	1.62	0.116	0	
S.A.R.		0.29			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				
TOTAL CHLORINE mg/L					
TOTAL SUSPENDED SOLIDS mg/L					
Equivalent lbs of lime per 12" of irrigated water				452	

SPARINGLY

SEPTEMBER 14, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KAS- KIMMELSHUE ORCHARDS**

SAMPLE: A4- 8802

Lab No.: 361 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	55.00	2.750	13	
Magnesium	Mg	36.88	3.073	8	
Potassium	K	0.63	0.016	0	
Sodium	Na	10.00	0.435	2	
Sulfate	SO4	46.50	0.969	11	
Carbonate	CO3				
Bicarbonate	HCO3	248.88	4.080	57	
Iron	Fe	0.04	0.002	0	
Chloride	Cl	10.92	0.308	3	
Salt Concentration (TDS)		353.11			
Hardness		288.91	5.825	66	
pH		7.70			SPARINGLY
Conductivity (mmhos/cm)		0.55			
Boron	B				
Nitrate	NO3-N	6.27	0.448	1	
S.A.R.		0.26			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 562

SEPTEMBER 14, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KAS- KIMMELSHUE ORCHARDS**

SAMPLE: A5X- 8803

Lab No.: 362		Parts per million - p.p.m.			
			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	158.13	7.906	36	SPARINGLY-DO NOT ADD P FERT UNSUITABLE
Magnesium	Mg	118.13	9.844	27	
Potassium	K	0.63	0.016	0	
Sodium	Na	22.50	0.978	5	
Sulfate	SO4	435.00	9.063	100	
Carbonate	CO3				
Bicarbonate	HCO3	209.84	3.440	48	
Iron	Fe	0.01	0.001	0	
Chloride	Cl	41.24	1.163	9	
Salt Concentration (TDS)		1307.83			
Hardness		880.44	17.751	203	
pH		7.20			SPARINGLY
Conductivity (mmhos/cm)		2.04			SPARINGLY
Boron	B				
Nitrate	NO3-N	26.40	1.886	6	
S.A.R.		0.33			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				
TOTAL CHLORINE mg/L					
TOTAL SUSPENDED SOLIDS mg/L					
Equivalent lbs of lime per 12" of irrigated water				474	

SEPTEMBER 14, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KAS- KIMMELSHUE ORCHARDS**

SAMPLE: A6- 8804

Lab No.: 363 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	24.38	1.219	6	
Magnesium	Mg	16.88	1.406	4	
Potassium	K	0.63	0.016	0	
Sodium	Na	6.88	0.299	2	
Sulfate	SO4	10.50	0.219	2	
Carbonate	CO3				
Bicarbonate	HCO3	141.52	2.320	33	
Iron	Fe	0.01	0.001	0	
Chloride	Cl	7.28	0.205	2	
Salt Concentration (TDS)		183.10			
Hardness		130.23	2.626	30	
pH		7.70			SPARINGLY
Conductivity (mmhos/cm)		0.29			
Boron	B				
Nitrate	NO3-N	1.16	0.083	0	
S.A.R.		0.26			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				

TOTAL CHLORINE mg/L

TOTAL SUSPENDED SOLIDS mg/L

Equivalent lbs of lime per 12" of irrigated water 320

SEPTEMBER 14, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KAS- KIMMELSHUE ORCHARDS**

SAMPLE: A7- 8805

Lab No.: 364		Parts per million - p.p.m.			
			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	95.63	4.781	22	UNSUITABLE
Magnesium	Mg	69.38	5.781	16	
Potassium	K	0.63	0.016	0	
Sodium	Na	13.13	0.571	3	
Sulfate	SO4	96.00	2.000	22	
Carbonate	CO3				
Bicarbonate	HCO3	366.00	6.000	84	
Iron	Fe	0.03	0.002	0	
Chloride	Cl	46.09	1.300	11	
Salt Concentration (TDS)		640.83			
Hardness		523.96	10.564	121	
pH		7.20			SPARINGLY
Conductivity (mmhos/cm)		1.00			SPARINGLY
Boron	B				
Nitrate	NO3-N	17.60	1.257	4	
S.A.R.		0.25			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				
TOTAL CHLORINE mg/L					
TOTAL SUSPENDED SOLIDS mg/L					
Equivalent lbs of lime per 12" of irrigated water				827	

SEPTEMBER 14, 2009

WATER REPORT

KINSEY'S AGRICULTURAL SERVICES
297 COUNTY HIGHWAY 357
CHARLESTON, MO 63834

SUBMITTED FOR: **KAS- KIMMELSHUE ORCHARDS**

SAMPLE: A8- 8806

Lab No.: 365 Parts per million - p.p.m.

			meq/L	lbs/acre-inch	Irrigation Use
Calcium	Ca	35.00	1.750	8	
Magnesium	Mg	19.38	1.615	4	
Potassium	K	0.63	0.016	0	
Sodium	Na	8.13	0.353	2	
Sulfate	SO4	10.50	0.219	2	
Carbonate	CO3				
Bicarbonate	HCO3	165.92	2.720	38	
Iron	Fe	0.03	0.002	0	
Chloride	Cl	8.49	0.240	2	
Salt Concentration (TDS)		196.17			
Hardness		167.01	3.366	38	
pH		7.80			SPARINGLY
Conductivity (mmhos/cm)		0.31			
Boron	B				
Nitrate	NO3-N	1.41	0.100	0	
S.A.R.		0.27			
Ammonia	NH3-N				
Phosphorus	P				
Copper	Cu				
Manganese	Mn				
Zinc	Zn				
TOTAL CHLORINE mg/L					
TOTAL SUSPENDED SOLIDS mg/L					
Equivalent lbs of lime per 12" of irrigated water				375	