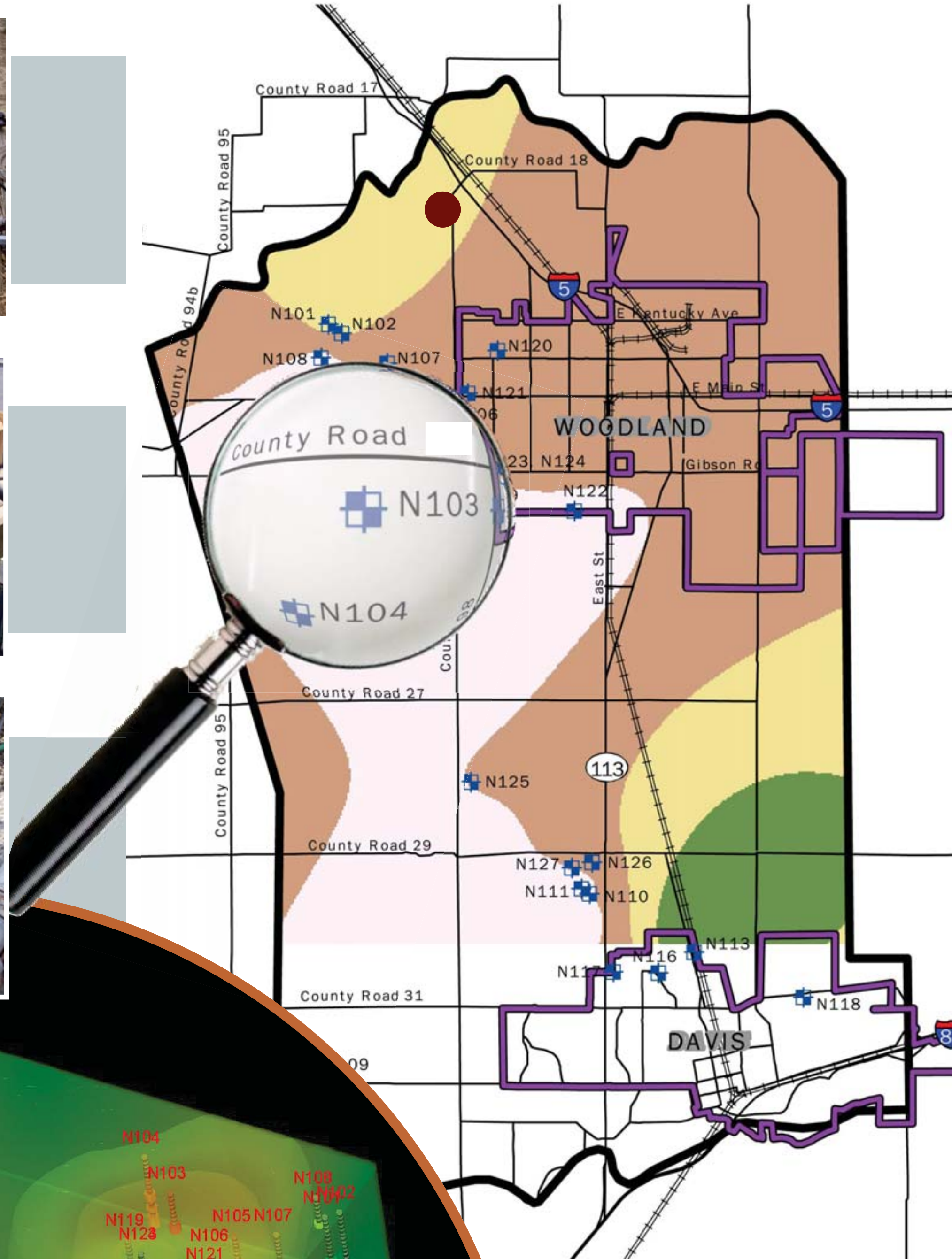
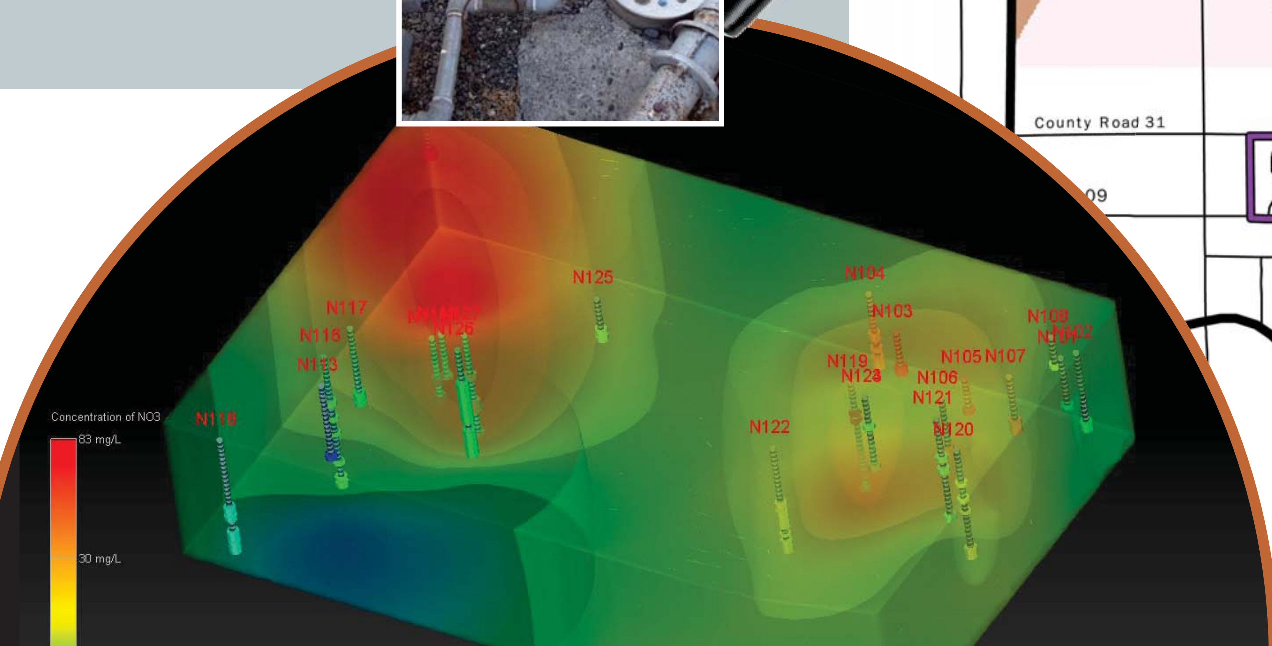
Brown AND Caldwell

Prepared for and in conjunction with
Yolo County Flood Control and Water Conservation District
Woodland, CA

Regional Conjunctive Use Enhancement: Nitrate Fingerprinting and Groundwater Age Determination Study

December 2012





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Brown and Caldwell
Project No. 139720

Yolo County Flood Control and Water Conservation District

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Regional Conjunctive Use Enhancement: Nitrate Fingerprinting and Groundwater Age Determination Study

ABSTRACT

Loading of nitrate to groundwater in Yolo County was estimated in a previous study to be 6.4 million pounds per year. Nine municipal wells have been lost by the cities of Davis and Woodland due to nitrate. Additionally, during 2007 – 2009, 232 drinking water wells were sampled by the Yolo County Health Department for nitrate, and 41 (18%) were found to be over the maximum nitrate health limit of 45 ppm (nitrate as NO3). Therefore, groundwater studies in Yolo County, near the cities of Davis and Woodland, CA, USA, were conducted to investigate nitrate sources (fingerprinting) and age of groundwater in order to better understand the sources, inputs, and timescales of nitrate in groundwater. Using chemical "fingerprinting" techniques, 24 wells were sampled. Fingerprinting determined that 83% of those wells had nitrate sources from chemical fertilizer and 17% from septic or manure sources. The age of groundwater was determined to be 20 to 40 years old for these wells, meaning that water from these wells was on the surface of the earth between 20 and 40 years ago. Horizontal flow of the groundwater was determined to be one mile every 13 years, on average, within the study area.

December 2012

Yolo County Flood Control and Water Conservation District
34274 State Highway 16
Woodland, CA 95695
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This study was funded by an AB303 Local Groundwater Assistance grant from the California Dept of Water Resources (DWR). Additional support was received from the Water Resources Association of Yolo County, the Cities of Davis and Woodland, the Yolo County Flood Control and Water Conservation District, the County of Yolo, and the DWR North Central Regional Office, Geology and Groundwater Investigations Section. A special thanks is given to the private well owners who allowed water quality samples to be taken from their wells.

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Acronyms and Abbreviations

bgs	below ground surface
bp	before present
CAFO	confined animal feeding operation
CDFA	California Department of Food and Agriculture
CDPR	California Department of Pesticide Regulation
CFCs	chloroflorocarbons
DWR	Department of Water Resources
EC	electrical conductivity, a measure of total salinity
EPA	Environmental Protection Agency
gpm	gallons per minute
IRWMP	Integrated Regional Water Management Plan
MCL	Maximum Contaminant Level
mg/L	milligrams per liter
PWS	public water system
SMOW	Standard Mean Ocean Water
TU	Tritium units
µg/L	micrograms per liter
WARMF	Watershed Analysis Risk Management Framework
WRID	Water Resources Information Database
WRIME	WRIME, Inc. consultants
YCIGSM	Yolo County Integrated Ground and Surface Model
YCFB	Yolo County Farm Bureau

Executive Summary

The Yolo County Integrated Regional Water Management Plan (IRWMP) (Yolo WRA, 2007) established actions and projects for improving water management in Yolo County. The first issue listed under the Water Quality section of the plan addressed nitrate:

"High nitrate levels in the drinking water wells of both cities and unincorporated communities that potentially present a risk to human health."

The study area encompasses eastern Yolo County between roughly the Plainfield Ridge on the west, County Road 102 on the east, Cache Creek on the north and Putah Creek on the south as shown in Figure ES-1. This area comprises the cities of Woodland and Davis, UC Davis, and the rural area of eastern Yolo County upgradient and between the urban areas.

In the Cities of Davis and Woodland, since October, 2011, nine municipal wells have been lost to elevated levels of nitrate. In Yolo County, between 2007 and 2009, all newly constructed private domestic wells were tested for nitrate, with 15% (18 of 117 wells) above the Maximum Contaminant Limit (MCL) of 45 mg/L nitrate. For the same time period, 115 Public Water Supplies (PWS) wells were monitored for nitrate in Yolo County with 20% above the MCL.

Other notable constituents of concern for public water supply systems in the area are total salts, boron, and selenium. These are naturally occurring constituents in groundwater that can affect beneficial uses of the water or that can affect wastewater discharge limits.

For the rural portion of the study area, the major sources of nitrogen would be expected to be fertilizers, manure, and crop residues, with possible localized pockets of loading from septic systems. For the urban portion of the study area, the sources of nitrogen could include those identified for the rural areas plus past use of septic systems.

ES 1.1 Use of Mineral Groundwater Quality Data for Source and Transport Evaluation

Water quality characteristics can be used to help determine the sources of the groundwater and the extents of an aquifer. Waters with similar qualities have a higher probability of being from similar recharge sources and/or geochemical zones within the aquifer. Minerals used in this study for groundwater source characterization include nitrate, total salinity (EC), hardness, boron, and selenium.

ES 1.2 Use of Isotope and Chlorofluorocarbon Data for Source and Transport Evaluation

ES 1.2.1 Nitrogen Fingerprinting

Nitrogen-15 (^{15}N) is a stable isotope of nitrogen that can be useful for determining the source and fate of nitrogen compounds in groundwater. The measured ratio of ^{15}N /^{14}N compared with the standard atmospheric ratio of ^{15}N /^{14}N provides $\delta^{15}N$. $\delta^{15}N$ tends to become enriched as a result of bacterial transformations, which makes the $\delta^{15}N$ for nitrate useful in identifying nitrogen sources and fate in the vadose zone and groundwater (Moetzer, 2006).

ES 1.2.2 Other Isotopes

Other useful isotopes for characterizing the apparent age and/or sources of groundwater include tritium (^3H), helium-3 (^3He), deuterium (^2H or D), and oxygen-18 (^{18}O).

ES 1.2.3 Chlorofluorocarbons

Chlorofluorocarbons (CFCs) are stable synthetic chemicals that were developed for use as refrigerants, solvents, and foam blowing gases. Production began in the 1940s. Groundwater dating with commercial compounds CFC-11, CFC-12, and CFC-113 is possible because the atmospheric mixing ratios of these compounds is known, the solubilities in water are known, and concentrations are high enough to be reliably measured (Plummer and Busenberg, 2012). Used together they provide a good tracer and dating tool for groundwater less than 50 years old.

ES 1.3 Previous Studies

In the East Yolo South subregion, the Yolo County Integrated Ground and Surface Model study (YCIGSM; WRIME, 2006) identifies groundwater supplying 103,497 acre-feet and surface water supplying 20,532 acre-feet of the 124,029 acre-feet of total annual demand. Therefore, most of the deep percolation in the East Yolo South subregion is from groundwater used for irrigation and precipitation. Over time, the predominant use of groundwater for irrigation will tend to increase salt concentrations in groundwater.

One of the main results of the CV-SALTS study (Larry Walker and Associates, 2010) found that nitrate loading to the aquifer (below near surface groundwater) occurred at 13,100 lbs per day (or 4.8 million lbs of nitrate per year as NO_3) in the Yolo Study area. The Yolo Study area (219,171 crop acres) is smaller than the total crop acres in Yolo County (293,284 crop acres, average from 1994-2009 from PUR database). Scaling up the loading based on the total crop acres of Yolo County would correspond to an annual loading of nitrate to the aquifer of 6.4 million lbs per year.

There are many sources of nitrate loading. The CV-SALTS study determined that 63% of nitrate loading to the near surface groundwater came from fertilizer land application, 17% from pumped groundwater used for irrigation, 17% from mineral weathering, and 3% from atmospheric deposition.

Additional studies that have contributed to the understanding in the areas are the Phase I and Phase II Deep Aquifer Studies (West Yost Associates, 1999; Brown and Caldwell, 2005), groundwater conceptual models, the YCFCWCD Groundwater Management Plan (YCFCWCD, 2006), and others described in the body of this report.

ES 1.4 Sampling and Analysis

Twenty-four shallow production and monitoring wells were sampled near and within the cities of Davis and Woodland. Surface water samples were also taken from Putah Creek and Cache Creek supply. The samples were analyzed for general minerals, EC, boron, and selenium. The samples were also analyzed for stable isotope ratios and CFCs for further characterization and age determinations. Samples from eight wells out of the 24 were also analyzed for tritium, helium-3, and noble gases to provide additional age dating and characterization for comparison with the CFC data.

ES 1.5 Results

The source of nitrate in groundwater (Table ES-1) was determined through a fingerprinting process using chemical isotope signatures and other process described in report Section 2.5. This fingerprinting method is subject to interpretation and is not intended to be a definitive guide. Groundwater is a constant mix of different sources of water and chemical constituents. However, the general trend in Table ES-1 shows that fertilizer sources of nitrate in groundwater dominate.

A summary of the source and fate of nitrate and the other constituents of concern for this study is provided in Table 5-2.

Table ES-1. Sources of nitrate in wells from the Woodland/Davis area, sampled fall 2011, as determined by the nitrate fingerprinting process described in report Section 2.5

Source of Nitrate	# of Wells	Percentage
Fertilizer	14	58%
Fertilizer / Natural Soil N mix	6	25%
Partial Animal (manure/septic)	3	13%
All Animal (manure/septic)	1	4%
Total Number of Wells	24	100%

The additional parameters used in the evaluation of groundwater recharge source in Table ES-1 were the nitrate concentration, CFC age, $\delta^{18}O$ (water), and hardness of water samples. Natural concentrations of nitrate would be expected to be relatively low in precipitation and stream runoff, differentiating those samples from samples indicating a fertilizer source of nitrate. The results for Davis #15 and the Davis F Street Shallow Well stood out from the other groundwater samples as mostly old water with some influence from deep percolation of manure or septic sources. Nitrate concentration contours are shown in Figure ES-2.

Nitrate concentrations are somewhat correlated with CFC apparent age of groundwater (see Figure ES-3), with younger water having higher concentrations of nitrate.

The correlation between nitrate and hardness values is high. This is another indication that high concentrations of nitrate in groundwater in the study area are likely associated with deep percolation from irrigated agriculture and turf areas.

Boron concentrations were also measured. As would be expected based on the sources of recharge water, the highest concentrations of boron are southwest of Woodland and the lowest concentrations are west of Davis. The high concentrations southwest of Woodland are undoubtedly due to the original source of groundwater in the area from Cache Creek and the evapoconcentration effect due to the predominant use of groundwater for irrigation in that area.

ES 1.6 Groundwater Flow Velocities

Estimates for horizontal and vertical groundwater flow velocities can be used to further characterize risks of groundwater well contamination from surface activities.

ES 1.6.4 Horizontal Flow Velocities

Table ES-2. Estimated Average Horizontal Groundwater Gradients and Velocities

Area	Gradient, [a] ft/ft	Est. Avg. Pore Velocity, ft/yr
Northwest of Davis	0.00380	411
North Central Davis	0.00113	122
Southwest of Woodland	0.00260	395
Northwest of Woodland	0.00155	235

[a] *Gradients based on averages of 2010 spring and fall values.*

Although there is a substantial amount of localized variability, groundwater could travel up to roughly 400 feet per year (a mile in 13 years) in the study area. Actual transport velocities for constituents of concern would vary based on dispersion, adsorption, and localized hydrogeologic factors. The potential for horizontal transport velocities of up to 400 feet per year highlights the particular risks for substantial amounts of nitrate in groundwater from agricultural areas to reach municipal wells near the southwest side of Woodland and the northwest side of Davis in less than a couple of decades after first reaching productive groundwater aquifer zones. This has already been seen dramatically in some of the Woodland wells.

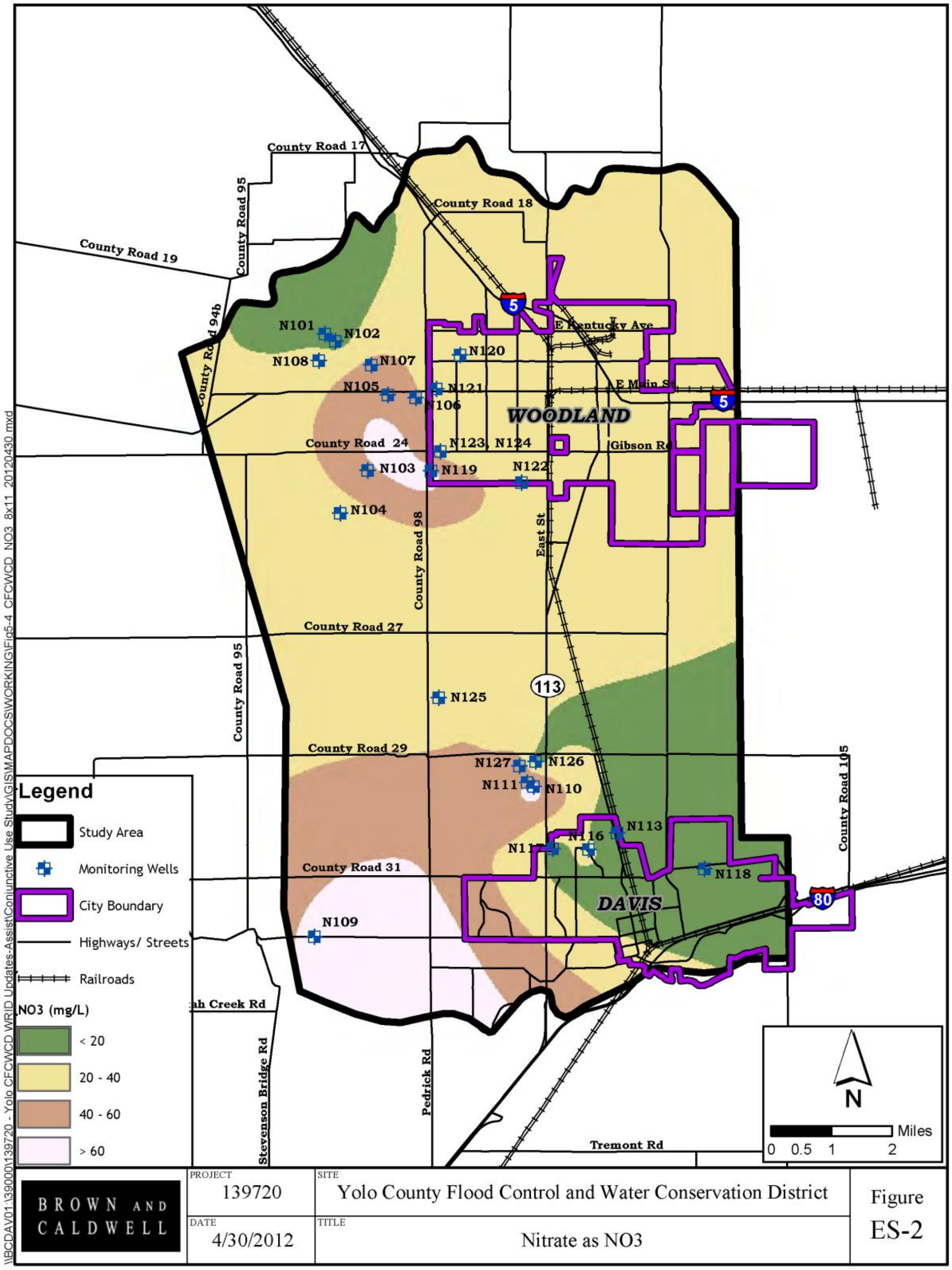


Figure ES-2. 2011 Nitrate Concentration Contours for Study Wells Listed In Table ES-1. (Contours were mapped for the entire study area, extrapolating into areas were no well sampling occurred. This extrapolation should be used for guidance only.)

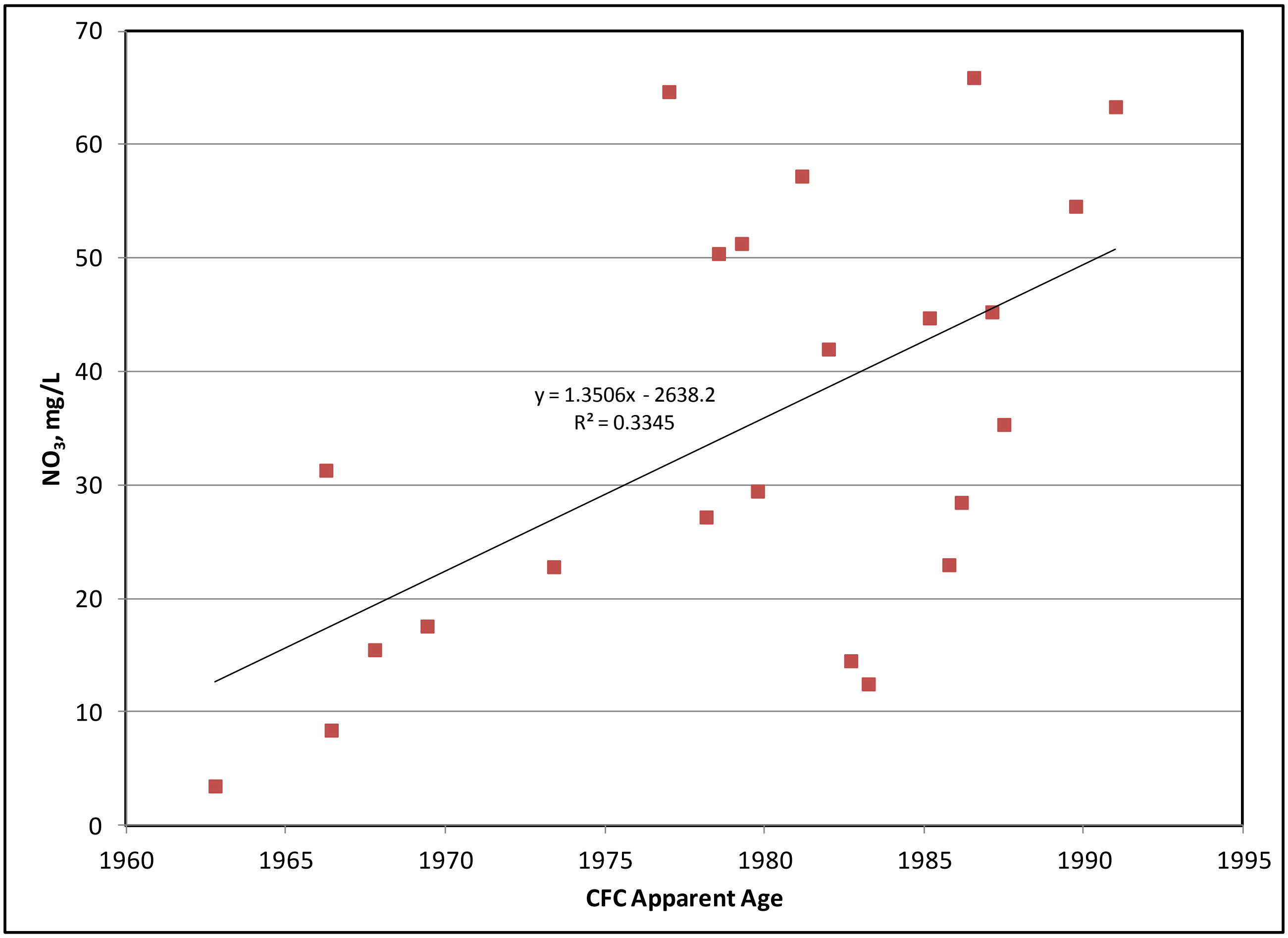


Figure ES-3. NO_3 vs. CFC Apparent Age for Study Wells Listed In Table ES-1

ES 1.6.5 Vertical Flow Velocities

Using estimates for deep percolation from the YCIGSM study (Yolo WRA, 2005) and an assumption of piston-type flow, the total vertical travel time to zones where wells are first screened would be roughly 40 years. With the more realistic assumption of preferential flow in larger pores, the leading edge of contamination at the ground surface could reach the first tapped groundwater zone in a couple of decades. The presence of improperly abandoned old shallow wells would further increase the rate of downward migration by providing flow conduits. Once contamination reaches the first zone tapped by a significant number of wells, it can rapidly migrate downward into deeper zones due to differential rates of pumping by season for different types of wells. Evidence of rapid vertical migration between screened aquifer zones is visible in the CFC apparent age where water from wells with a weighted average screen depth of 400 feet is only about 15 years older than water from wells with a weighted average screen depth of 150 feet (17 ft/year effective vertical travel time).

ES 1.7 Conclusions

ES 1.7.6 Sources of Groundwater Nitrate Contamination

Fertilizer applications to irrigated agricultural lands appear to be the greatest source of nitrate to groundwater in the study area, followed by soil nitrate from weathering and organic nitrogen mineralization. There appears to be some contribution of nitrogen to groundwater from manure or septic systems in north-central Davis and possibly a small amount northwest of Woodland in residential wells closest to Cache Creek.

ES 1.7.7 Water Quality Risks to Municipal Wells

Wells on the southwest side of Woodland appear to be the most affected by nitrate from agriculture and have the most risk of further contamination into deeper screened zones. Wells on the northwest side of Davis and in the Davis Golf Course and North Davis Meadows areas also have substantial risk of further nitrate contamination into deeper screened zones. The relatively greater first screen depth and average weighted screen depth for the Davis municipal wells appears to have slowed the rate of increase of nitrate concentrations in those wells compared to other wells in the study area. Wells further east in Davis appear to have groundwater that is more pristine and with less risk for nitrate contamination.

ES 1.7.8 Potential Effects of Conjunctive Use

Conjunctive use would increase the use of YCFCWCD (Cache Creek) water to recharge groundwater in the study area in most normal or wet years. The recharge effects would be positive in that the Cache Creek water used for recharge would have much lower nitrate and salinity concentrations than deep percolation from farmland, thereby diluting the nitrate and salts in groundwater over time. Increased groundwater pumping for extraction during dry periods would accelerate downward vertical movement of deep percolate, but this effect would be short term and more than offset by the benefits of the higher quality recharge during wetter conditions.

ES 1.7.9 Potential Actions to Reduce Risks to Municipal Water Wells

There are a number of actions that could potentially benefit water quality in municipal and other drinking water supply wells over the long term. Improved fertilization and irrigation practices have good promise for long term improvements. These are summarized in Table ES-3.

Table ES-3. Potential Actions to Reduce Risks to Municipal Drinking Water Wells

ID	Potential Action	Benefit
1	Conjunctive Use	More recharge with better quality water
2	Lower Fertilizer Use Rates	Reduced nitrate in deep percolate
3	Drip Irrigation of Crops	Better fertilization control, reduced nitrate in deep percolate
4	Convert Row Crops to Trees	Could allow reduced fertilizer usage, especially as trees mature
5	Complete Ag Wells in Shallower Zones Only	Would reduce downward movement of nitrate and salts to zones tapped by municipalities
6	New Deep Wells in Woodland	No nitrate, selenium, or chromium
7	Properly Destroy Abandoned Wells	Reduce vertical flow paths for contamination

Section 1

Introduction

The Yolo County Integrated Regional Water Management Plan (IRWMP) (Wood Rodgers, 2007) established actions and projects for improving water management in Yolo County. The first issue listed under the Water Quality section of the plan addressed nitrate:

"High nitrate levels in the drinking water wells of both cities and unincorporated communities that potentially present a risk to human health."

This issue resulted in recommended action WQ8 in the IRWMP, which described a countywide study of sources and trends associated with nitrate contamination. The objective was to identify ways to stop or slow the spread of contamination before municipalities have to close wells. Elevated levels of salts and boron were also identified as water quality issues in the IRWMP.

The IRWMP also discussed the potential importance of YCFCWCD's Comprehensive Conjunctive Water Use Program (designated as WS16) to enable enhanced storage of water in aquifers and improved drought protection. Understanding the fate of nitrates, salts, and other constituents is important for evaluating whether conjunctive use would have adverse water quality impacts.

The overall objective of this study was to provide foundational data in support of recommended actions WQ8 and WS16 in the IRWMP. The focus of this study was the use of water quality and isotope data from wells near and in the cities of Davis and Woodland to evaluate contaminant sources, prevalence, fate, and transport. Salinity, boron, and selenium were also evaluated as constituents of concern for municipal water supply wells.

1.1 Study Area

The study area encompasses eastern Yolo County, roughly between the Plainfield Ridge on the west, County Road 102 on the east, Cache Creek on the north and Putah Creek on the south as shown in Figure 1-1. This area comprises the cities of Woodland and Davis, UC Davis, and the rural area of eastern Yolo County upgradient and between the urban areas. The Plainfield Ridge was chosen as the western boundary of the study area because it provides an impediment to groundwater flow from areas further west. Willow Slough is the major west-to-east drainage way through the middle of the study area between Putah Creek and Cache Creek. Hydrologic subregions as defined in the Yolo County Integrated Ground and Surface Water Model (YCIGSM; WRIME, 2006) Study are also shown on Figure 1-1.

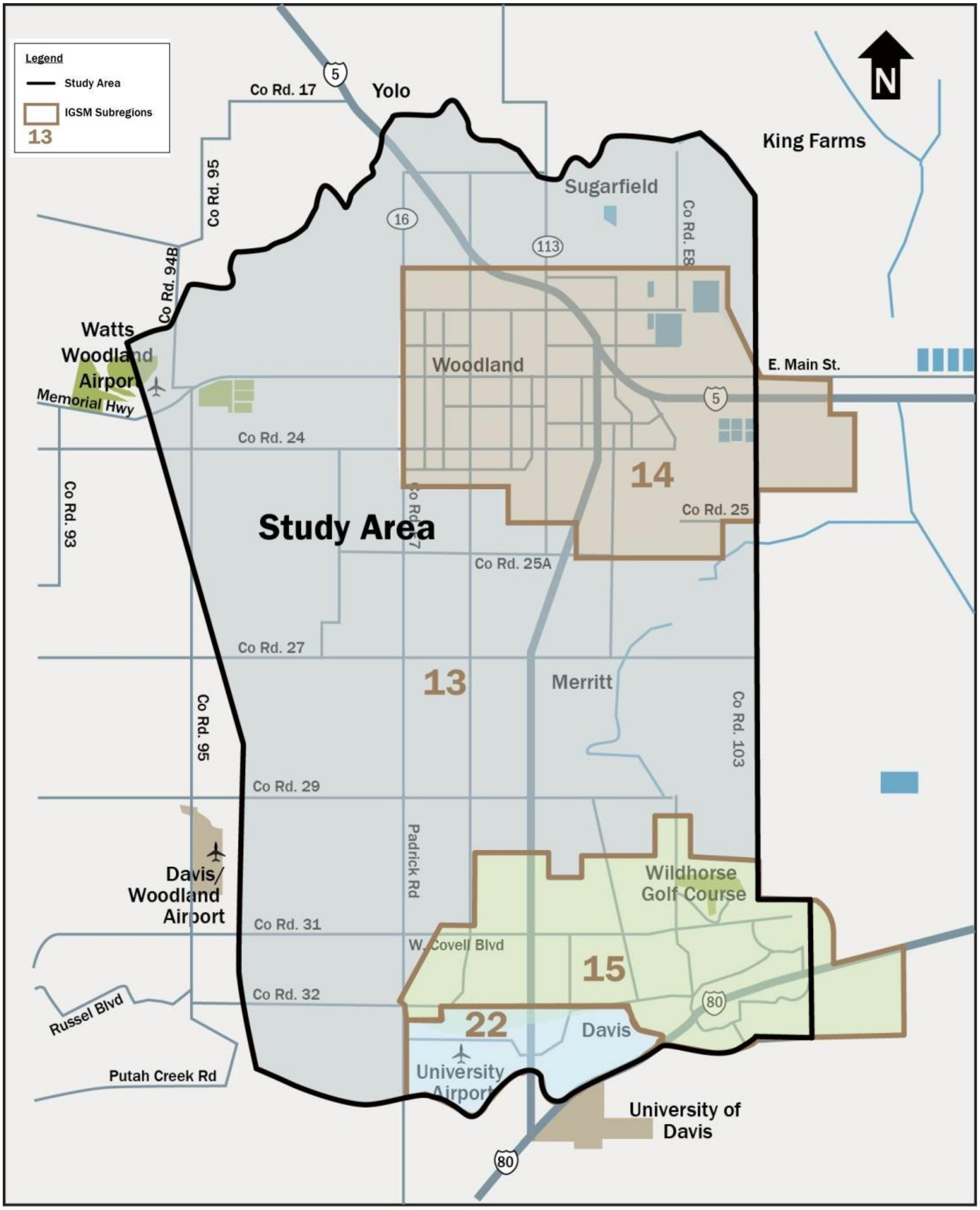


Figure 1-1. Study Area Boundaries and YCIGSM Subregions

Section 2

Background

2.1 Groundwater Nitrate and Other Mineral Quality Concerns

The concentration of nitrate in groundwater wells in Yolo County has been on a generally upward trend. Trends for shallow, intermediate depth, and deep wells near Davis are shown in Figure 2-1.

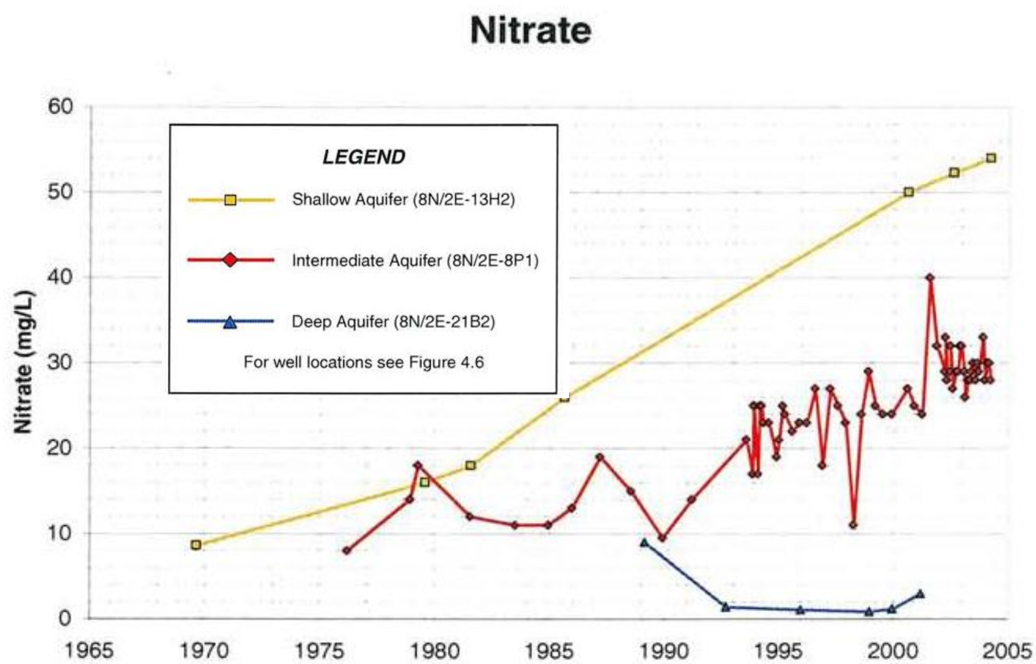


Figure 2-1. Trends of Rising Nitrate in Three Example Wells near Davis, CA

Notes: The blue line is a deep well, more than 600 feet deep. Data from YCFCWCD GWMP (2006).

The Yolo County Department of Public Health requires a one-time nitrate test when a new well is constructed. From March 31, 2007 to July 28, 2009, 117 well construction permits were issued for private, non-public water system drinking water wells in Yolo County. New irrigation wells do not require a test. During this time, 15% (18) of these newly drilled wells produced water exceeding the MCL of 45 mg/L nitrate as nitrate. Forty-one wells, or 35%, were above 22.5 mg/L nitrate, more than halfway to the MCL.

The Yolo County Department of Public Health also requires regular testing of public water system (PWS) wells for nitrate. During this time period, 346 samples were taken from 115 individual PWS systems. Samples were tested at the same Monterey County lab as the non-PWS wells using the same methods. Twenty percent of wells had samples above the MCL for nitrate. Forty-nine, or 43% of wells, were above the halfway point of 22.5 mg/L nitrate. These data were supplied by the Monterey County Health

Department Laboratory, which does the testing for Yolo County. The data were summarized for this study.

The Cities of Davis and Woodland have or will abandon 10 wells due to excessive nitrate contamination (Table 2.1). Based on the recent trends in private and public wells, groundwater nitrate concentrations are clearly a major concern in Yolo County.

Table 2-1. Municipal wells lost in the Cities of Davis and Woodland.

Well ID	Date	Reason
Davis 16	1998	High Nitrate
Davis 18	1999	High Nitrate
Davis EM 2	2008	High Nitrate
Woodland 9	2009	High Nitrate
Woodland 17	2011	High Nitrate, pumps to waste @ 42 mg/l
Woodland 6	future	planned to retire because of High Nitrate
Woodland 19	future	planned to retire because of High Nitrate
Woodland 22	2010	High Nitrate
Woodland 15	2010	High EC and screen failure
Woodland 10	future	planned to retire because of High Nitrate

Other notable constituents of concern for public water supply systems in the area are total salts, boron, and selenium. These are naturally occurring constituents in groundwater that can affect beneficial uses of the water or that affect the ability to meet wastewater discharge limits. Total salts affect the aesthetic quality of water and can be subject to wastewater discharge limits. Boron can adversely affect some crops and landscape plants. There are strict wastewater discharge limitations for selenium to surface waters (3.2 µg/L for Woodland, 4.4 µg/L for Davis). The cities of Davis and Woodland are considering alternative water supply sources partly because of the levels of these constituents in groundwater.

2.2 Well Construction Considerations

Well construction can have an effect on the potential pathways for contamination into a well and between screened zones. Residential wells are typically only sealed for the first 20 feet and are often screened beginning at less than 100 feet. Locally, agricultural wells are typically screened throughout all productive zones encountered from approximately 100 to 400 feet below ground surface. Intermediate depth municipal wells are sealed for at least 50 feet and then screened in intervals from approximately 150 to 500 feet below ground surface. Deep municipal wells are typically screened in intervals starting at 500 feet or deeper and sometimes extending down to almost 2,000 feet.

2.3 Sources of Groundwater Mineral Constituents of Concern

2.3.1 Nitrate

Nitrogen in the form of nitrate, ammonia, or urea is a major component of most synthetic fertilizers. Urea is mineralized to ammonia and ammonia is converted to nitrate by bacterial action in aerobic soils. Nitrate is susceptible to leaching from the soil profile into groundwater.

Other potential sources of nitrogen include manure, septic systems, and crop residues. Organic nitrogen from these sources tends to be mineralized more slowly over time than synthetic fertilizers. Rainfall and water in streams can also have low concentrations of nitrogen. Groundwater used for irrigation may contain previously leached nitrate.

For the rural portion of the study area, the major sources of nitrogen would be expected to be fertilizers, manure, and crop residues, with possible localized pockets of loading from septic systems. For the urban portion of the study area, the sources of nitrogen could include those identified for the rural areas plus past use of septic systems.

2.3.2 Salinity

Salts are brought into the study area by the streams and by the irrigation canals carrying water from Cache Creek. Salts are concentrated in groundwater due to evapoconcentration of applied irrigation water plus additional contact with sediments as deep percolate travels to groundwater and as groundwater travels to wells. Fertilization also adds some salinity to soils, and wastewater contains salts added by domestic use.

2.3.3 Boron

Boron is a naturally occurring element in groundwater in the study area. Its source in Yolo County is runoff from the Coast Range. In Cache Creek, the main source of Boron is the Bear Creek tributary (Stevenson, 2006). Boron concentrations in the Sacramento River, Cache Creek and Putah Creek range from 30 to 100 µg/L, 700 to 2,200 µg/L, and 600 to 1,700 µg/L, respectively (Water Resources Association, 2005). Therefore, boron is a good indicator of the source of the recharge water to groundwater aquifers in the study area.

2.3.4 Selenium

Selenium is a naturally occurring element in the study area. Selenium concentrations in groundwater tend to be variable throughout the study area. The selenium concentrations found in many of the intermediate depth municipal wells in Woodland and Davis exceed the maximum allowable wastewater discharge standards for those cities.

2.4 Use of Mineral Groundwater Quality Data for Source and Transport Evaluation

Water quality characteristics can be used to help determine the sources of the groundwater and the extents of an aquifer. Waters with similar qualities have a higher probability of being from similar recharge sources and/or geochemical zones within the aquifer. The best chemical indicators are those that have a relatively low reactivity with aquifer materials. Other general water quality parameters can also be useful for characterizing groundwater.

2.4.1 Nitrate

High concentrations of nitrate in groundwater are an indication of leaching from agronomic or waste disposal land uses. Soils in the study area adsorb very little nitrate, allowing it to travel readily with percolate to groundwater.

2.4.2 Boron

Boron is a useful constituent for helping to determine the source of groundwater. As mentioned previously, Cache Creek has the highest average boron concentration, followed by Putah Creek, and then a much lower average concentration in water from the Sacramento River. Transport of boron through sediments can be slowed by the adsorption of boron mineral complexes on some types of clays.

2.4.3 Salinity and Hardness

Salts in irrigation water are concentrated in the soil because the water is lost by evapotranspiration and the minerals are mostly left behind. Because of this concentrating effect, deep percolate from irrigated areas carries more concentrated salts to groundwater. Deep percolate can also dissolve minerals from soils and sediments. Therefore, gradually increasing concentrations of salts in groundwater can be an indication of deep percolate from irrigated areas mixing with the pristine groundwater. Increased groundwater hardness can likewise be an indication of percolation from irrigated areas.

2.4.4 Other Individual Ions

Other individual ions such as sulfate, chloride, calcium, magnesium, and others can be used to evaluate groundwater source characteristics. The relative concentrations of different mineral ions in groundwater samples are often plotted to group and compare samples by common characteristics.

2.5 Use of Isotope and CFC Data for Source and Transport Evaluation

Isotopes and CFCs can be useful tools for determining age, source, and specific fate/history of waters. Radioactive isotopes can provide a method for dating groundwater by comparing the amounts of radioactive isotopes in a groundwater sample with estimates for the original amounts of the isotope when the water first entered the ground. CFCs, being a recent anthropogenic class of chemicals with known atmospheric concentrations, can be used in a similar manner as short-lived radioactive isotopes. Heavy stable isotopes tend to concentrate due to evaporation, biological reactions, and other conditions relative to their common lighter counterparts. This effect can be used to help determine the source and transformation history of these elements when analyzed in groundwater.

2.5.1 Tritium and Carbon-14

Radioactive isotopes such as tritium (^{3}H) or carbon-14 (^{14}C) can be used to determine the approximate age of a water sample. Carbon-14 has a long half-life and is most useful for dating water from prehistoric ages. Carbon-14 was used to date the mostly pristine groundwater samples taken in the Phase I and Phase II Deep Aquifer Studies.

Tritium has a short half-life of 12.3 years, allowing it to be used for determining the approximate age of water that has recently percolated to groundwater. Bomb-produced tritium from the 1950s and early 1960s can be used as a tracer in studying young groundwaters to help determine flow rates, directions, and mean residence times. It can also be helpful in observing preferential flow paths and in investigating the mixing of waters.

The use of tritium for groundwater aging is somewhat limited by uneven global distribution and local variations due to continued nuclear releases. One approach used to improve the accuracy of tritium analysis for groundwater dating is to include the analysis of its daughter product, 3He, and other noble gases.

2.5.2 Stable Isotopes of Hydrogen and Oxygen

Stable isotopes of hydrogen (deuterium or D) and oxygen (^{18}O) are integral parts of the water molecule that provide a characteristic signature for groundwater that is unaffected by chemical reactions with aquifer materials. Stable isotopes can be used to estimate the approximate age of water and to identify waters that have similar origins.

^{18}O and deuterium (D) data are normalized to Standard Mean Ocean Water (SMOW) by comparing the ratios of $^{18}O/^{16}O$ and D/H ratios of the unknown water to the $^{18}O/^{16}O$ and D/H ratios of SMOW. The oxygen and deuterium normalized ratios are reported as $\delta^{18}O$ and δD, respectively, in parts per thousand (‰ or per mil).

As water changes phase, the heavy isotopes will generally prefer to be in the most stable phase. For example, in evaporation, the heavier isotope is more likely to remain behind in the liquid phase. When water condenses, the heavier isotope is prone to go into the liquid phase rather than remain in the vapor phase. Also, when water freezes, the heavier isotopes would concentrate in the ice. These effects are more pronounced in $H_2{}^{18}O$ versus $H_2{}^{16}O$ rather than DHO versus H_2O because of the larger differences in molecular weight. Greater positive deviations in $\delta^{18}O$ will reflect water that has had a history of greater evaporation.

2.5.3 Nitrogen-15

^{15}N is a stable isotope of nitrogen that can be useful for determining the source and fate of nitrogen compounds in groundwater. The ratio of $^{15}N/^{14}N$ compared with the standard atmospheric ratio provides $\delta^{15}N$. $\delta^{15}N$ tends to become enriched as a result of bacterial transformations, which makes the

$\delta^{15}N$ for nitrate useful in identifying nitrogen sources and fate in the vadose zone and groundwater (Moetzer, 2006). Rolston et al (1996) presented comparative data for $\delta^{15}N$ values from the vadose zone and groundwater under sites with differing nitrogen sources in the Davis and Salinas areas. Combining the analysis of $\delta^{15}N$ (of nitrate) with $\delta^{18}O$ (of nitrate) and with other isotopic methods for the water can help fingerprint the original source of the nitrate. However, nitrate derived from ammonium fertilizer, soil organic matter, and animal manure have overlapping $\delta^{18}O$ values such that $\delta^{18}O$ does not help differentiate those sources.

2.5.4 CFCs

Chlorflourocarbons (CFCs) are stable synthetic chemicals that were developed for use as refrigerants, solvents, and foam blowing gases. Production began in the 1940s. Groundwater dating with commercial compounds CFC-11, CFC-12, and CFC-113 is possible because the atmospheric mixing ratios of these compounds is known, the solubilities in water are known, and concentrations are high enough to be reliably measured (Plummer and Busenberg, 2012). Used together they provide a good tracer and dating tool for groundwater less than 50 years old. An example of the use of CFC dating along with $\delta^{15}N$ and NO_3 data is shown in Figure 2-2 for a Maryland site.

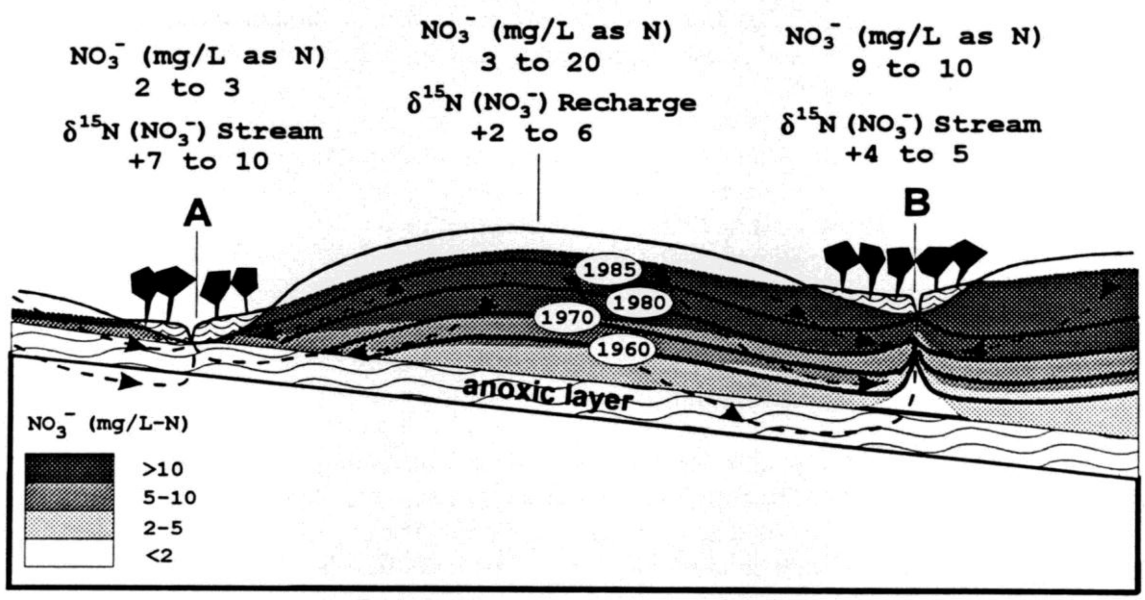


Figure 16.5. Schematic cross-section through an agricultural catchment in the Delmarva Peninsula, Maryland (USA) showing the increase in age of waters (solid lines, based on CFC data) and decrease in nitrate concentration with depth (shaded zones). Flowlines (dashed) to stream A are more shallow than the flowlines to stream B, intersect the riparian zone, and many flowlines are within the anoxic bedrock unit; hence, enchanced denitrification along the flowlines contributing to stream A results in lower nitrate concentrations and higher $\delta^{15}N$ values than in stream B. Modified from Böhlke and Denver (1995).

Figure 2-2. Example Usage of CFC Age and $\delta^{15}N$ Values

Source: http://wwwrcamnl.wr.usgs.gov/isoig/isopubs/Fig16-5.jpg

Section 3

Previous Groundwater Studies

3.1 Yolo County Integrated Ground and Surface Water Model

The most thorough recent study of groundwater flow and transport in Yolo County was performed for the development of the Integrated Ground and Surface Water Model (YCIGSM; WRIME, 2006). The YCIGSM study assembled and incorporated data from all previous major hydrology and groundwater studies into a single study and model. The model was used to evaluate the interaction between surface water and groundwater on a large scale.

The YCIGSM Study divided Yolo County up into 22 subregions. The relevant YCIGSM subregions for this current study were the East Yolo South, Woodland, Davis, and UCD (Yolo) subregions, whose boundaries were shown on Figure 1-1. The geologic formations in these subregions are the recent alluvial deposits roughly 100 to 200 feet thick underlain by the upper and lower portions of the Tehama formation.

Intermediate depth water wells for Woodland and Davis principally tap the upper portion of the Tehama formation (up to 500' deep in Woodland, 700' deep in Davis). Some of the deeper Davis and UC Davis wells tap the lower portion of the Tehama formation.

According to the YCIGSM study, in the horizontal direction "groundwater flows most easily in the direction of fan growth, in a rough plain of deposition." In the vertical direction, "Groundwater … flows at a relatively slow rate because the groundwater must travel through layers of fine- and very fine- grained sediments that interfinger with the channel lenses of the coarser sands and gravels." The horizontal fan deposition in this study area follows the general west to east direction of flow for Cache Creek, Putah Creek, Willow Slough, and other local drainage ways.

The overall groundwater budget for each of the subregions is shown in Table 3-1. It is interesting to note that subsurface inflow into the subregion represents 60% of the groundwater pumping for Woodland and 57% for Davis.

In the East Yolo South subregion, the YCIGSM study identifies groundwater supplying 103,497 acre-feet and surface water supplying 20,532 acre-feet of the 124,029 acre-feet of total annual demand. Therefore, most of the deep percolation in the East Yolo South subregion is from groundwater used for irrigation and precipitation. Over time, the predominant use of groundwater for irrigation will tend to increase salt concentrations in groundwater.

Table 3-1. Groundwater Budget for Study Area (all values in ac. ft. / year for an average year)

Subregion	Deep Percolation	Gain from Stream	Recharge	Subsurface Inflow	Groundwater Pumping	Net Inflow
East Yolo South	61,351	41,340	266	3,303	-103,497	2,777
Woodland	10,964	0	0	14,374	-23,875	1,463
Davis	8,400	0	0	9,658	-16,961	1,097
UCD Yolo	2,686	0	0	403	-2,855	234

3.2 Annual Groundwater Monitoring

Water level monitoring is performed twice annually for representative wells by the YCFCWCD and more frequently by cities for their wells. This data is combined in the Yolo Water Resource Information Database (YCFCWCD, 2006). The groundwater hydraulic gradient can be estimated from those measurements.

3.3 Deep Aquifer Units Conceptual Model

A hydrogeologic conceptual model of the deep aquifer zone in the Davis area was developed in 2003 (Ludhorff and Scalmanini, 2003) and expanded north to include the Woodland area in 2005 (Ludhorff and Scalmanini, 2005). These studies provided insights on depositional patterns and groundwater flow directions in the middle to deeper portions of the Tehama formation.

3.4 Initial Stable Isotope Study

Groundwater samples were taken through Yolo County and analyzed for the stable isotopes of oxygen and hydrogen (Davisson and Chris, 1993). Recharged agricultural irrigation water was found to have enriched isotopic concentrations relative to local precipitation, $\delta^{18}O$ greater than -7.0‰, as a result of evaporation on the surface during application and some evaporation in the vadose zone (Davisson et al, 1993). Pristine, shallow groundwater in Yolo County reflects the isotopic concentrations of local rain. The deep groundwater, found below approximately 750 feet, has $\delta^{18}O$ less than or equal to -8.0‰ and δD less than or equal to -54‰. One result of the study in terms of groundwater flow was an estimate for horizontal infiltration from Putah Creek into the intermediate depth aquifer zone at a rate of 60 meters per year.

3.5 Phase I Deep Aquifer Study

The Phase I Deep Aquifer Study (West Yost Associates, 1999) evaluated data from previous reports, water quality data, pumping test results, and isotopic analyses to describe the characteristics of the deep (700' – 2,000') groundwater production zone in the Davis area.

The Phase I Deep Aquifer Study contained a summary of relevant chemical groundwater quality data from the City of Davis, UC Davis, and the California Department of Water Resources (DWR). Some of the data from the City included zone specific sampling from recently constructed deep wells. Distinct chemical characteristics of water from the Deep Aquifer included much lower values for hardness, nitrate, and selenium than water from shallower depths. The deeper waters were also found to have generally higher concentrations of sodium and, in some locations, higher concentrations of manganese and arsenic than the Intermediate Aquifer.

Isotopic data (D, ^{18}O, and ^{14}C) obtained in the Phase I Deep Aquifer showed that the isotopic characteristics of water from the Deep Aquifer were distinct from the characteristics of the shallower waters. Groundwater from the deeper aquifer zone was also found to have carbon-14 ages of approximately 10,000 – 20,000 years compared with water from the intermediate depth wells having ages of a few hundred to a few thousand years.

The Phase I study concluded that vertical interaction between aquifers at different depths takes place gradually, except where wells completed into multiple zones allows more rapid flow between those zones. The study results also suggested that meandering stream deposits comprised most of the productive aquifer zones rather than continuous "pancake" layers of aquifer material. Based on pumping tests, the transmissivity of the deep aquifer zone was estimated to be roughly 4,000 sq ft/d. The study also concluded that the groundwater production capacity of the deep aquifer zone was limited because of the highly confined nature of the productive aquifer zones.

3.6 Phase II Deep Aquifer Study

The Phase II Deep Aquifer Study (Brown and Caldwell, 2005) utilized additional groundwater quality results, isotopic analyses, and pumping tests to further characterize and compare water from deep wells with water from intermediate depth wells. The Phase II study also included some limited data for the Woodland area.

Based on the isotopic results for the deep wells, natural recharge to the deep aquifer zone was greatest from western streams and washes. Natural (pre-pumping) recharge was not from widespread surface percolation because isotopic enrichment was not evident. Recharge under current (pumping) conditions could be more vertical and widespread than recharge during pre-pumping conditions. The softer water conditions in the Deep Aquifer reflect long travel and residence time in contact with clays to exchange calcium and magnesium for sodium.

The isotopic results for intermediate depth wells sampled in the Phase II study is shown in Table 3-2. Water from intermediate depth wells showed more evidence of isotopic enrichment due to evaporation, implying a mix of pristine groundwater and recharge from agricultural deep percolation.

Table 3-2. Groundwater Isotope Analysis Results for Intermediate Depth Wells

Well ID		$\delta^{18}O$, ‰	δD, ‰	^{14}C, years bp
Davis #18		-6.2	-45	330
Davis #19		-7.4	-52	3,560
Davis #21		-7.3	-53	4,250
Davis #22		-7.1	-51	3,850
Davis #25		-7.4	-53	4,240
Woodland #24	Zone 4 (490' -510')	-7.1	-50	7,350
Woodland #24	Zone 5 (370'-410')	-5.7	-42	--

The conclusions from the Phase II Deep Aquifer Study were consistent with the Phase I Study with the exception of a moderately higher average transmissivity for the deep zone compared to the Phase I study. The Phase II Study also produced a substantial additional amount of detailed information versus depth from the area north of Davis into Woodland.

3.7 Irrigation Water Constituents Analysis

A report on the concentrations of boron, salinity, and nutrients in Yolo County irrigation water was prepared in 2006 (Stevenson, 2006). This report summarized available historical data for surface water quality, groundwater quality, and irrigation source data. The report focused on Cache Creek and the area served by YCFCWCD. One of the conclusions of the report was that a major contribution to the increase in salinity in shallow Yolo County groundwater over the last few decades was the use of high EC groundwater for irrigation and the drainage of shallow groundwater into waterways in gaining reaches.

3.8 Woodland Well Condition Assessment

The condition, performance, and water quality of wells in Woodland was evaluated to determine the priorities for well replacement and efficiency improvements (Brown and Caldwell, 2006). Nitrate concentrations have been steadily increasing in many municipal wells in Woodland, especially those along the western edge of town. Patches have been placed over perforations for shallow zones in Wells 17 and 20 to prevent drawing water with high nitrogen concentrations from those wells.

The condition assessment also contained data on well construction and production. The specific capacity of wells in western Woodland ranged from 12 to 179 gpm/ft.

3.9 CV-SALTS Pilot Implementation Study

The Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) Initiative is a project of the Central Valley Salinity Coalition. Recently, the Coalition commissioned a report on salt and nitrate loading, Salt and Nitrate Sources Pilot Implementation Study Report (Larry Walker Associates, 2010). Three areas were chosen for the study. One study area included a large portion of Yolo County and attempted to describe all nitrate and salt loading for the year 2002. The major results of study will be presented and analyzed here. Results will be compared to farmer based estimates of fertilizer application rates and fertilizer sales data collected by the California State Department of Food and Agriculture.

One of the main results of the CV-SALTS study found that nitrate loading to the aquifer (below near surface groundwater) occurred at 13,100 lbs per day (or 4.8 million lbs of nitrate per year as NO_3) in the Yolo Study area. The Yolo Study area (219,171 crop acres) is smaller than the total crop acres in Yolo County (293,284 crop acres, average from 1994-2009 from PUR database). Scaling up the loading based on the total crop acres of Yolo County would correspond to an annual loading of nitrate to the aquifer of 6.4 million lbs per year.

There are many sources of nitrate loading. The study determined that 63% of nitrate loading to the near surface groundwater came from fertilizer land application, 17% from pumped groundwater used for irrigation, 17% from mineral weathering, and 3% from atmospheric deposition. Nitrogen in the form of ammonia from septic systems was estimated at only 180 lbs/day (Table ES-5 of the CV-SALTS report). Ammonia-N can be converted to nitrate in the soil, but the rate calculate from septic systems is a low 5.47 lbs/day (Table 4-2 of the CV-SALTS report). Nitrate from other source, such as dairies and other CAFOs, was also very low, at around 10 lbs/day. Dairies can be a large source of nitrate loading, but there are few dairies in the Yolo County area (only 3 in 2002).

Nitrate fertilizer application rates are not tracked by any entity, so these rates were estimated in the CV-SALTS study. First, crop types and other land uses were summarized by total acres. Then, the recommended N fertilizer rate, from sources such as UC Cooperative Extension, was multiplied by the acreage for each crop. Then the percent of nitrate-N versus other types of N fertilizer was used to calculate the total amount of nitrate applied per year. The total applied N fertilizer of all types in the Yolo County study area was calculated to be 165 lbs N/ ac yr for all crop land (Table 3-3).

Data sources 1 and 2 in Table 3-3 used crop acreage estimates multiplied by nitrogen fertilizer application rates. Data source 1 used recommended rates of N fertilizer applications by crop, while data source 2 used actual use estimate by a group of Yolo County Farm Bureau farmers. Data source 3 used nitrogen fertilizer sales data, divided by the acreage of all crops planted in Yolo County.

Nitrogen fertilizer is available in many forms, and not all forms contain nitrate. The CV-SALTS study reported estimates of total N used as fertilizer. Then the percent N fertilizer as nitrate was estimated for each crop category and nitrate loading was determined from total N fertilizer applied. Table 3-3 shows application rates for all sources of N, not just nitrate.

Table 3-3. Yolo County Nitrogen Fertilizer Application Rates

Data Source	Total Applied N (avg. lbs N / ac yr)
1. CV-SALTS report	165
2. CV-SALTS rates adjusted by YCFB	120
3. Fertilizer Sales Data (avg of 1994-2009)	99

3.10 Nitrogen Fertilizer Data Source 1: CV-SALTS Report

The Watershed Analysis Risk Management Framework (WARMF) model used for the CV-SALTS report assigned Yolo catchments to align with the Central Valley Hydrologic Model grid within Yolo County. The WARMF model tracks the mass of each chemical constituent as it passes through the soil and undergoes transformations. Chemical reactions, adsorption, mineral soil weathering, and precipitation are modeled.

The CV-SALTS study results did not present nitrate or N loading in lbs/ ac yr, only in total amounts of N applied. However, acreage data for all crops was presented, enabling the calculation of application rates as shown in Table 3-4.

Table 3-4. Estimated N Fertilizer Rates by Crop

Land Cover Class	Applied N rate lbs / ac yr CV -SALTS	Acres in WARMF	CV-SALTS Applied lbs N / yr
Rice	180	14,302	2,574,360
Vines	70	2,943	206,010
Cotton	180	1,342	241,560
Orchard	100	21,001	2,100,100
Flowers and Nursery	165	318	52,470
Other CAFOs	100	138	13,800
Olives, Citrus, and sub-tropicals	180	185	33,300
Other row crops	120	51,081	6,129,720
Perrennial forages	25	27,414	685,350
Warm season cereals and forages	300	40,279	12,083,700
Winter grains and safflower	200	60,168	12,033,600

Source:

Salt and Nitrate Sources Pilot Implementation Study; Final Report February 2010. Submitted by Larry Walker Associates
http://www.cvsalinity.org/index.php/component/content/article/18-events/60-admin
Applied N rates are taken from the CV-SALTS report, Table 3-6, and acreage data from CV-SALTS report, Table 3-2.

3.11 Nitrogen Fertilizer Data Source 2: CV-SALTS Rates Adjusted by YCFB

For the purposes of the AB 303 grant, during a Yolo County Farm Bureau Executive Committee meeting on August 1, 2011, the five experienced farmers present were asked to review the CV-SALTS application rate data from Table 3-4. These farmers adjusted the N application rates down to what they thought were more 'typical' and 'actual' application rates as practiced in Yolo County (Table 3-5). Some application rates were described as a range of values.

Table 3-5. N Fertilizer Application Rates (Local Farmers Experience) Data Source 2

Land Cover Class	Applied N rate lbs / ac yr Farm Bureau
Rice	130
Vines	70
Cotton	180
Orchard	100
Flowers and Nursery	165
Other CAFOs	100
Olives, Citrus, and sub-tropicals	180
Other row crops	120
Perrennial forages (alfalfa)	25
Warm season cereals and forages	--
Corn	200 - 250
Sudan grass	120
Winter grains	75 - 120
Safflower	90 - 120

When the results of the CV-SALTS study are recalculated based on the rates as seen by experienced Yolo County Farmers, the total lbs N/ ac yr applied in Yolo County is reduced from 165 lbs N / ac yr to 120 Lbs N / ac yr (see Tables 3-4 and 3-5 for details by crop types). Application rates in Table 3-6 for warm season cereals and forages, winter grains, and safflower used the middle of the ranges presented in Table 3-5.

Table 3-6. Recalculated N Fertilizer Application Rates from Data Source 2

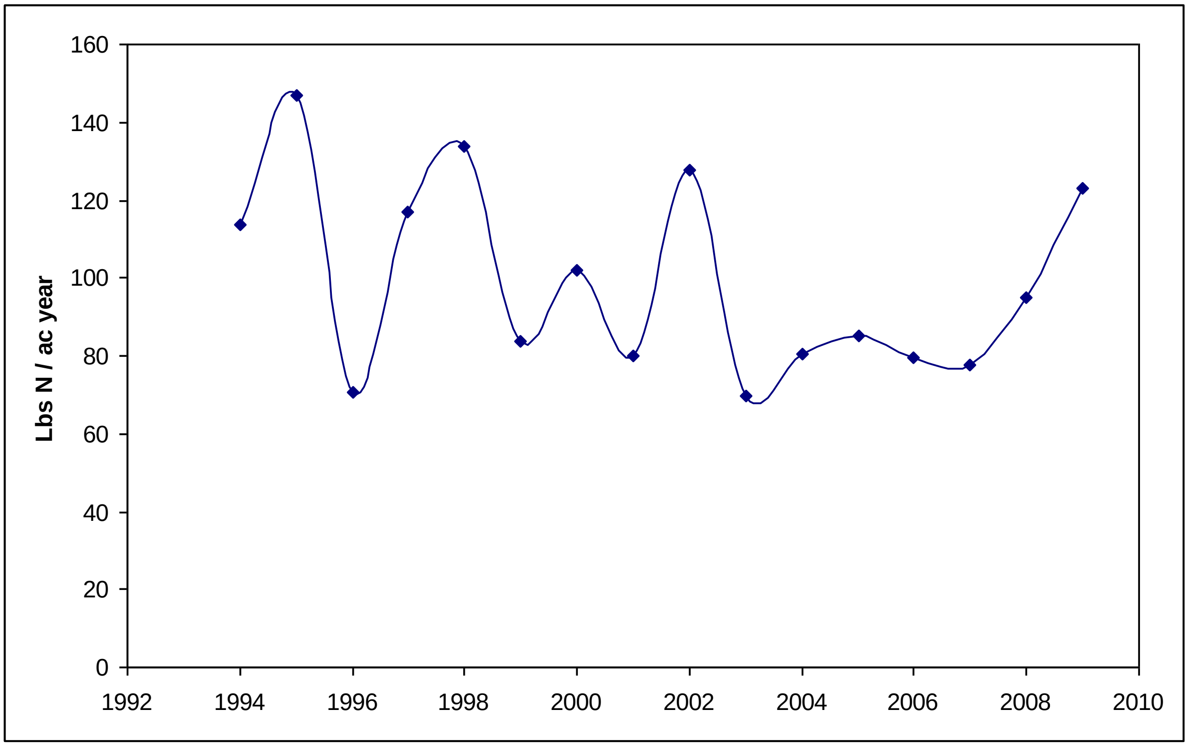
Land Cover Class	Applied N rate lbs / ac yr YCFB	Acres in WARMF	YCFB Applied lbs N / yr
Rice	130	14,302	1,859,260
Vines	70	2,943	206,010
Cotton	180	1,342	241,560
Orchard	100	21,001	2,100,100
Flowers and Nursery	165	318	52,470
Other CAFOs	100	138	13,800
Olives, Citrus, and sub-tropicals	180	185	33,300
Other row crops	120	51,081	6,129,720
Perennial forages	25	27,414	685,350
Warm season cereals and forages	225	40,279	9,062,775
Winter grains and safflower	97.5	60,168	5,866,380

3.12 Nitrogen Fertilizer Data Source 3: Fertilizer Sales Data

Fertilizer sales data have been collected by the California Department of Food and Agriculture (CDFA) since 1991 and are published annually. The California Department of Pesticide Regulation (CDPR) also collects data on acres of crops planted, and this data is available on-line. The fertilizer sales and crop acreage data can be combined to calculate Lbs of N per acre per year. This was done for Yolo County for the years from 1994 to 2009 (Figure 3-1). These data can be used as a comparison to the CV-SALTS study results, as in Table 3-3. For all source data used in this analysis, please see Appendix A.

It appears that both farmer estimates (Data Source 2) and fertilizer sales data (Data Source 3) show that nitrogen fertilizer application in Yolo County is probably less than the rates estimated in the CV-SALTS study. It may be useful to redo the mass balance calculation from the CV-SALTS study with these revised application rates. A better estimate of nitrate loading to the deep aquifer may be achieved.

Figure 3-1. Rate of applied nitrogen fertilizer in lbs/acre each year in Yolo County. Rates calculated from fertilizer sales data and crop acreage (Data Source 3 in Table 3-3).



Section 4

Sampling and Analytical Methods

Detailed goals, specific wells to be targeted for sampling, and a preliminary sampling schedule were developed in meetings between District staff, Brown and Caldwell, and stakeholders from the Cities of Davis and Woodland. A work plan (Appendix B) was prepared describing the water quality monitoring program. This plan included a listing of wells, schedule, sampling to be performed, labs, copies of sampling protocols, and well locations.

The selection of the area for sampling was based on an evaluation of the groundwater gradients in the vicinities of Davis and Woodland. Water level contours for fall and spring, 2010 are shown in Figures 4-1 and 4-2. The groundwater gradient, shown by the black arrows, is generally steepest towards Woodland from the southwest, although the gradient is towards Woodland most of the way around the city. The groundwater gradient is steepest towards Davis from the west and lessens around the north of Davis. Wells were selected generally in areas that had the steepest gradients towards the cities or within the cities near those boundaries.

Volunteer landowners were approached and asked if they would allow sampling at their well. Landowners were provided documentation from 4 government agencies (Yolo County, CDPR, CDPH, and the CVRWQCB) stating that drinking water quality in private wells is not regulated (Appendix F.)

Based on the groundwater gradients and willing volunteer landowners, twenty four shallow production and monitoring wells were sampled near and within the cities of Davis and Woodland (Figure 4-3). Surface water samples were also taken from Putah Creek and Cache Creek supply. The samples were analyzed for general minerals, EC, boron, and selenium. The samples were also analyzed for stable isotope ratios and CFCs for further characterization and age determinations. Samples from eight wells out of the 24 were also analyzed for tritium, helium-3, and for noble gases to provide additional characterization and for comparison with the CFC data.

The labs used for the project and the respective analyses are listed in Table 4-1

Table 4-1. Labs and Analytes Tested

Lab	Analyses
UC Davis AnLab	minerals
UC Davis Stable Isotope Facility	δ15N
Zymax (through DWR)	δD and δ^{18}O
University of Utah Dissolved and Noble Gas Lab	CFCs, tritium, ^{3}He, and noble gases

Sampling was performed in accordance with procedures given in Appendix B. Laboratory analysis was performed in accordance with Environmental Protection Agency (EPA) methods, Standard Methods, and laboratory quality control standards by a state certified laboratory. Isotope sampling was performed in accordance with the standards and procedures listed in Appendix B to assure quality results.

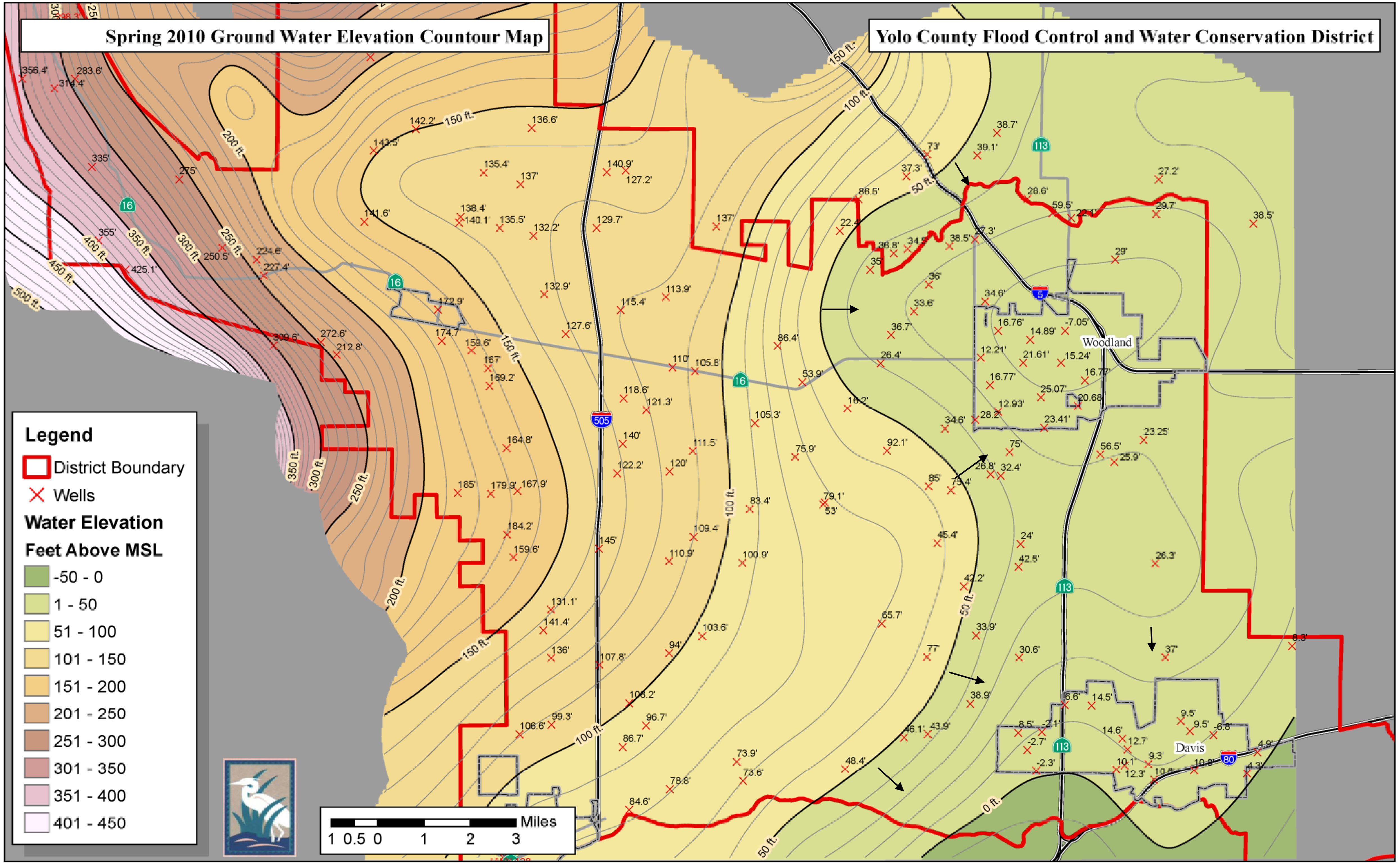


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Figure 4-1. Spring 2010 Groundwater Levels (from YCFCWCD)

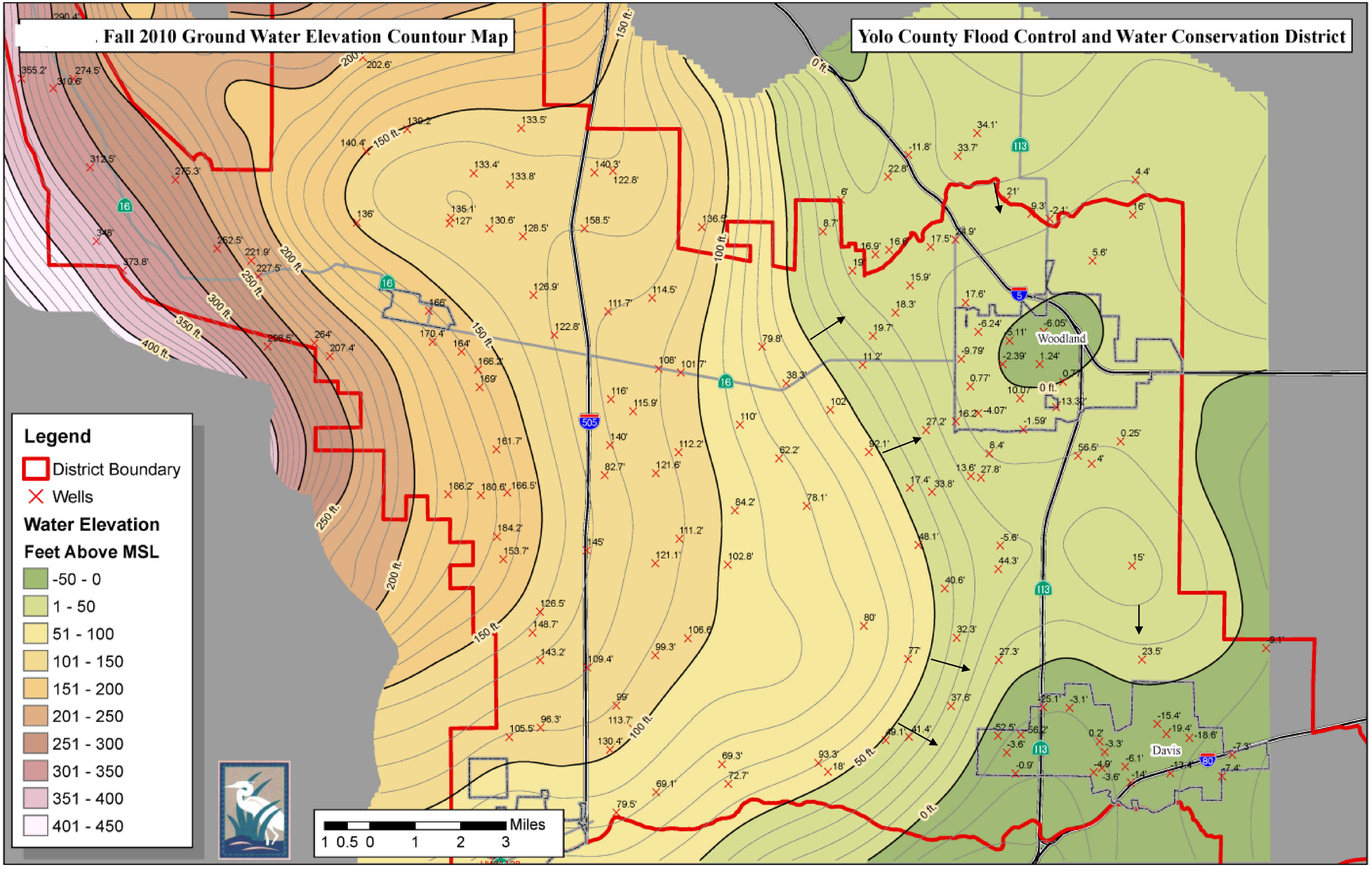

Figure 4-2. Fall 2010 Groundwater Levels (from YCFCWCD)

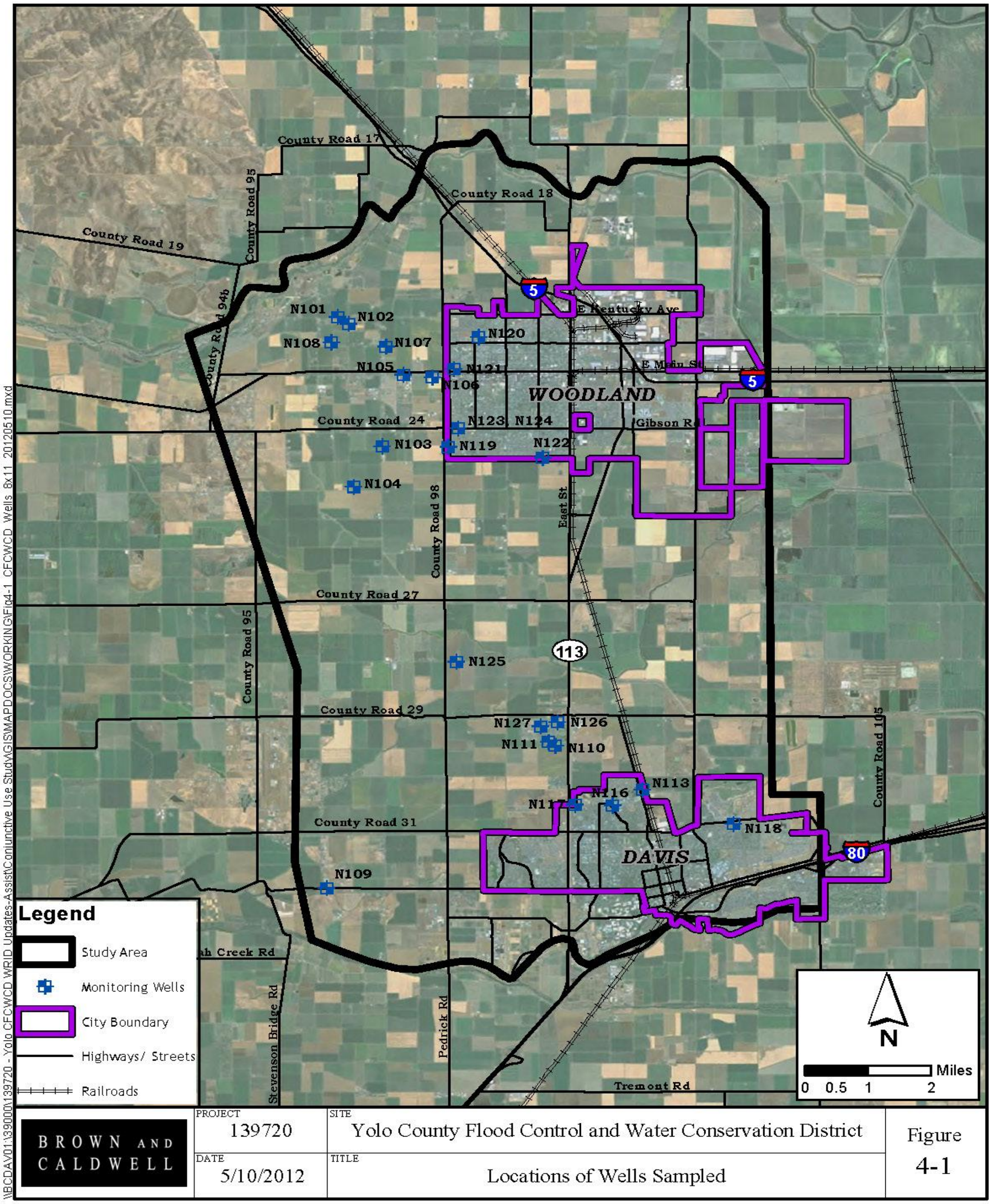

Figure 4-3. Locations of Wells Sampled in Study

4-3

Section 5

Evaluation of Water Quality and Isotope Results

The detailed analytical results for mineral constituents are shown in Table C-1 in Appendix C. The CFC and isotopic data is shown in Table D-1. Detailed results for the tritium, ^{3}He, and noble gas analyses are shown in Table D-2. Well construction details are provided in Appendix E. Parameters and their measured values used for determining the sources of recharge water and nitrate are discussed in order of relative importance in this section. Additional constituents of concern, salinity, boron, and selenium are also discussed.

5.1 Nitrate Stable Isotopes

^{15}N was used as the primary tool for determining the source of nitrate to groundwater. General guidelines for interpretation of $\delta^{15}N$ data according to Moetzer are shown in Table 5-1. The data from Rolston et al for $\delta^{15}N$ are also shown in Table 5-1. A chart showing relative values and relationships to $\delta^{18}O$ of nitrate is shown in Figure 5-1. Although not measured in this study, Figure 5-1 shows how $\delta^{18}O$ of nitrate can also be used to help differentiate between natural and anthropogenic sources. Contours for values of $\delta^{15}N$ for the study area are shown in Figure 5-2.

Table 5-1. Interpretative Ranges for 15N

Potential Source	Moetze (Table 1)	Ralston et al (referenced)	Ralston et al (measured averages)
Commercial Fertilizer	-4 to +4	-3 to +2	+1.6 to +4.4
Precipitation	-3	--	--
Organic Nitrogen in Soil	+4 to +9	+2 to +8	+2.6
Animal or Human Waste	>10	+6 to +25	+7.3 to +13.9

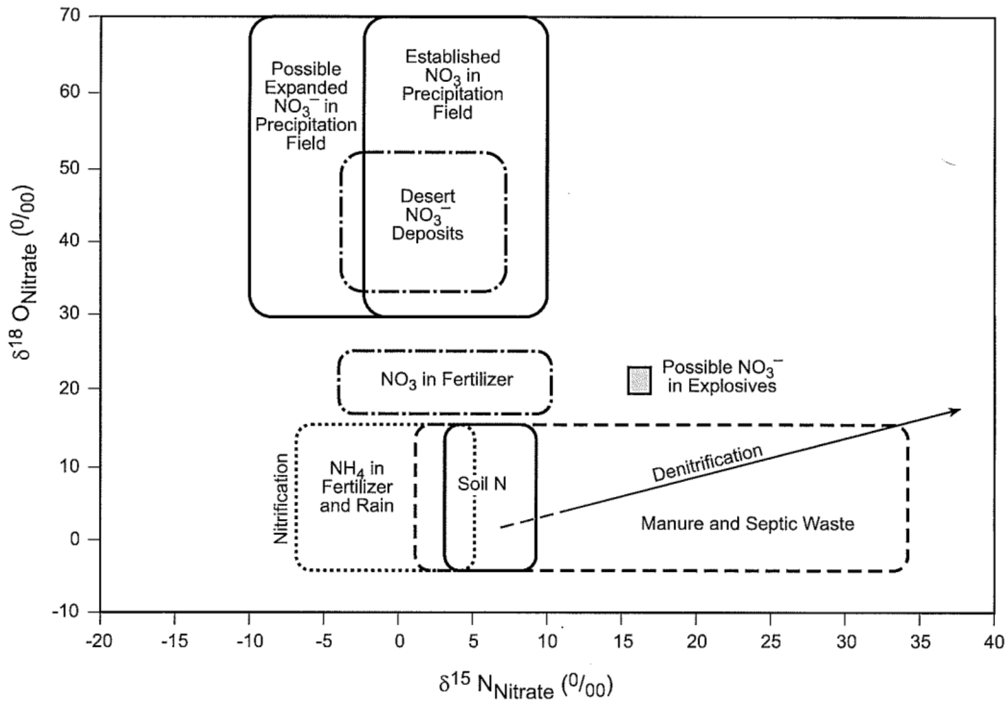

Figure 5-1. Source Interpretation Chart for $\delta^{15}N$ (of Nitrate) and $\delta^{18}O$ (of Nitrate)

A summary of the most relevant results for determination of the source and fate of nitrate and the other constituents of concern for this study is provided in Table 5-2. In general, $\delta^{15}N$ values less than 5 were indicative of a predominantly fertilizer source for nitrate in groundwater. $\delta^{15}N$ values between 5 and 7 were judged to be either predominantly from fertilizer or from fertilizer together with some nitrate from weathering or mineralization/nitrification of soil organic nitrogen. The additional parameters used in the evaluation were the CFC age, $\delta^{18}O$ (water), and hardness. Samples with $\delta^{15}N$ values greater than 7 were judged to have some influence from manure or septic nitrogen sources. The values for Davis #15 and the Davis F Street Shallow Well stood out as mostly old water with some influence from deep percolation of manure or septic sources. Detailed isotope and CFC results are summarized in Table D-1 in Appendix D.

For the study area, natural concentrations of nitrate would be expected to be relatively low as seen in the surface water samples for Cache Creek and Putah Creek (samples N128 and N129 in Table 5-2). Therefore, the absolute nitrate concentrations from wells in the study area were used to differentiate between likely natural versus agricultural and other anthropogenic sources.

The percentage of wells sampled that had nitrate predominantly from fertilizer was 58.3%. Wells having a mixture of nitrate sources, but likely still a majority of nitrate from fertilizer was 33.3%. Of the wells sampled, only one (N113), had a $\delta^{15}N$ value indicative of exclusively septic or manure sources. Of note, this well had the lowest absolute nitrate concentration of all wells in the study. Table ES-1 has a summary of these results.

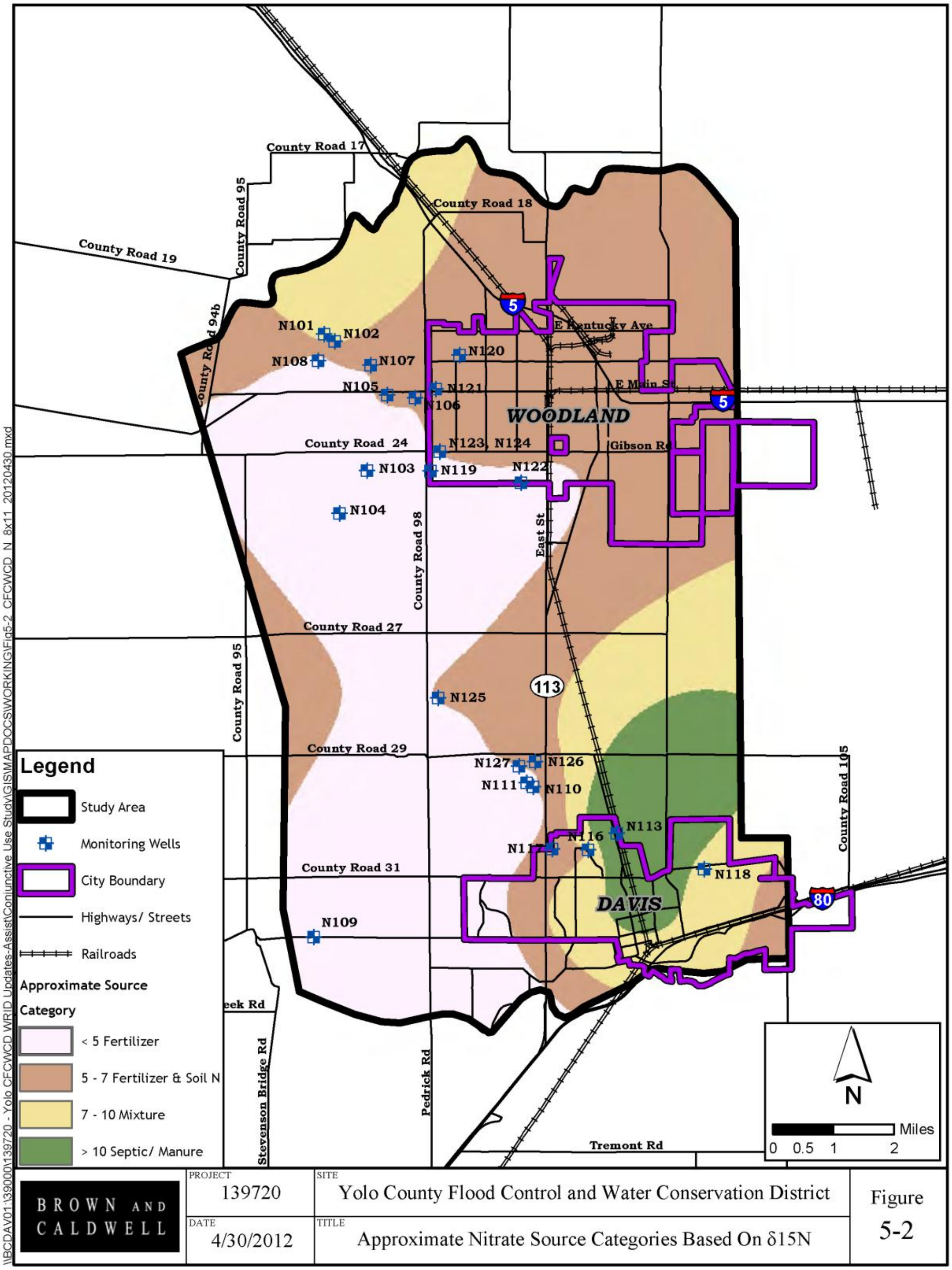

Figure 5-2. $\delta^{15}N$ Value Contours for Wells Sampled in Study. (Contours were mapped for the entire study area, extrapolating into areas were no well sampling occurred. This extrapolation should be used for guidance only.)

Table 5-2. Nitrate, Isotopic, and Other Key Data

Well	Description	Wtd. Avg. Screen Depth, ft.	δ^{15}N	NO3, mg/L	NO3 Source Interpretation	Avg. CFC Date	CFC Age (years) (a)	Tritium, TU	δ^{18}O	δD	Hardness, mg/L as CaCO3	EC, dS/m	B, mg/L	Se, µg/L
N101	Shop/Business	224	7.09	14.5	Fert./Soil N/Manure	1983	29	2.19	-5.38	-45	264	0.69	1.71	0.5
N102	Residential	340	7.65	12.5	Fert./Soil N/Manure	1983	28	NA	-5.49	-42.5	258	0.7	1.67	<0.5
N103	Ag	172	3.70	57.2	Fert.	1981	31	2.96	-5.65	-44.7	465	1.15	1.94	1.3
N104	Residential	268	3.71	29.5	Fert.	1980	32	NA	-5.51	-42.7	359	0.9	1.53	0.8
N105	Shop/Business	151	5.30	54.6	Fert.	1990	22	2.50	-5.93	-44.2	481	1.155	2.58	1.3
N106	Residential	240	5.2	44.7	Fert.	1985	27	2.46	-5.64	-43.3	479	1.13	2.28	1.2
N107	Shop/Business	230	5.19	45.3	Fert.	1987	25	NA	-6	-44.7	470	1.16	2.64	<0.5
N108	Residential	132	4.52	28.5	Fert.	1986	26	NA	-5.62	-43.3	342	0.93	2.6	1
N109	Residential	220	2.97	63.3	Fert.	1991	21	NA	-5.62	-42.6	448	1.01	0.7	<0.5
N110	Davis Golf Course 1	236	4.8	65.9	Fert.	1987	25	NA	-6.35	-46.2	678	1.74	1.36	8.8
N111	Davis Golf Course 2	193	3.81	51.3	Fert.	1979	32	1.95	-6.18	-45.1	615	1.59	1.28	4
N113	Davis MW F St. Shallow	330	17	3.5	Septic/Manure	1963	49	NA	-7.61	-51.8	277	0.84	1.14	2.6
N116	Davis #19	418	6.87	22.8	Fert./Soil N	1973	38	NA	-7.35	-50.3	440	1.16	0.9	23
N117	Davis #27	323	6.04	17.6	Fert./Soil N	1969	42	0.59	-7.13	-52.3	316	0.9	0.89	3.2
N118	Davis #15	424	9.1	8.4	Septic/Fert.	1966	45	NA	-7.16	-50.2	358	1.04	1.04	11.7
N119	Woodland #17	337	3.37	64.7	Fert.	1977	35	NA	-5.6	-42	506	1.31	2.78	6.9
N120	Woodland #10	373	5.8	31.3	Fert./Soil N	1966	45	NA	-5.6	-42.9	405	0.97	2.09	1.4
N121	Woodland #20	301	5.76	24.0	Fert./Soil N	N/A	N/A	2.28	-5.37	-44.7	348	0.86	1.71	1.4
N122	Woodland #16	363	4.82	35.4	Fert.	1988	24	2.35	-5.19	-43.8	420	1.03	1.87	8.9
N123	Woodland 25 MW Shallow	136	6.51	23.0	Fert./Soil N	1986	26	NA	-4.98	-40	332	0.88	2.06	3.2
N124	Woodland 25 MW Int.	324	4.07	42.0	Fert.	1982	30	NA	-5.45	-42.6	465	1.11	2.39	5.4
N125	Ag	164	5.02	27.2	Fert.	1978	34	NA	-4.75	-38.5	396	1.02	1.72	0.9
N126	North Davis Meadows #1	317	5.8	15.5	Fert./Soil N	1968	44	NA	-7.22	-51.1	319	0.92	0.89	13.8

Table 5-2. Nitrate, Isotopic, and Other Key Data

Well	Description	Wtd. Avg. Screen Depth, ft.	$\delta^{15}N$	NO3, mg/L	NO3 Source Interpretation	Avg. CFC Date	CFC Age (years) [a]	Tritium, TU	$\delta^{18}O$	δD	Hardness, mg/L as CaCO3	EC, dS/m	B, mg/L	Se, µg/L
N127	North Davis Meadows #2	310	5.18	50.4	Fert.	1979	33	NA	-6.54	-47	488	1.27	1.24	5.9
N128	Cache Creek at Capay Dam	N/A	6.06	0.9	Precip.	>2003	<9	NA	-4.66	-38.6	155	0.39	1.24	<0.5
N129	Putah Creek	N/A	2.45	0.5	Precip.	>2002	<10	NA	-4.69	-36	175	0.35	<0.20	<0.5

[a] *Note: Groundwater is typically a mixture of old and recent water sources.*
Waters shown as more than 40 years old may reflect predominantly old (>1000 years old) water mixed with a small amount of modern water.

NA = not available

N/A = not applicable

5.2 Nitrate Concentrations

Along with being a concern for compliance with the drinking water MCL, absolute nitrate concentrations can provide information for the evaluation of groundwater recharge water sources. As discussed previously, high concentrations of nitrate are rarely found naturally in groundwater, the exceptions being some desert areas. For the study area, recharge from precipitation, the local creeks, and water provided by YCFCWCD would have low concentrations of total nitrogen. Water percolating through farm fields can pick up nitrogen fertilizer and soil nitrogen from weathering and decaying organic matter.

Eight of the 24 wells sampled (33%) were above the 45 ppm drinking water limit for nitrate (Table 5-2). This is consistent with the 232 wells sampled by Yolo County from 2007-2009 (Section 2.1).

Nitrogen concentration contours for the wells sampled in this study are shown in Figure 5-4. An oblique 3D view of nitrate concentrations for the cut line A-A' in Figure 5-4 is shown in Figure 5-5. The highest concentrations of nitrate in groundwater were found in the areas west/southwest of Woodland, west of Davis, and near the Davis Golf Course.

5.3 CFC and Tritium

CFCs are of interest for short-term aging of groundwaters. Finding young groundwater indicates relatively rapid recharge and transport characteristics in the vicinity of the sampled well. Tritium and its daughter product, helium-3, were also evaluated for some of the groundwater samples for comparison with CFC data.

5.3.1 CFC Results

The basis for evaluation of the CFC data is the history of the relative concentration of the three main CFC compounds in the atmosphere, shown in Figure 5-3. CFC Values greater than 40 years old are likely a mix of a small amount of modern water with pristine groundwater.

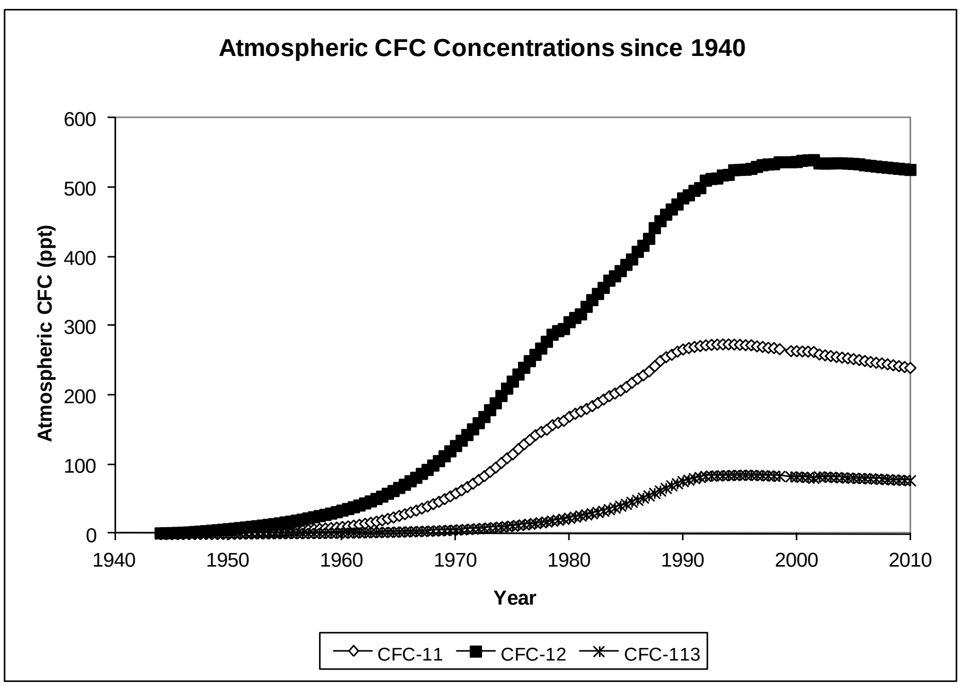

Figure 5-3. CFCs – Atmospheric Concentrations Since 1940

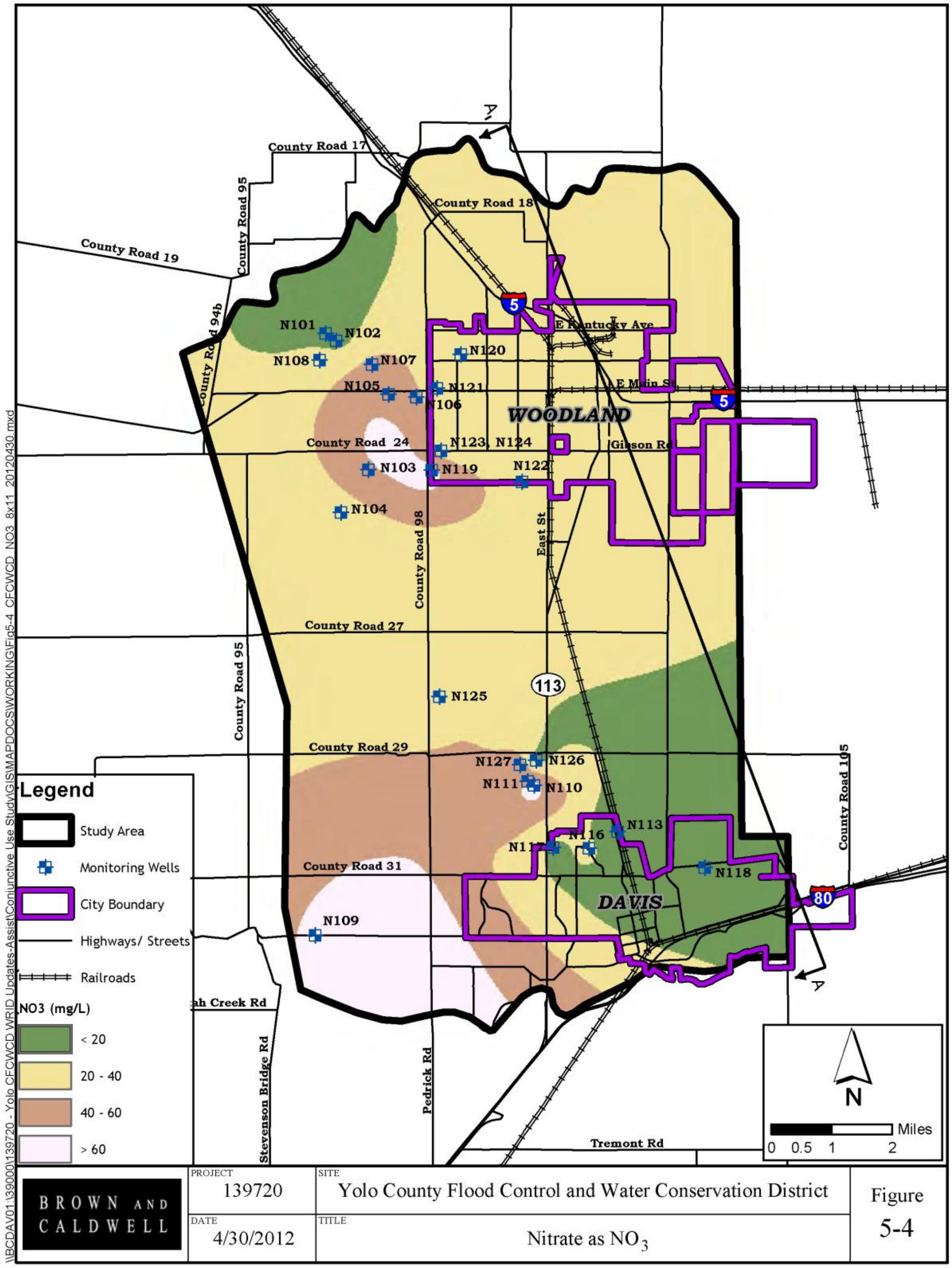

Figure 5-4. Nitrate Concentration Contours for Wells Sampled in Study (as NO_3). (Contours were mapped for the entire study area, extrapolating into areas were no well sampling occurred. This extrapolation should be used for guidance only.)

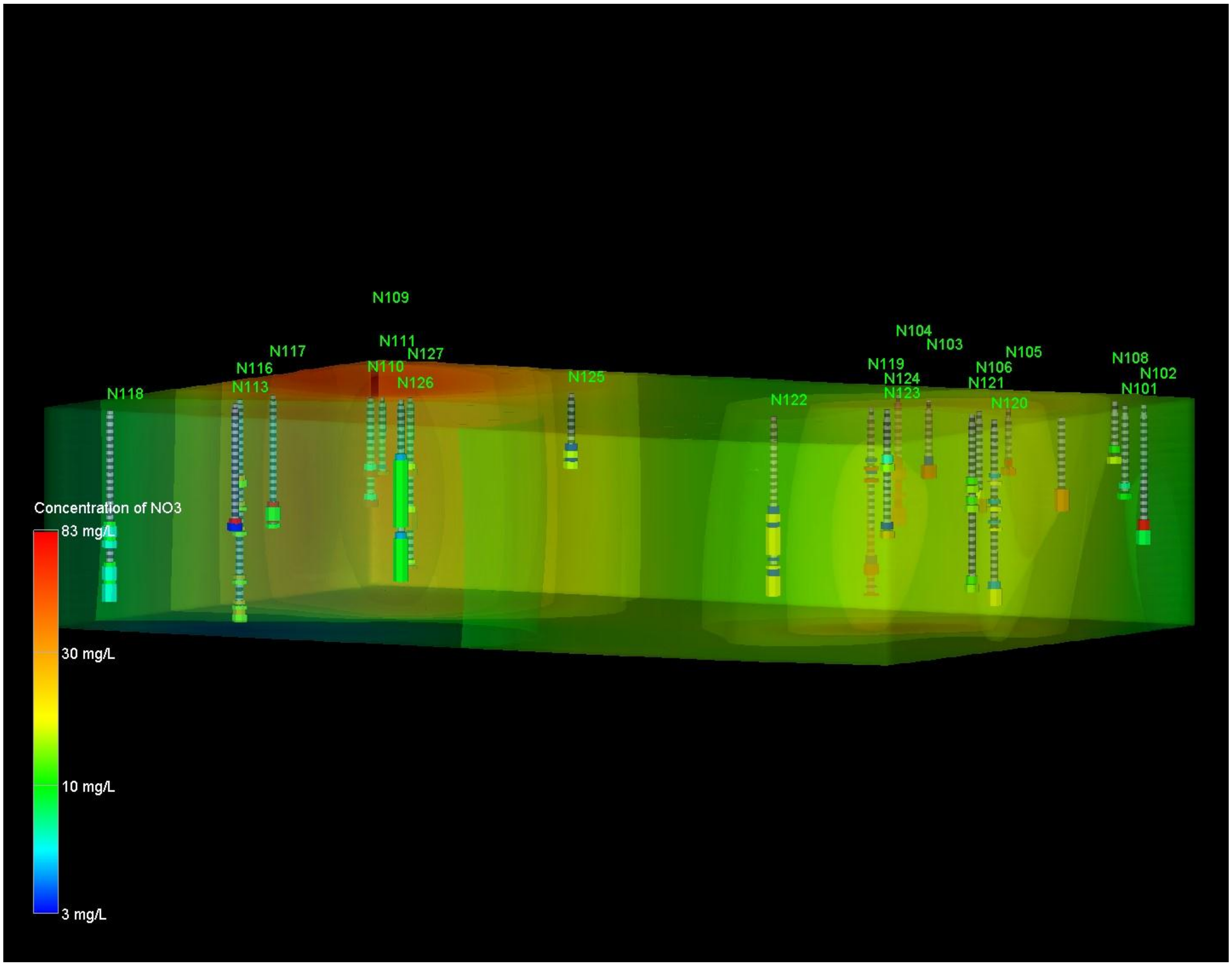

Figure 5-5. 3D View of Nitrate Concentrations of Wells Sampled in Study

Detailed CFC results are shown in Appendix D, Tables D-3 and D-4. CFC-11 is slowly biodegraded in an anaerobic environment. Because of this, it is not unusual to have CFC-11 apparent ages up to a decade older than CFC-12.

A plot of the correlation between CFC nitrate and CFC apparent ages for individual wells is shown in Figure 5-6, indicating that younger water is generally higher in nitrates. CFC apparent age contours are shown in Figure 5-7. The areas with younger CFC ages roughly correspond to the areas with higher nitrate concentrations (Figure 5-4). Age will also be a function of the depths to the screened intervals in wells (Table 5-2 and Appendix E).

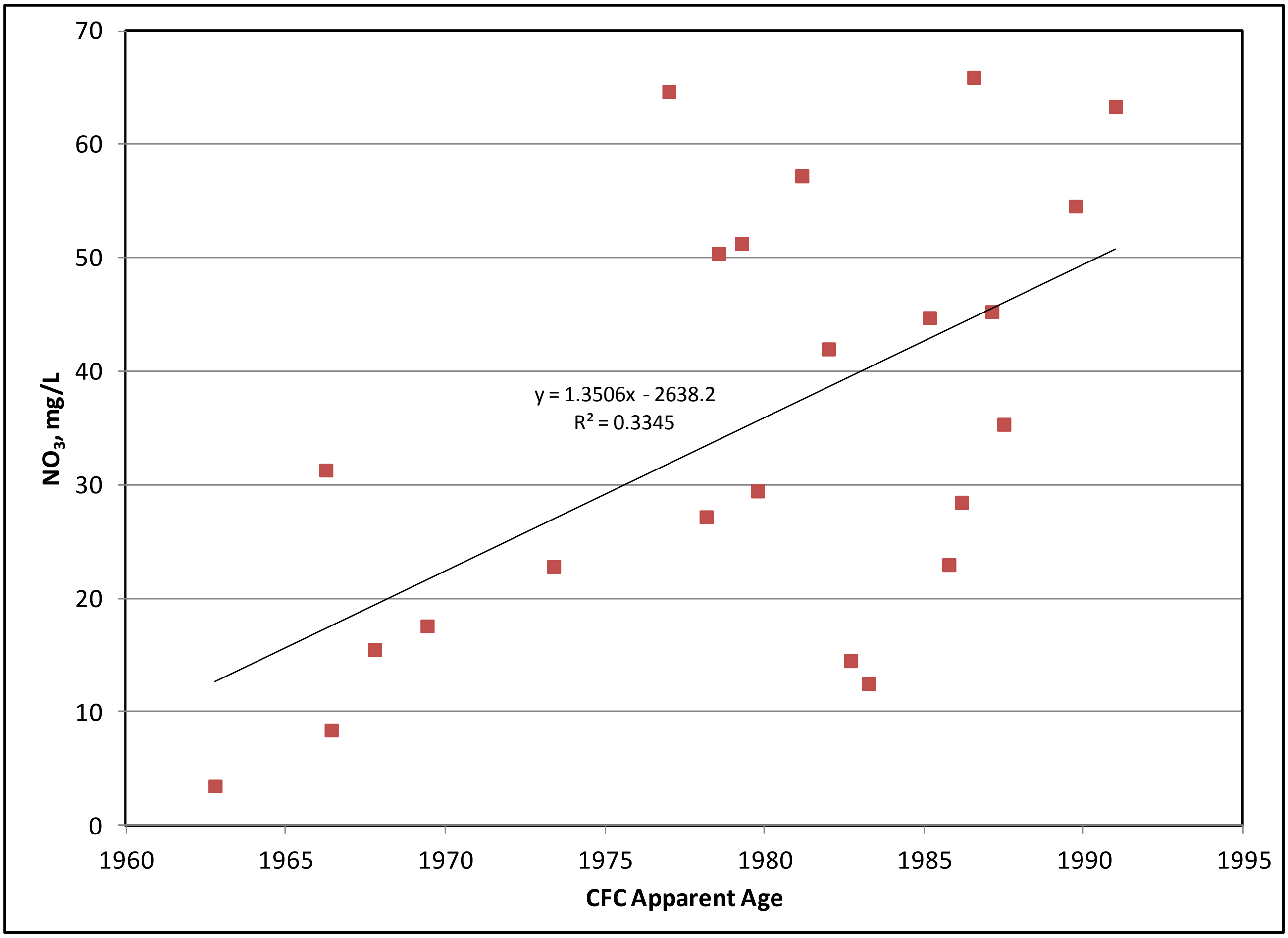

Figure 5-6. NO_3 vs. CFC Apparent Age

One of the advantages of CFCs versus tritium is that CFC age does not start until the CFCs reach the water table, while tritium ages start upon infiltration into the vadose zone. For the area in Yolo County west of the cities of Davis and Woodland, the water table will often be more than 20 feet below the ground surface. This could correspond to several years of travel time for water through the vadose zone and needs to be taken into account when comparing CFC versus tritium/^{3}He apparent ages.

A plot of δ^{15}N versus CFC apparent age is shown in Figure 5-8. This figure shows that, in general, younger water tends to have more of a fertilizer source component for nitrate.

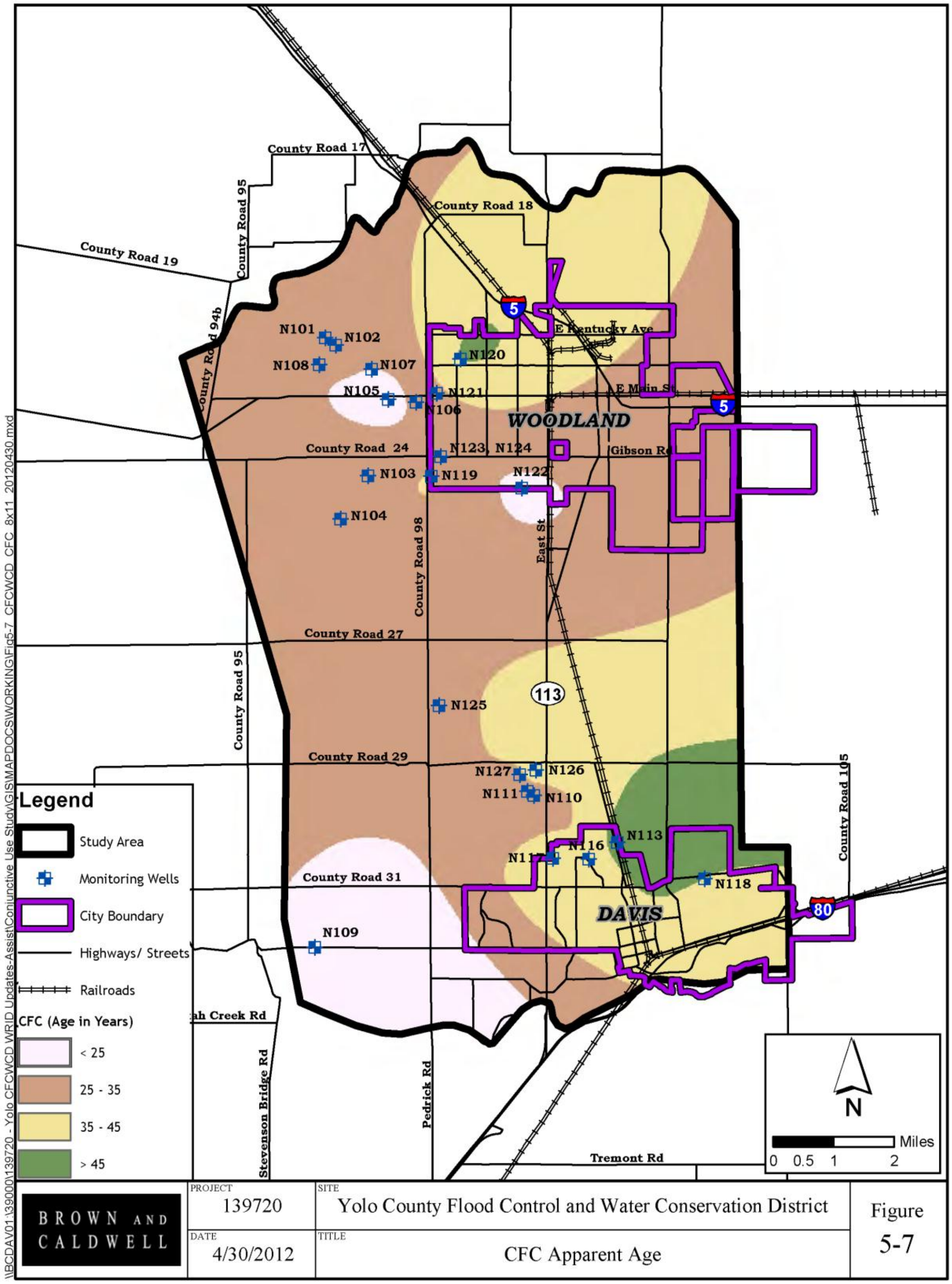

Figure 5-7. CFC Apparent Age Contours for Wells Sampled in Study. (Contours were mapped for the entire study area, extrapolating into areas were no well sampling occurred. This extrapolation should be used for guidance only.)

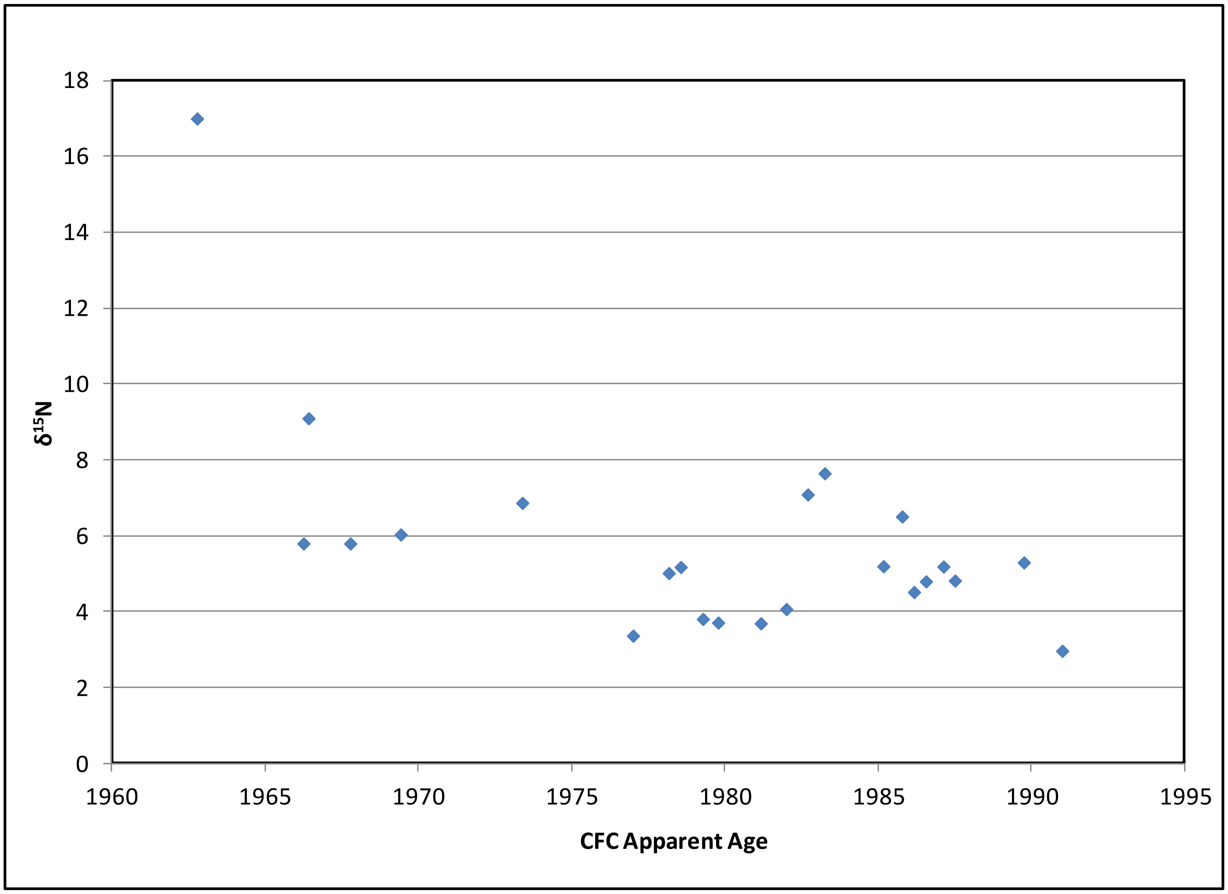

Figure 5-8. $\delta^{15}N$ versus CFC Apparent Age

5.3.2 Tritium

The large pulse of tritium that entered the hydrologic cycle in the 1960s can be used to establish the age of recent groundwater recharge. High levels of tritium (>~15 TU) indicate water that was recharged during the late 1950s or early 1960s; moderate concentrations indicate modern recharge; levels close to detection (~1 TU) are likely submodern or paleogroundwaters that have mixed with shallow modern groundwaters.

General guidelines for interpretation of tritium data are shown in Table 5-3.

Table 5-3. General Guidelines for Interpretation of Tritium Data	
<0.5 TU	submodern (prior to 1950s)
.5 - 3 TU	mix of submodern and modern
3 - 8 TU	modern (<15 to 20 years)
8 - 15 TU	some bomb tritium
>15 TU	pulse of recharge in the 1960s to 1970s
>25 TU	pulse of recharge in the 1960s

(after Clark and Fritz, 1997; divided by 2 for current dates and tritium half-life)

Samples for tritium and noble gases were taken from 8 wells. The tritium data for the wells was listed previously in Table 5-2. The interpretation of the tritium values corresponds reasonably well to the CFC apparent age data. The value for N117 (Davis Well #27) was indicative of almost entirely submodern water. Data for the other wells were indicative of a mixture of submodern and modern water.

Tritium along with measurement of the ^3He daughter product and noble gases can provide a better estimate of actual groundwater age than tritium alone. Complete tritium, ^3He, and noble gas data is provided in Appendix D, Table D-2. There are two different models that can be utilized with the tritium and noble gas data. Tritium decay reveals the ^3He /^4He ratio, resulting in a value designated the R/Ra value. The Ne model uses helium He3/He4 values only for modeling. The EA model allows for sample fractionation by partially dissolving Ar/Ze. R/Ra ratios greater than 1.0 indicate an age of source water and are factored into modeling, as seen in Table D-2 in Appendix D.

The ^3He and noble gas data can be affected by stripping losses of those gases to the atmosphere and to air pockets during sampling. Sample stripping is typically a result of well pump cavitation or carbon dioxide in the source water bearing zone. Excess air note may indicate that atmospheric gas is present in the sample source water bearing zone or was an artifact within the copper sampling tube.

Most of the samples taken reflected some level of excess air or gas stripping. For groundwater samples that have a high percentage of deep percolate from areas irrigated with groundwater, excess stripping would be expected. Until recently, most fields in the study were sprinkler irrigated for at least a portion of the season, which would have stripped noble gases from the irrigation water. While not obtaining reliable noble gas data was disappointing, the excess stripping was consistent with the interpretation for other measured constituents.

5.4 Deuterium and Oxygen-18

The absolute amount of the heavy isotope that will be in any phase is temperature dependent. For example, precipitation that falls in the Sierra Nevada and the Cascade Mountains typically have $\delta^{18}O$ of -13‰ or lower (Ingraham and Taylor, 1991), while precipitation in the Davis area has a $\delta^{18}O$ of -7.5‰ (Davisson et al, 1993). Water from Putah and Cache Creeks originates as precipitation, but has enriched stable isotope concentrations as a result of evaporation during long term impoundment in their respective reservoirs. The values for Cache and Putah Creek shown in Table 5-2 were from October 2011 and would be considered indicative of water with a high amount of evaporative effects from long term reservoir storage.

The comparison of $\delta^{18}O$ and δD values (see Figures 5-9 and 5-10) with the standard meteoric water line can provide an indication of how much groundwater would be considered pristine (from precipitation and pre-reservoirs creek seepage) versus more recent creek recharge or deep percolation from irrigated lands. The deep percolation and more recent creek recharge will be more enriched (less negative values) in $\delta^{18}O$ versus δD because of evaporation. Wells in the Woodland area have much more enriched $\delta^{18}O$ values than wells in Davis, indicating a greater proportion of more recently recharged water.

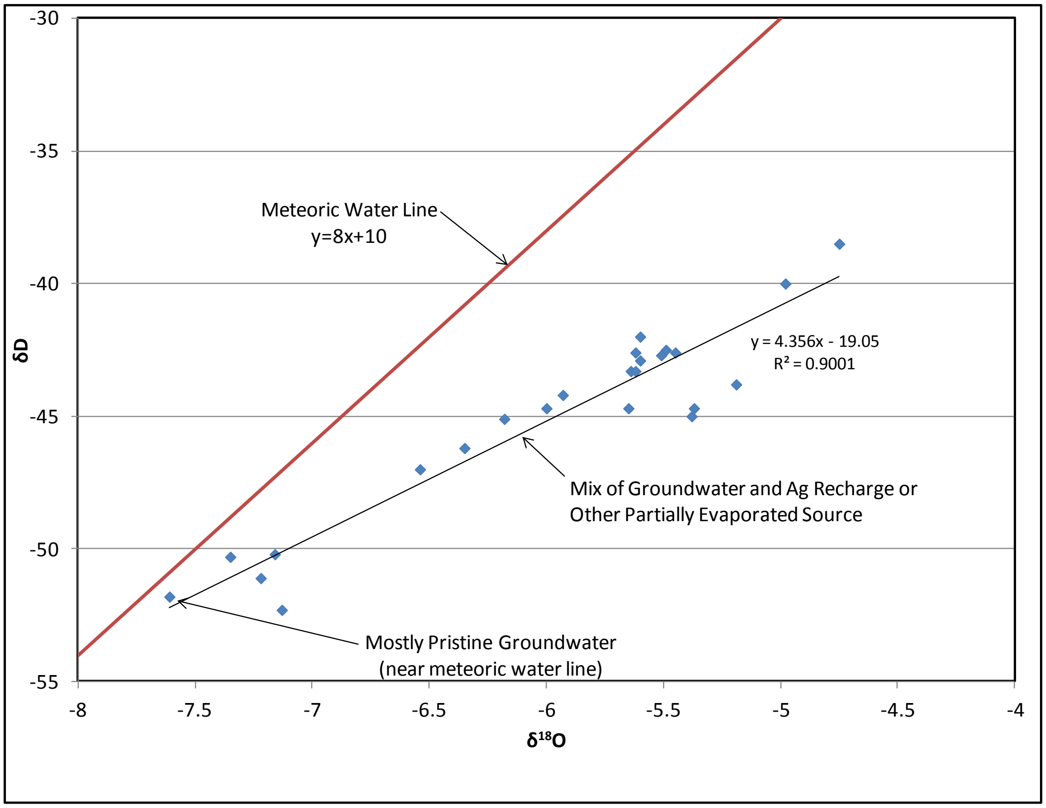

Figure 5-9. δD vs. $\delta^{18}O$

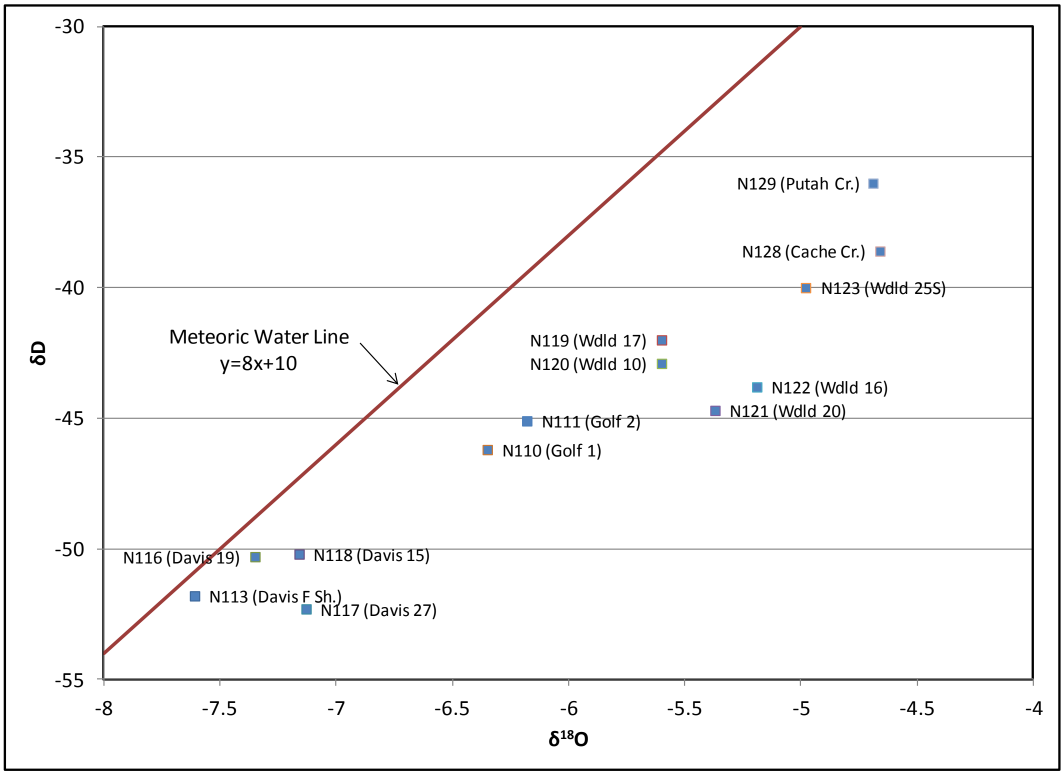

Figure 5-10. δD vs $\delta^{18}O$ by Well

5.5 Hardness and Salinity

Hardness is a measure of calcium and magnesium ions in groundwater. Hardness is the primary factor causing scaling in and on household fixtures and irrigation devices. Hardness leads to the use of water softeners in households, which substantially increase the salinity of wastewater discharges.

Calcium and magnesium are typically present in soils in the form of mineral precipitates. Rainfall, the addition of other salts, respiration by plant roots and nitrification of ammonia tend to cause dissolution or desorption of a portion of the calcium and magnesium. These processes are more pronounced in irrigated agriculture than in unirrigated lands. Crop evapotranspiration also increases the concentrations of all salts in deep percolate. Over time, the calcium and magnesium show up as increased hardness in groundwater. Therefore, higher concentrations of salinity and hardness in groundwater can be an indication of more recharge to the groundwater coming from deep percolation from cropped areas.

A plot of nitrate concentration versus hardness for the study area is shown in Figure 5-11. The correlation between the two measurements is high. This is another indication that high concentrations of nitrate in groundwater in the study area are likely associated with deep percolation from irrigated agriculture and turf areas. The similarities between the hardness concentration contours (Figure 5-12) and nitrate concentration contours (Figure 5-4) support a similar conclusion.

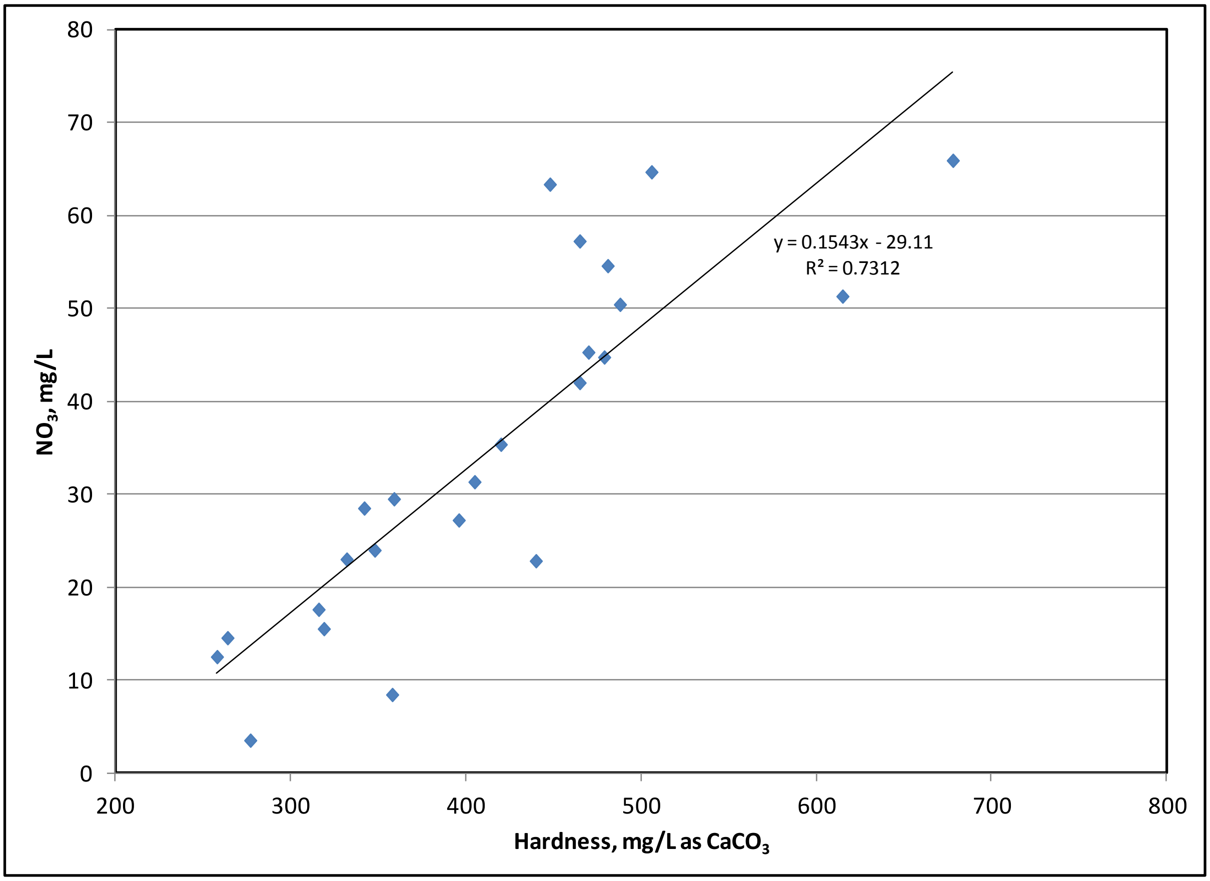

Figure 5-11. Hardness vs. NO_3

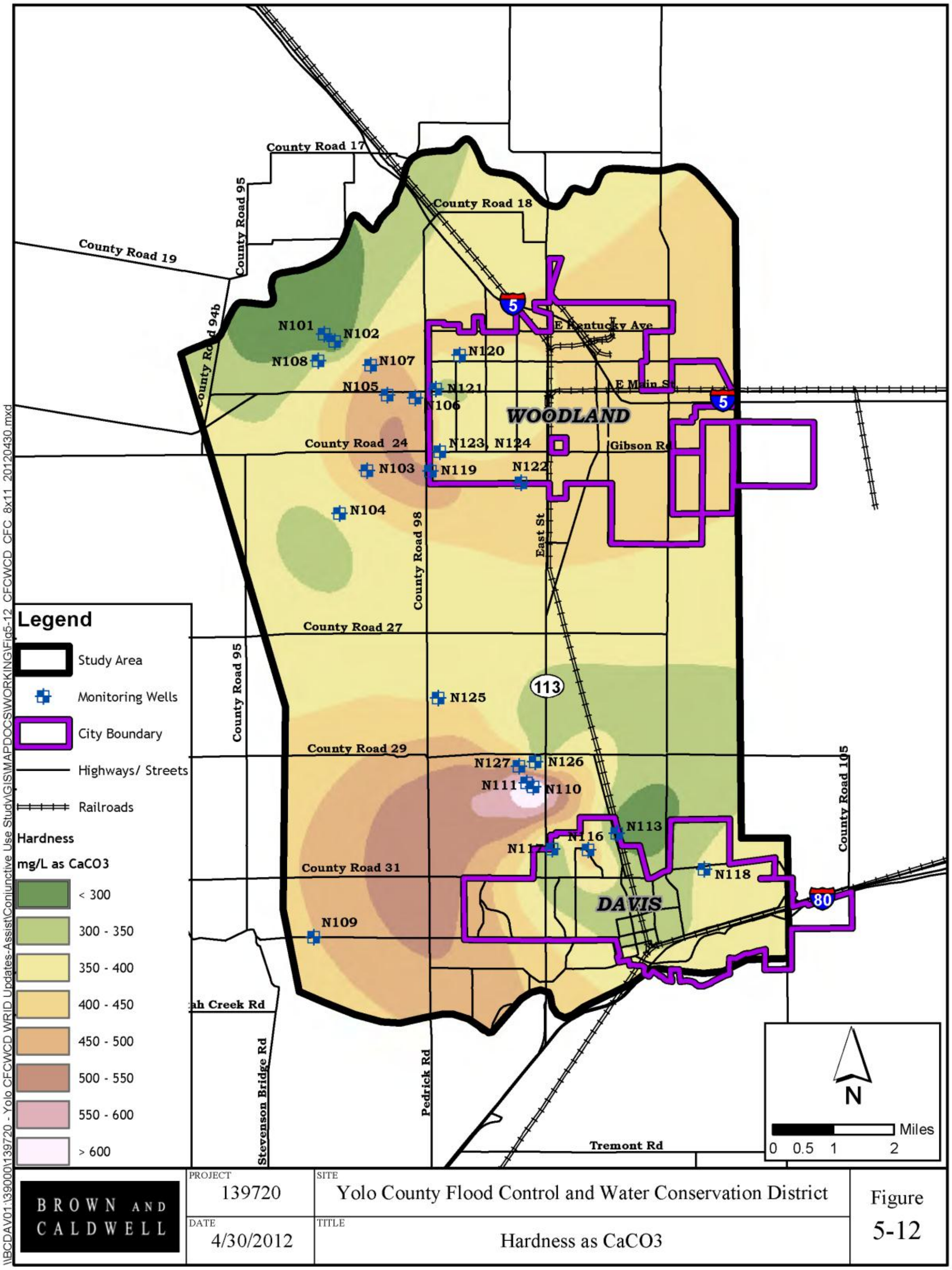

Figure 5-12. Hardness Concentration Contours for Wells Sampled in Study. (Contours were mapped for the entire study area, extrapolating into areas were no well sampling occurred. This extrapolation should be used for guidance only.)

5.6 Selenium

Selenium is of concern because of wastewater discharge requirements for the Cities of Davis and Woodland. Its origin is in sedimentary materials from the Coast Range that have been deposited in the study area. As was seen previously in Table 5-2, Cache Creek and Putah Creek are not significant direct sources of selenium. Selenium seems to be more prevalent in groundwater from intermediate depths, especially around the north-central side of Davis and south-central side of Woodland.

Selenium concentrations also seem to increase with depth up to 500 feet as shown in Figure 5-13. At depths below 600 feet, selenium concentrations in the Davis area generally become non-detect (Phase II Deep Aquifer Study, Brown and Caldwell, 2005). Selenium dissolution may be a function of both the deposits and the redox potential of water in portions of the study area. Selenium does not appear to be correlated with any other parameters measured in the study.

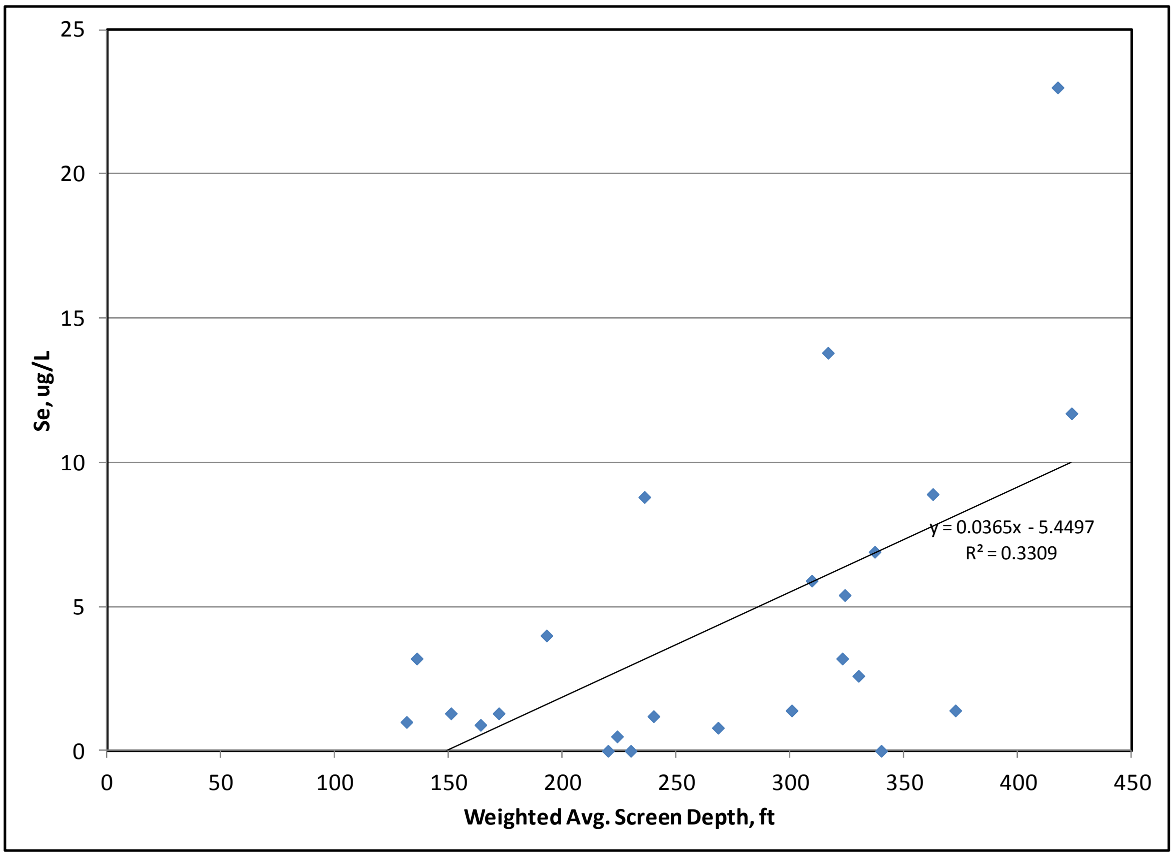

Figure 5-13. Selenium Concentrations versus Screen Depth

5.7 Boron

High boron concentrations are an indicator of Cache Creek as the original source water for the area, while moderate boron concentrations are an indicator of Putah Creek source water. Boron is not added to soils or water in the study area by human activities in any appreciable amounts. The highest boron concentrations are found where more groundwater is used for irrigation, increasing the concentration of boron in deep percolate because of evapoconcentration. The boron concentration contours for the study area are shown in Figure 5-14.

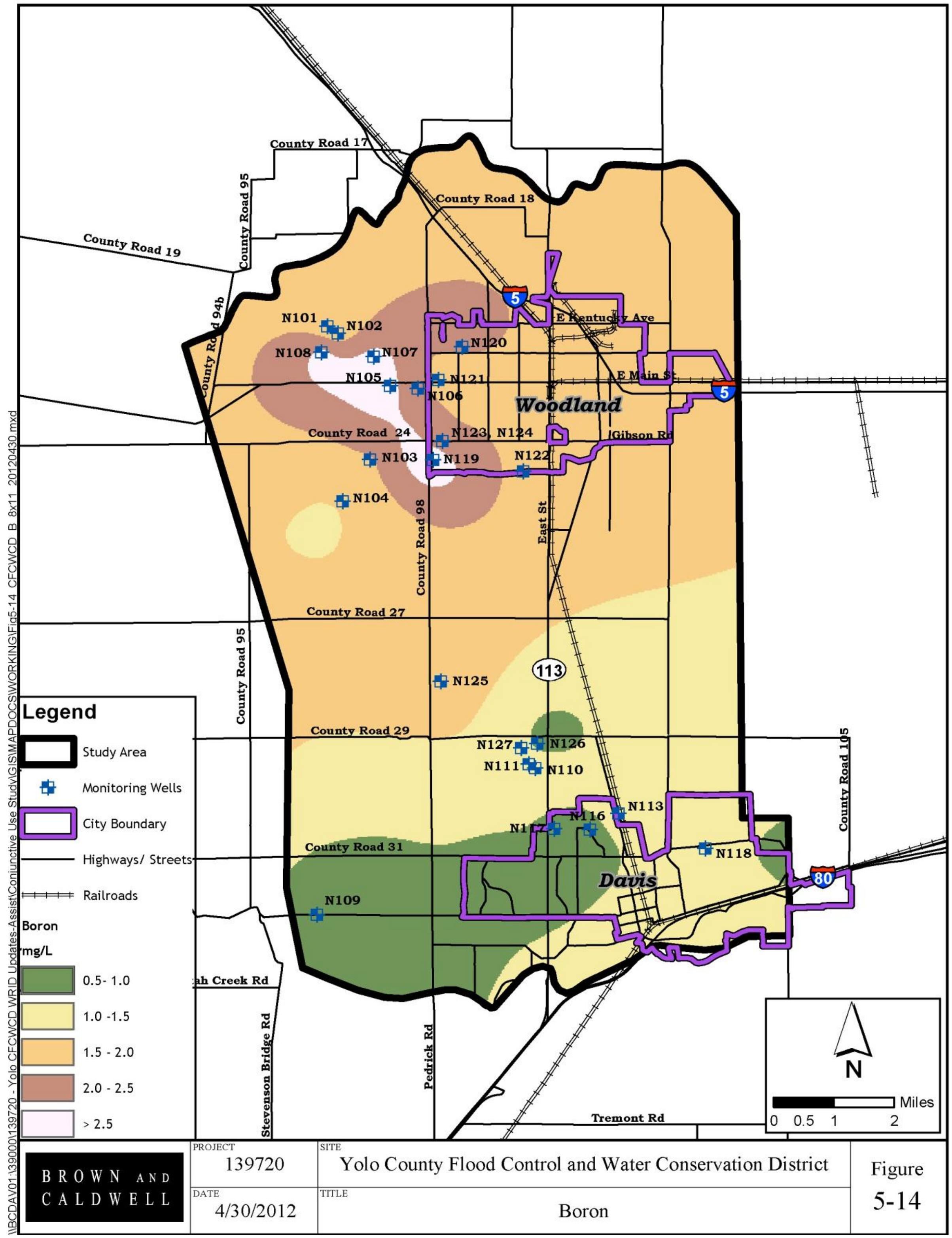

Figure 5-14. Boron Concentration Contours for Wells Sampled in Study. (Contours were mapped for the entire study area, extrapolating into areas were no well sampling occurred. This extrapolation should be used for guidance only.)

As would be expected based on the sources of recharge water, the highest concentrations of boron are southwest of Woodland and the lowest concentrations are southwest of Davis. The high concentrations of boron southwest of Woodland are undoubtedly due to Cache Creek being the original source of groundwater in the area and the subsequent evapoconcentration from the use of mostly groundwater for irrigation.

Section 6

Groundwater Flow Velocities

The apparent groundwater ages given in Section 5 provide some indication of how quickly contaminants are moving into groundwater. Estimates of groundwater flow velocities based on groundwater gradients and hydraulic conductivities can provide an indication of the rate of movement of contaminants once they have entered groundwater. Determination of flow velocities is especially important for understanding risks to municipal wells due to the transport of nitrate and other contaminants originating outside of the city boundaries.

6.1 Aquifer Characteristics

The ability of sand and gravel aquifers to transmit water to wells is typically quantified in transmissivity values. Horizontal hydraulic conductivity of aquifer zones is simply calculated by dividing the transmissivity by the aquifer zone thickness. Vertical hydraulic conductivities can be estimated from material samples or sophisticated pumping tests. Groundwater pore velocities can be calculated using the groundwater gradient times the hydraulic conductivity (Darcy's Law) divided by the effective porosity.

Most of the municipal wells and a few of the non-municipal wells in the study area have been tested for specific capacity, which is the rate of change in production per unit drop in water level in the well. For semi-confined aquifers, the transmissivity can be estimated using the following formula (Driscoll, 1986):

$$T = 1700 * (S.C.)/7.48$$

Where T is transmissivity in ft2/d and S.C. is Specific Capacity in gpm/ft.

The estimated transmissivities (T) and hydraulic conductivities (K) for the wells in the study area with available data are shown in Table 6-1.

Table 6-1. Estimated Aquifer Characteristics for Wells in the Study Area

Well	Est. T, ft2/d	Est. Effective Total Aquifer Thickness, ft	Est. K, ft/d
N109	2131	30	71
N110	5865	37	159
N111	3892	10	389
N116	10021	80	125
N117	5682	55	103
N118	5911	110	54
N126	807	50	16
N127	2552	80	32
Average, Davis Area	4608	n/a	119
N119	2795	65	43
N120	40682	86	473

Table 6-1. Estimated Aquifer Characteristics for Wells in the Study Area			
Well	Est. T, ft2/d	Est. Effective Total Aquifer Thickness, ft	Est. K, ft/d
N121	3205	82	39
N122	18182	164	111
Average, Woodland Area	16216	n/a	166

n/a = not applicable

For comparison purposes, the YCIGSM study listed transmissivities of 4,000 to 18,000 ft^2/d for the Davis area and 10,000 to 105,000 ft^2/d for the Woodland area.

6.2 Horizontal Groundwater Velocities

Groundwater level contours for fall and spring 2010 were shown previously in Figures 4-1 and 4-2. Average gradients for areas around Woodland and Davis are shown in Table 6-2. The average values for hydraulic conductivities and estimated horizontal groundwater velocities are also shown in Table 6-2. Estimates for pore groundwater velocities assumed an effective porosity of 0.4.

Table 6-2. Estimated Average Horizontal Groundwater Gradients and Velocities		
Area	Gradient, [(a)] ft/ft	Est. Avg. Pore Velocity, ft/yr
Northwest of Davis	0.00380	411
North Central Davis	0.00113	122
Southwest of Woodland	0.00260	395
Northwest of Woodland	0.00155	235

[(a)] *Gradients based on averages of 2010 spring and fall values.*

The calculated velocities shown in Table 6-2 are only rough averages for the respective areas. There is a high degree of localized variability in hydraulic conductivity as shown previously in Table 6-1. However, on average, groundwater could travel up to approximately 400 feet per year (a mile in 13 years) in the study area. Actual transport velocities for constituents of concern would vary based on dispersion, adsorption, and localized hydrogeologic factors. The potential for horizontal transport velocities of up to 400 feet per year highlights the particular risks for substantial amounts of nitrate in groundwater from agricultural areas to reach municipal wells near the southwest side of Woodland and the northwest side of Davis in less than a couple of decades. This has already been seen dramatically in some of the Woodland wells.

6.3 Vertical Groundwater Movement and Cross-Contamination

The water balance in the YCIGSM study gave an estimate of 61,400 ac-ft/yr of deep percolation in the 51,000 acre East Yolo South subregion. This would equal a deep percolation rate of 1.2 feet per year. Using the data from the YCIGSM study and the WRID, depth to first groundwater in the study area appears to be approximately 10 to 30 feet. Assuming an average of 20 feet of travel through the vadose zone, this would translate to about 5 years for uniform piston style flow. Assuming an additional 100 feet to the first tapped groundwater zone, the total travel time assuming piston flow would be roughly 40 years. In reality, water flows preferentially through larger pores and channels. With typical preferential flow, the leading edge of contamination at the ground surface could reach the first tapped groundwater zone in a couple of decades. The presence of improperly abandoned old shallow wells would further increase the rate of downward migration by providing flow conduits.

Irrigation pumping in the summer and municipal/residential pumping in the winter will frequently provide a downward differential pressure between the shallow and deeper groundwater zones. During these periods, wells not running that are screened across multiple zones can serve as conduits for vertical transmission of water from shallow zones to the deeper zones. Therefore, once contamination reaches the first zone tapped by a significant number of wells, it can rapidly migrate downward into deeper zones.

Evidence of rapid vertical migration between screened aquifer zones is visible in the CFC apparent age data as shown in Figure 6-1. Although there is a large amount of variability, the CFC apparent age of water from wells with a weighted average screen depth of 400 feet is only about 15 years older than water from wells with a weighted average screen depth of 150 feet (17 ft/year effective vertical travel time).

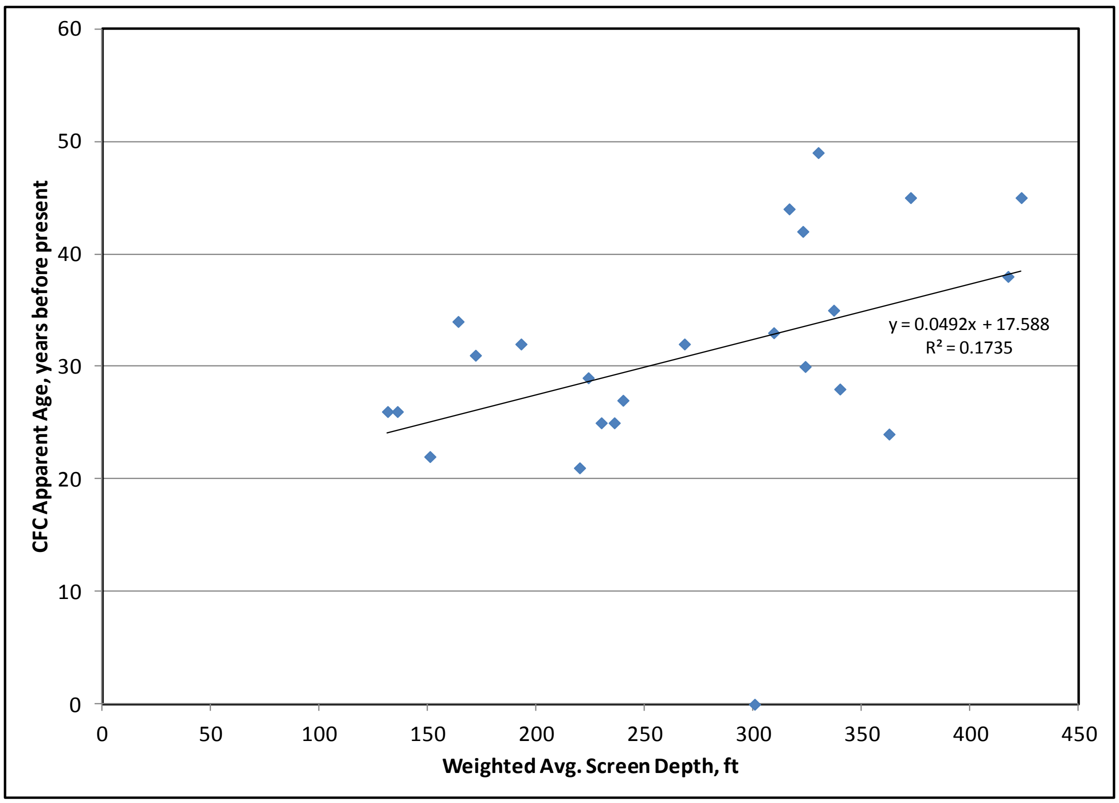

Figure 6-1. CFC Apparent Age versus Average Screen Depth

Section 7

Conclusions and Recommendations

7.1 Conclusions

The data from the study supports several conclusions regarding the sources of constituents of concern to groundwater, water quality risks to municipal wells, and the potential risks to groundwater quality as a result of a conjunctive use program by YCFCWCD.

7.2 Sources of Groundwater Nitrate Contamination

The results of this study are consistent with the results from the CV-Salts Pilot Study for Yolo County (Larry Walker Associates, 2010) and the broad findings from the UC Davis study of nitrate sources to groundwater in the San Joaquin and Salinas Valleys (Harter and Lund, 2012). Fertilizer applications to irrigated agricultural lands appear to be the greatest source of nitrate to groundwater in the study area, followed by soil nitrate from weathering and organic nitrogen mineralization. There appears to be some contribution of nitrogen to groundwater from manure or septic systems in north-central Davis and possibly a small amount northwest of Woodland in residential wells closest to Cache Creek.

Nitrate concentrations are strongly correlated with groundwater hardness in the study area, indicating deep percolation from agricultural and turf irrigated areas as the predominant source of nitrate. Nitrate concentrations are somewhat correlated with CFC apparent age of groundwater, with younger water having higher concentrations of nitrate. Downward vertical transport of nitrate has likely been enhanced by wells screened across multiple zones and by improperly abandoned old wells.

7.3 Water Quality Risks to Municipal Wells

Wells on the southwest side of Woodland appear to be affected by nitrate from agriculture and have risk of further contamination into deeper screened zones. Although wells in northwest Woodland have definitely been affected by nitrate contamination from agriculture, the dilutive effect of seepage from Cache Creek may slow the rate of increase over time, especially for deeper zones. Wells in eastern Woodland were not evaluated as part of this study.

Wells on the northwest side of Davis and in the Davis Golf Course and North Davis Meadows areas also have substantial risk of further nitrate contamination into deeper screened zones. The relatively greater first screen depth and average weighted screen depth for the Davis municipal wells appears to have slowed the rate of increase of nitrate concentrations in those wells compared to other wells in the study area. Wells further east in Davis appear to have groundwater that is more pristine and with less risk for nitrate contamination.

Wells in the southwest portion of Woodland appear to have a risk for gradual increases in salinity and boron concentrations over time because the recharge to the upgradient area is mostly from deep percolation under agricultural lands irrigated with groundwater. The salt and boron concentrations will likely continue to increase due to evapoconcentration effects. Wells in the Davis area tend to be slightly higher in salinity and lower in boron.

Selenium occurs naturally in certain intermediate depth aquifer zones, especially in the municipal wells. Selenium concentrations are lower in residential and agricultural wells upgradient of the cities of Woodland and Davis. Selenium concentrations in municipal wells will likely decrease over time as upgradient groundwater flows towards the municipal wells.

7.4 Potential Effects of Conjunctive Use

Conjunctive use would increase the use of YCFCWCD (Cache Creek) water to recharge groundwater in the study area in most normal or wet years. The recharge effects would be positive in that the Cache Creek water used for recharge would have much lower in nitrate and salinity concentrations than deep percolation from farmland, thereby diluting the nitrate and salts in groundwater over time.

In dry years, the YCFCWCD would pump additional groundwater from the study area into its canals. The increased groundwater pumping would accelerate downward vertical movement of deep percolate. Over the next decade or so, that could increase the rate of transport of existing constituents into aquifers. However, this effect would be short term and more than offset by the benefits of the higher quality recharge during wetter conditions.

7.5 Potential Actions to Reduce Risks to Municipal Water Wells

There are a number of actions that could potentially benefit water quality in municipal and other drinking water supply wells over the long term. These are summarized in Table 7-1.

Table 7-1. Potential Actions to Reduce Risks to Municipal Drinking Water Wells

ID	Potential Action	Benefit
1	Conjunctive Use	More recharge with better quality water
2	Lower Fertilizer Use Rates	Reduced nitrate in deep percolate
3	Drip Irrigation of Crops	Better fertilization control, reduced nitrate in deep percolate
4	Convert Row Crops to Trees	Could allow reduced fertilizer usage, especially as trees mature
5	Complete Ag Wells in Shallower Zones Only	Would reduce downward movement of nitrate and salts to zones tapped by municipalities
6	New Deep Wells in Woodland	No nitrate, selenium, or chromium
7	Properly Destroy Abandoned Wells	Reduce vertical flow paths for contamination

The potential actions shown in Table 7-1 are listed without regard to difficulty of implementation. Some of the actions, such as #3 and #4, are already happening due to free market forces. Lowering overall fertilizer use rates (#2) independently of actions #3 and #4 could be administratively and politically difficult to implement. Action #5 would have to happen over time as wells need to be replaced and would probably require incentives for participation. Action #6 has good potential, but may require additional wellhead treatment for constituents such manganese that are found in deep wells. Action #7 would likely require an organized program with supplemental incentive funding for proper well destruction costs.

Section 8

Limitations Statement from Brown and Caldwell

Assistance provided in preparing this document was solely for the Yolo County Flood Control and Water Conservation District in accordance with professional standards at the time the services were performed and in accordance with the contract between YCFCWCD and Brown and Caldwell. This assistance provided for this document is governed by the specific scope of work authorized by YCFCWCD; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by YCFCWCD and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

Section 9

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Appendix A: Fertilizer Sales Data

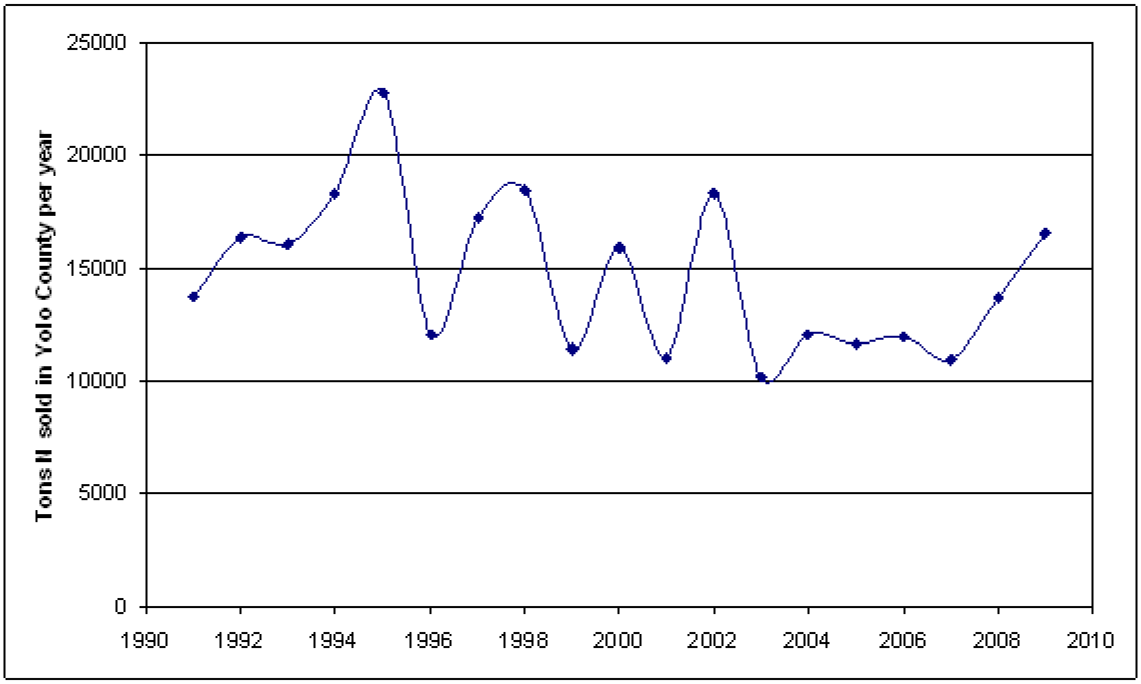

Figure A-1. Annual Sales of Nitrogen Fertilizer in Yolo County

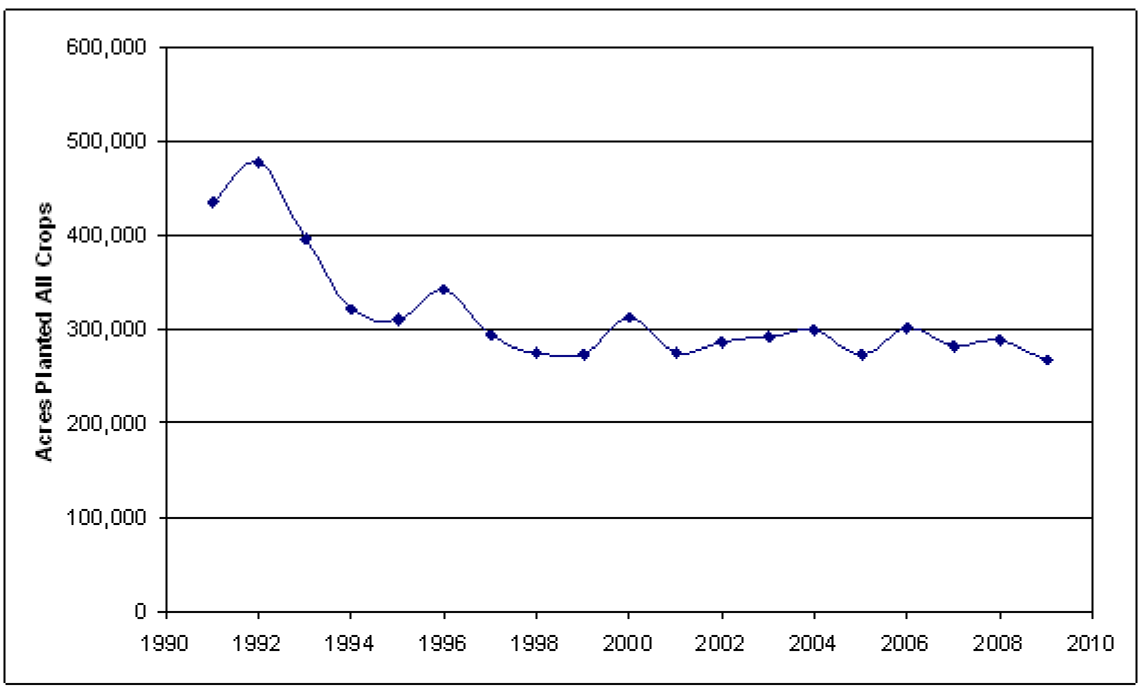

Figure A-2. Farmland Acreage Planted in Yolo County

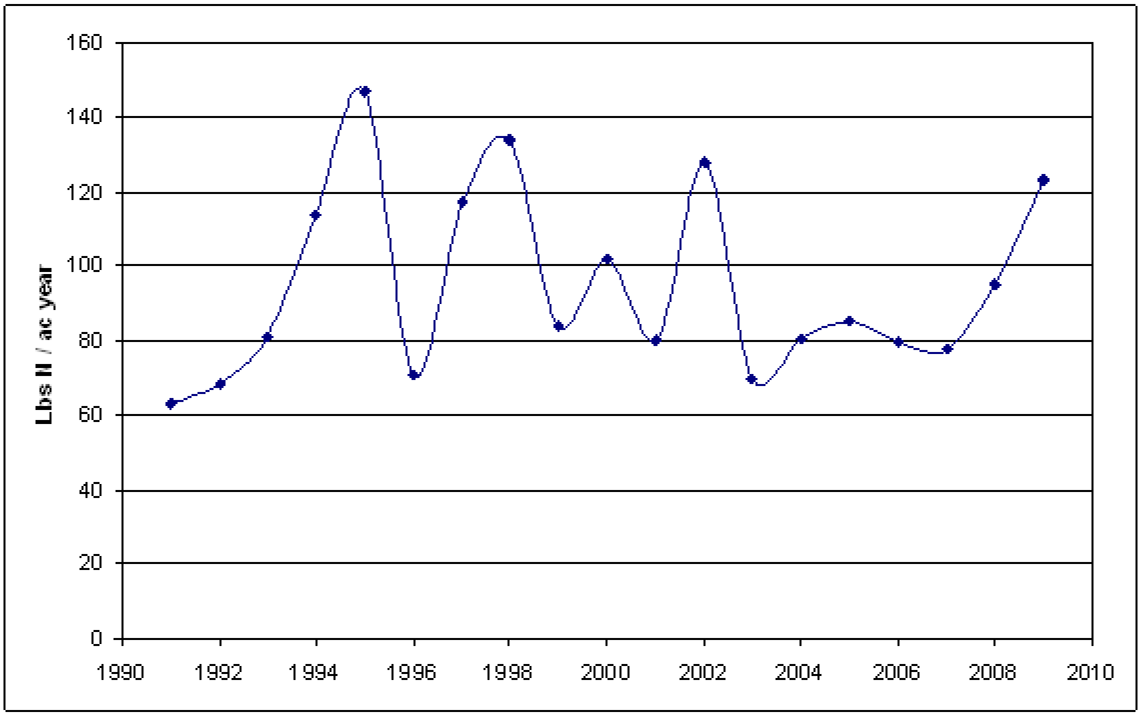

Figure A-3. Calculated Annual Nitrogen Fertilizer Use per Acre in Yolo County

CDFA FERTILIZING MATERIALS TONNAGE REPORT Jan-June 2009. California Dept of Food and Ag. Feed, Fertilizer, and Livestock Drugs Regulatory Services, Division of Inspection Services. Sacramento, CA 95814 http://www.cdfa.ca.gov/is/fflders/Fertilizer_Tonnage.html

Acres Planted data from: Kegley, S.E., Hill, B.R., Orme S., Choi A.H., PAN Pesticide Database, Pesticide Action Network, North America (San Francisco, CA, 2010), http:www.pesticideinfo.org. http://www.pesticideinfo.org/List_CA_Chem_Use.jsp?chk=00&cok=57&sk=00

Appendix B: Sampling and Analysis Work Plan

Brown AND Caldwell

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Prepared for: Yolo County Flood Control and Water Conservation District (YCFCWCD), Woodland, California

Project Title: Regional Conjunctive Use Enhancement Feasibility Study

Project No: 139720

Subject: Field Sampling Plan

Date: May 27, 2011 (date originally prepared)

May 8, 2012 (format revised)

To: Max Stevenson, YCFCWCD

From: Rob Beggs

1. Introduction

This field sampling plan describes planning and logistics under the Regional Conjunctive Use Enhancement Feasibility Study. The overall objective of this task is to use water quality and isotope data from wells to evaluate water quality risks to municipal water supply wells and whether conjunctive use actions could potentially affect those risks.

1.1 Scope of Work

BC will sample 24 shallow production and monitoring wells near and within the cities of Davis and Woodland, Cache Creek, and Putah Creek surface waters. The effort will be split into two separate mobilizations; the first will include 5 wells and the second will include the remaining 21 wells and creeks. A list of sampling locations is provided below (Table 1). The samples will be analyzed for general minerals, electrical conductivity (EC), boron, manganese and selenium; and stable isotope ratios and chloroflourocarbons (CFCs) for age determinations. The general minerals group will include nitrate.

Table 1. Sampling Locations

YCFCWCD ID	Sampling Location Description	Well Location	Sample Port Status
N101	Shop/Business	10N01E26C001M	Yes
N102	Residential Well	10N01E26C002M	No
N103	Ag Well	No SWN	Yes
N104	Residential Well	09N01E02Q001M	Yes
N105	Shop/Business Well	10N01E36C001M	No
N106	Residential Well	10N01E36A002M	No
N107	Shop/Business Well	10N01E25M002M	No
N108	Residential Well	10N01E26E003M	Yes
N109	Residential Well	08N01E11N001M	No
N110	Davis Golf Course 1	09N02E32G002M	Yes
N111	Davis Golf Course 2	09N02E32G001M	Yes
N113	Davis MW F St. Shallow	Not available	To be determined
N116	Davis #19	08N02E04K001M	Yes
N117	Davis #27	08N02E04M001M	Yes
N118	Davis #15	08N02E02Q001M	Yes
N119	Woodland #17	09N02E06E001M	Yes
N120	Woodland #10	10N02E30G001M	Yes
N121	Woodland #20	10N02E30N001M	Yes
N122	Woodland #16	09N02E05G001M	Yes
N123	Woodland 25 MW Shallow	Not available	To be determined
N124	Woodland 25 MW Int.	Not available	To be determined
N125	Ag Well	09N02E19P001M	No
N126	North Davis Meadows #1	09N02E32C001M	Yes

Table 1. Sampling Locations			
YCFCWCD ID	Sampling Location Description	Well Location	Sample Port Status
N127	North Davis Meadows #2	09N02E32C002M	Yes
N128	Cache Creek at Capay Dam	Not available	Not Needed
N129	Putah Creek	Not available	Not Needed

1.2 Field Logistics

Brown and Caldwell will team with YCFCWCD staff for every sampling event. Team members will coordinate prior to mobilizing to determine well IDs and meeting locations. YCFCWCD staff will interface with all well operators and owners to provide access and ensure that the well is operational and outfitted with the appropriate sample port.

Brown and Caldwell staff will fill all containers, as described below. In general, field sampling will require containment and processing. The estimated time for sampling at each wellhead is 1 to 2 hours.

1.3 Sample Management and Submittal

This section describes field methods and sample submittal requirements. A list of analytical laboratory contacts is provided as Table 2.

1.3.1 University of Utah

CFC analysis

1. See US Geological Survey sampling procedures (Attachment A) (in short, put bottle into beaker, fill bottle directly from copper tubing and let it overflow, cap, and wrap cap with electrical tape to seal).
2. Repeat to fill a total of 3 100 mL bottles.
3. It is best that the water contacts no plastics (CFC will absorb and leach from plastics).

Tritium analysis (First 5 wells only)

1. Uses 2 500 mL Nalgene plastic bottles (or comparable).
2. Do not have any "glowing" items in contact with the water sample when sampling as luminescence from such items contain small amount of tritium.

Helium 3 and noble gas analysis (First 5 wells only)

1. Requires copper tubing sampling technique. See attached sampling procedures (Attachment B).

- Samples should be shipped without ice in coolers or appropriate boxes.
- There are no analyte hold time limitations.
- Water conductivity, temperature and wellhead elevation should be provided in mean sea level to laboratory.
- Deliver all to Alan Rigby under Brown and Caldwell chain of custody.

1.3.2 University of California Davis Stable Isotope Facility

Nitrogen 15 Analysis

1. Collect samples in 1 30-60 mL Nalgene type bottle.
2. Must freeze, if possible. Otherwise, chill on ice and deliver within 24 hours.
3. http://stableisotopefacility.ucdavis.edu/no3samplepreparation.html
4. Deliver to Katherine Pecsok with lab's sample list.

1.3.3 University of California Davis Analytical Laboratory

Nitrate, EC, Boron, Selenium, Manganese, General Minerals

1. Collect samples in 2 500 Ml Nalgene bottles.
2. Must chill on ice and deliver within 24 hours.
3. Deliver to Nikki Schwab/Dirk Holstege with lab's sample list.

1.3.4 Department of Water Resources

Stable Isotopes – 018 and Denterium

1. Collect samples in 1 20 mL glass vial.
2. No chilling required, no hold time.
3. Deliver to Bill Brewster under Brown and Caldwell chain of custody.

Table 2. Laboratory Contacts	
Alan Rigby **University of Utah, Dept. of Geology and Geophysics** 115 South 1460 East, Room 383 Salt Lake City, UT 84112 (801) 585-5214 office (801) 232-3026 cell	Katharine Pecsok Ewert **UC Davis Stable Isotope Facility** Plant and Environmental Sciences Bldg., Rooms 3112 or 2255 One Shields Ave, MS 1 Davis, CA 95616 (530) 754-7517 office
Bill Brewster **State of California Department of Water Resources** 3500 Industrial Blvd West Sacramento, CA 95691 (916) 376-9622 office (916) 952-9162 cell	Nikki Schwab/ Dirk Holstege **UC Davis Analytical Lab** Hoagland Annex University of California One Shields Avenue Davis CA 95616 (530) 752-0147 office (530) 752-0266 receiving Area

Attachment A

The Reston Clorofluorocarbon Laboratory, CFC Sampling Method,
US Geological Survey

The Reston Chlorofluorocarbon Laboratory

CFC Sampling Method - Bottles

A procedure that involves filling and capping simple glass bottles with special foil-lined caps under water has been tested. Samples analyzed after storage over 6 months demonstrate the validity of the new method. This document describes the sampling procedure and presents results of tests with the CFC bottle method.

CFC bottle method

If archival of water samples for CFC or other VOC analysis for periods of more than 6 months is required, then it is recommended that water samples be collected in fused borosilicate ampoules, as before (Busenberg and Plummer, 1992). Otherwise, water samples for CFC analysis can be collected in glass bottles capped with a special foil-lined cap, as described below.

Source of bottles and caps

Bottles and caps can be obtained from the Scientific Specialties company at 800-648-7800. The bottles are 125ml (4 oz) boston round clear glass and have a cap size 22-400.

Item No. B73504 is a case of 24 bottles with teflon lined caps. **These bottles have the wrong caps!** Discard these caps and replace them with the caps below.

Bottles are also available from any Wheaton glass supplier as Wheaton part number 217112, which is a case of 24 bottles with no caps.

The caps are sold as Scientific Specialties item no. A69522, white plastic caps with aluminum foil liner in a bag of 72. **Use only these aluminum lined caps! This cap is the key to the method.** Discard any caps, if the foil liner appears scratched, dented, or altered in any way.

Filling procedure

Instruction given below must be followed to the letter to obtain good results with the bottle sampling method for CFCs in ground water.

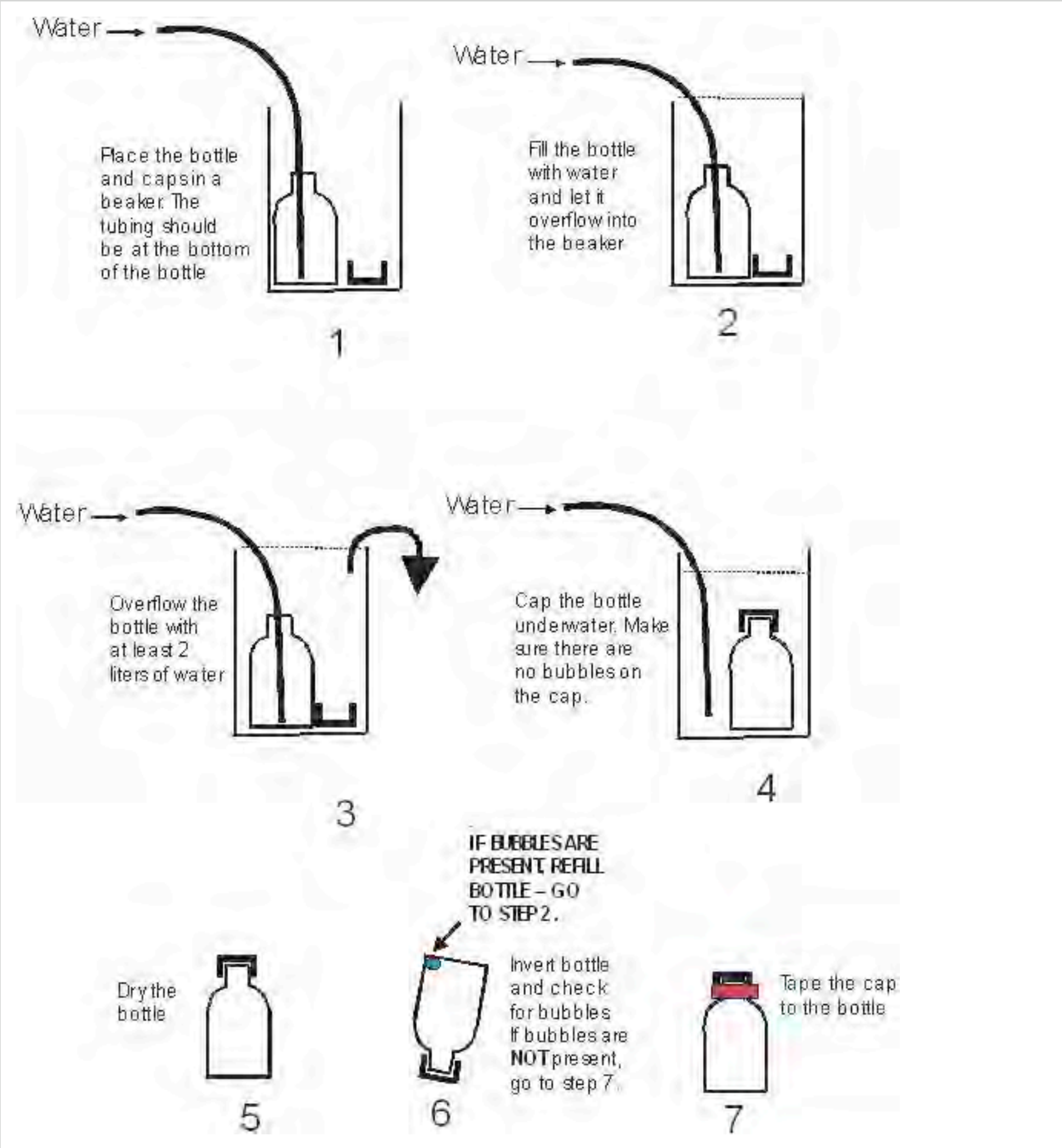
We are receiving too many samples with loose caps and caps that are not properly taped (see below for examples).

The bottles and caps should be **thoroughly** rinsed with the ground water. The bottles are filled **underwater in a beaker and capped underwater**. Refrigeration-grade copper tubing is required. The filling procedure is carried out within a two to four liter beaker. A plastic beaker is fine. Collect 5 bottles per well or spring.

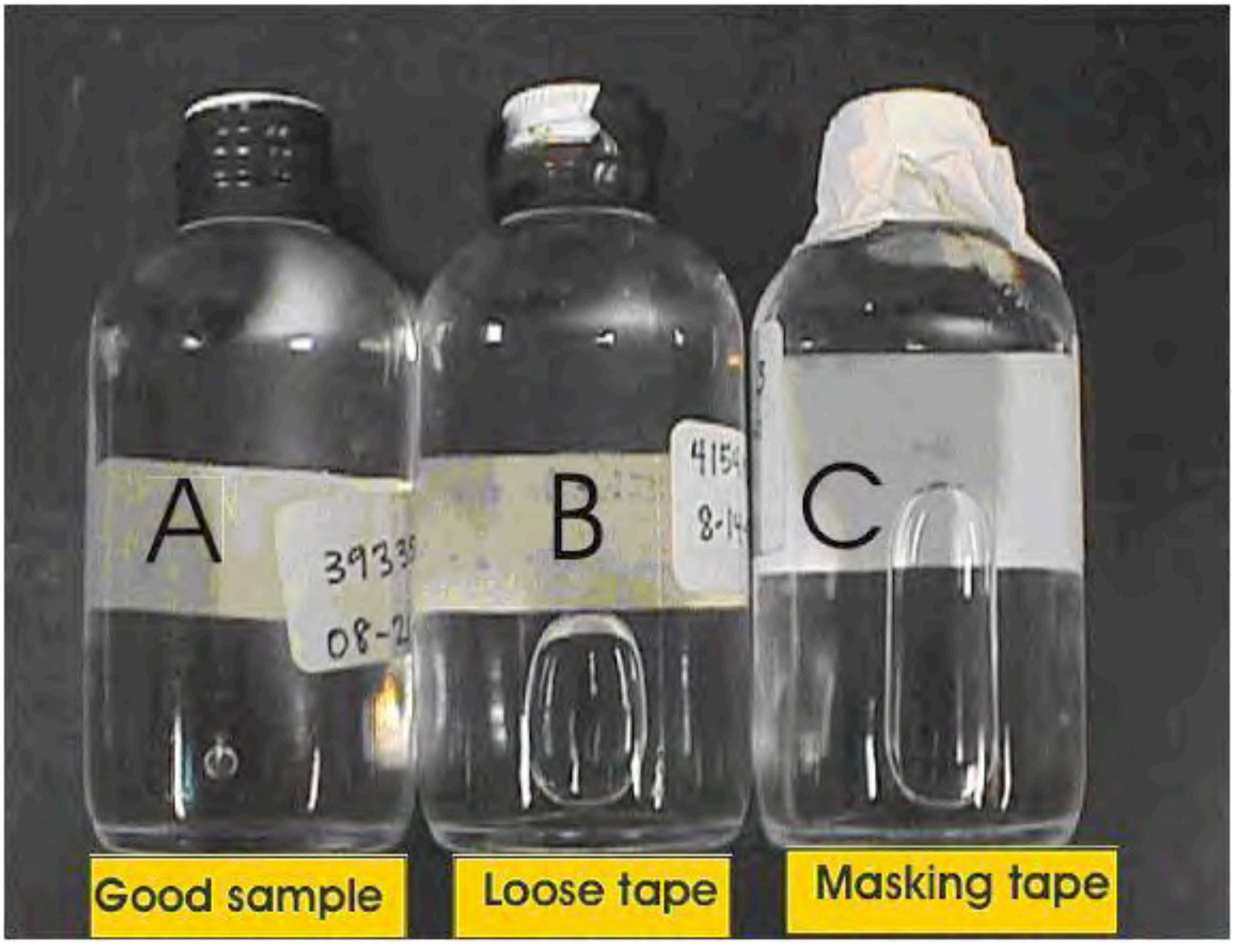
The procedure is shown below:

1. After the well has been purged, place the bottle in the beaker and then insert the end of the copper tubing from the pump all the way into the **bottom** of the bottle.
2. Fill the bottle as shown with well water until it overflows.
3. Continue to overflow the bottle until the beaker overflows. Allow at least 2 liters of water to flow through the bottle and out of the beaker.
4. Select a cap and tap it under water to dislodge air bubbles. Remove the copper tube from the bottle and **tightly cap the bottle underwater** without allowing the water in the bottle to come in contact with air. Flushing the bottle with more water is far better than with less water.
5. Remove the capped bottle from the beaker, dry the bottle and **RE-tighten** the cap. The tighter the cap the better.
6. Invert the bottle, tap it and check it for air bubbles. If there are bubbles, repeat the procedure from step 2 above. If it is necessary to refill the bottle, you must use a **new** cap.

7. If there are no bubbles present, tape the cap securely to the bottle with electrical tape. Wrap the tape in a clockwise direction looking down from the bottle top. Two rounds of electrical tape are needed. Do not forget to label each bottle with the well name, date, and time of sampling and the sequence number of each bottle as it was collected, one through five, in the order of collection.
8. Store bottles upside down until shipment. A bubble will form in most samples. This is normal.



Examples of properly and improperly sealed bottles



A. Good example. Very tiny bubble formed.
B. Poorly taped cap, air leak - note the large bubble that formed.
C. Cap taped with masking tape, poor seal and large air bubble formed.

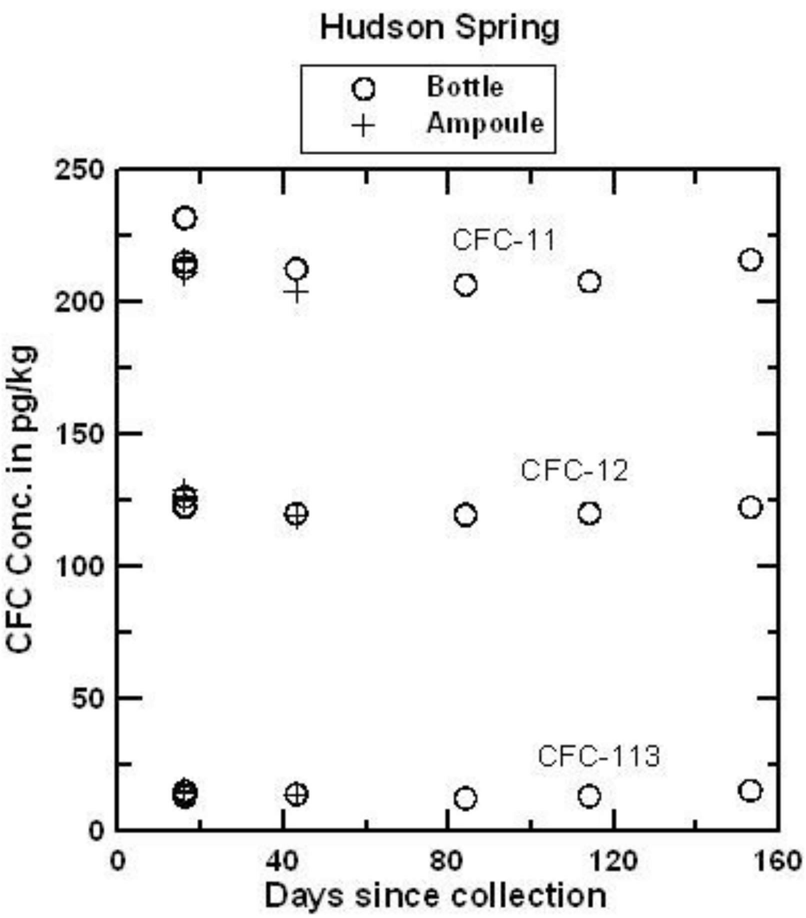
Results of tests comparing CFC analyses of waters collected in ampoules and in bottles

A large number of ampoules and bottles were collected from two sources--

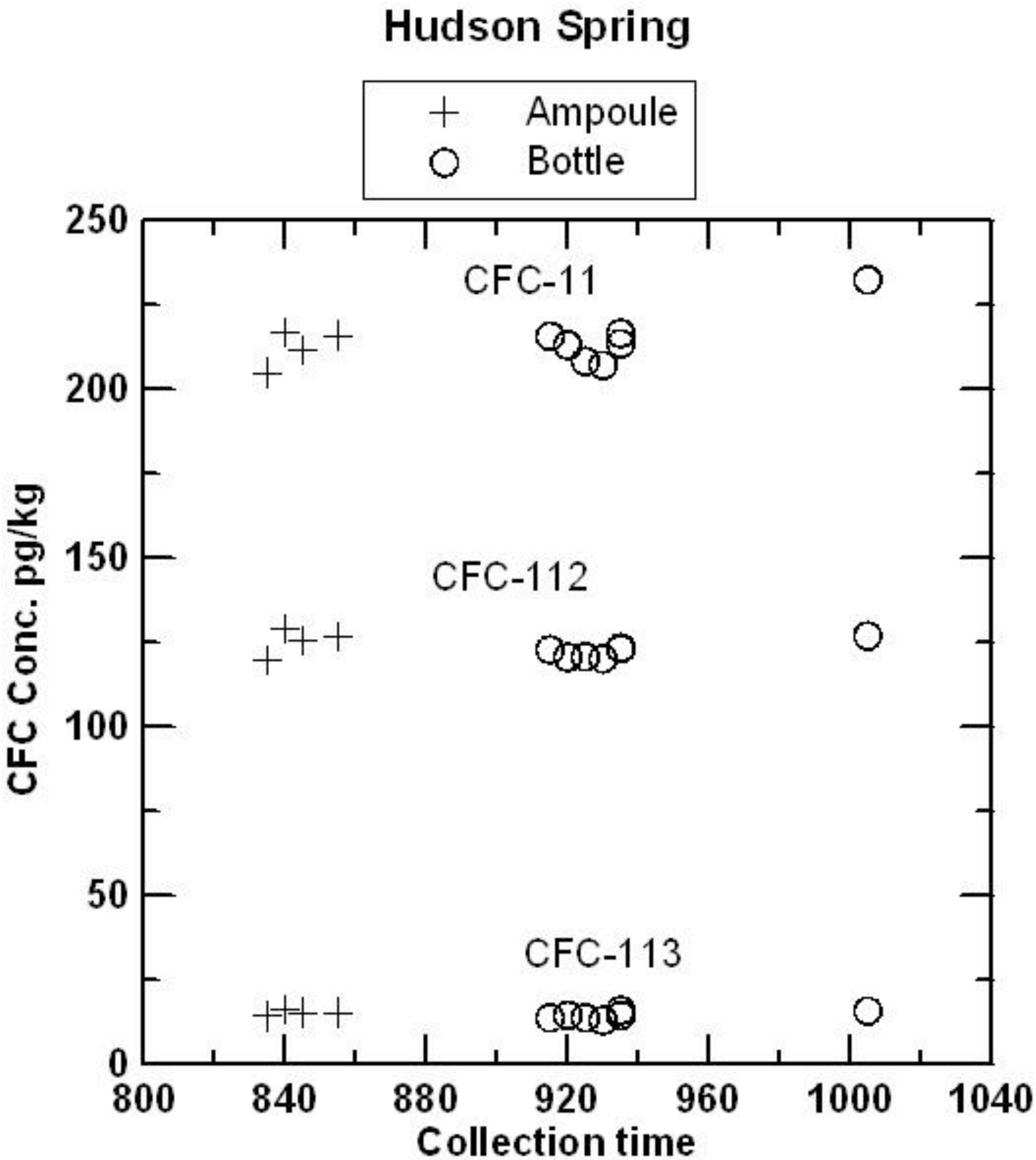
(1) water from Hudson Spring which discharges from a limestone karst near the base of the Blue Ridge Mountains at Luray, Virginia, and

(2) water from a deep well in Coastal Plain sands near Milford, Virginia.

Hudson Spring has been sampled for CFCs and $^3H/^3He$ over a period of several years and has consistently yielded water with mid-1970s apparent age. Water from the Milford well was expected to be at or near the detection limit for all CFCs. The comparison of ampoules and bottles has continued for 153 days for water from Hudson Spring and 98 days for water from the Milford well. CFC concentrations in water from the Milford well were near or below the detection limit of 2 pg/kg in both ampoules and bottles. In a few cases, water from the Milford well contained detectible CFC-12 but pairs of ampoules and bottles agreed within ± 1 pg/kg in a range of 0 to 10 pg/kg (pre-1954 water). Apparently, there was some small variation in the CFC composition of water discharged from the well. CFC-113 was not detected in either ampoule or bottle, which eliminated the possibility of air contamination during storage. There was an interference of an unknown VOC that gave the appearance of 4-5 pg/kg of CFC-11. Even with the trace interference. The interpreted apparent CFC-11 recharge date was be pre-1950 for CFC-11 which is near the detection limit of the dating method. The figures below compare concentrations of CFC-11, CFC-12, and CFC-113 measured in water from ampoules and bottles from Hudson Spring, as a function of storage time and as a function of collection time. The tests are being continued, but preliminary results indicate that blanks can be collected and stored using the bottle method. It is anticipated that water samples collected in bottles will be analyzed within 4 months of the date they are received at the Reston Chlorofluorocarbon Laboratory. Samples should be shipped promptly to the Reston Chlorofluorocarbon Laboratory following collection.

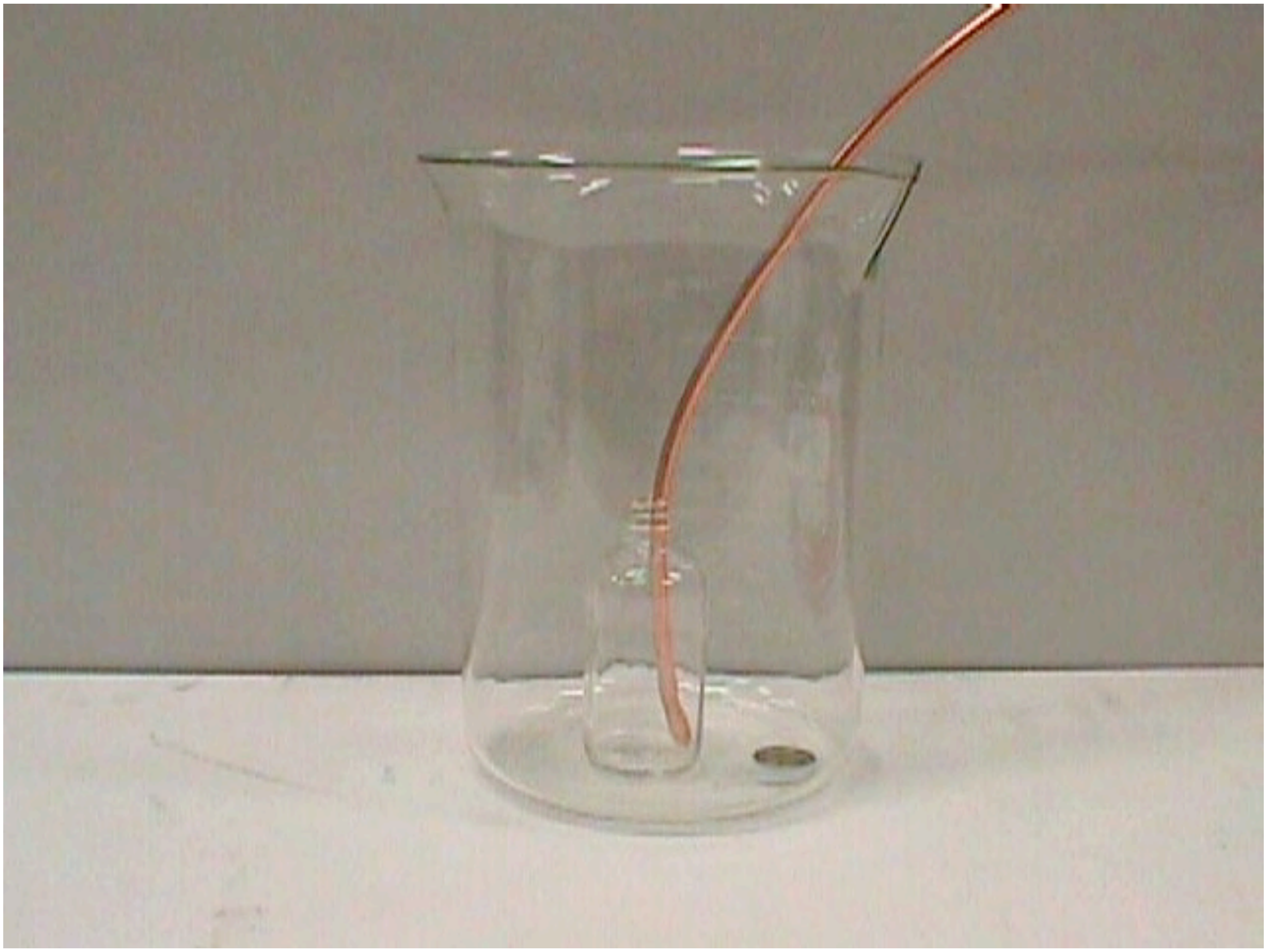


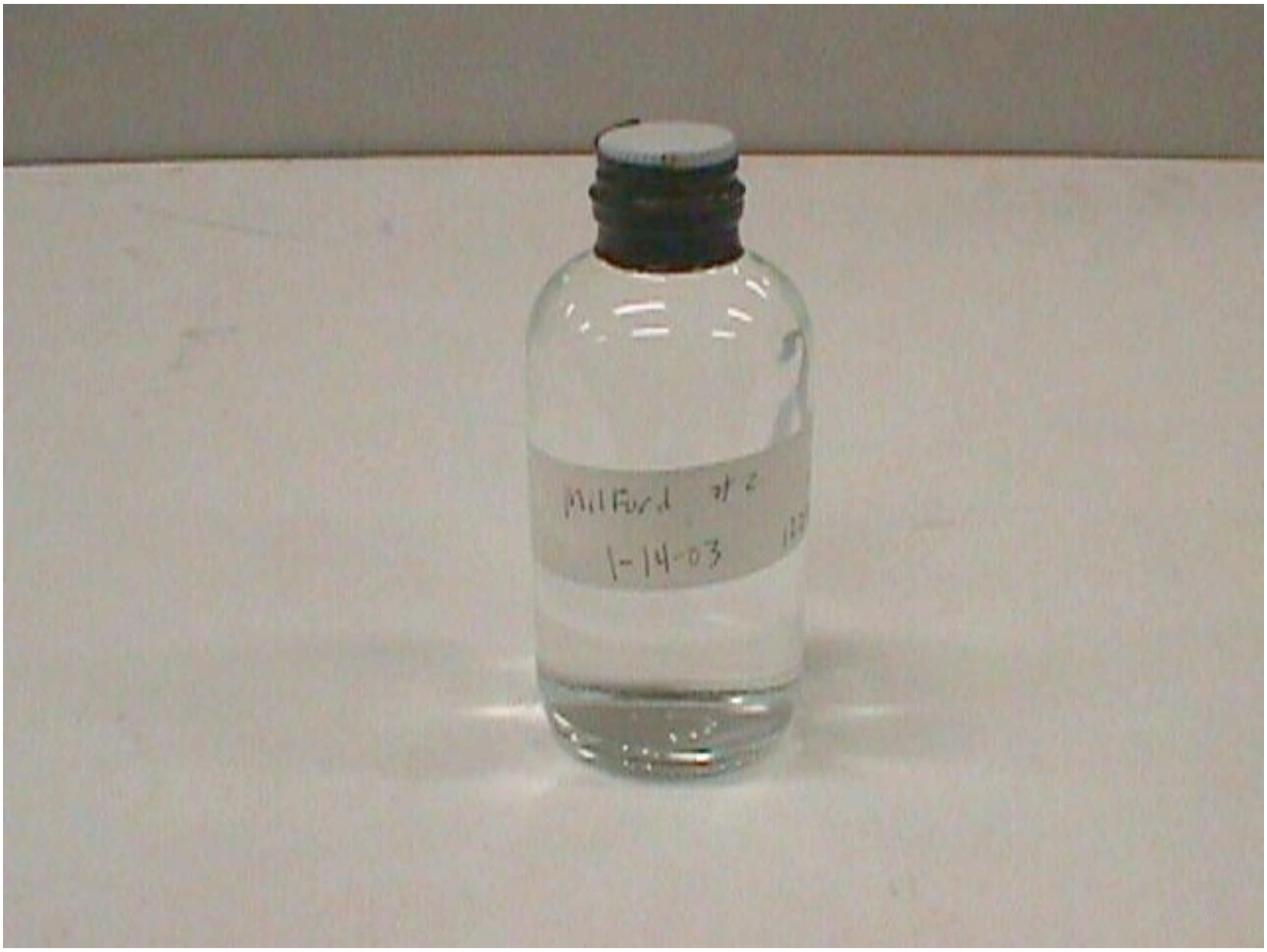
Plot comparing CFC-11, CFC-12 and CFC-113 concentrations in water from Hudson Spring analyzed after storage of more than 40 days in fused borosilicate ampoules and more than 150 days in glass bottles. In the apparent recharge age of the water. The small variations in CFC concentrations are equivalent to differences of less than 0.5 years. And as shown below, the small differences in likely reflect differences in concentrations in discharge from the spring over the period of collection of ampoules and bottles (several hours), rather than changes on storage.



Comparison of CFC-11, CFC-12, and CFC-113 measured in ampoules and bottles plotted in sequence of field collection. The plot suggests that at least some of the very small variations observed represent real variations in water composition discharging from the spring, rather than changes occurring during storage.

Photos





Accessibility FOIA Privacy Policies and Notices

U.S. Department of the Interior | U.S. Geological Survey
URL: http://water.usgs.gov/lab/chlorofluorocarbons/sampling/bottles/
Page Contact Information: cfc@usgs.gov
Page Last Modified: Monday, 13-Aug-2007 15:18:26 EDT

Attachment B

Dissolved Gas Sampling, University of Utah

Dissolved Gas Sampling using Copper Tubing

Dissolved Gas Lab

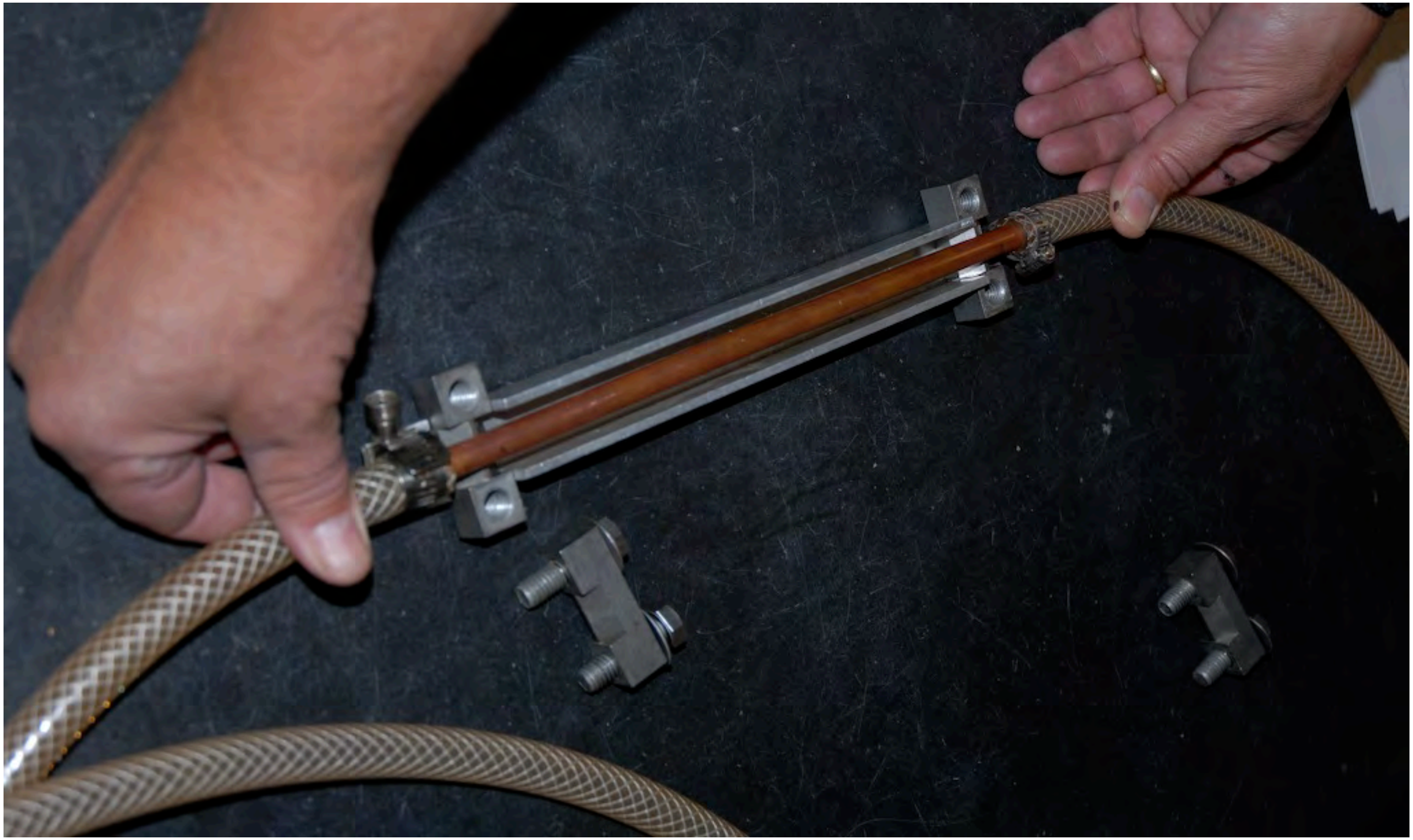
University of Utah

General Comments

- Dissolved gas water samples must be collected according to the procedures described to prevent common sampling artifacts. The most common problem in sampling for noble gases is bubble formation. If the sampling equipment is not leak-tight, air bubbles may form as outside air is pulled into the sampling-string. Noble gases have low solubilities in water and even a very small bubble can provide enough of a gas phase for noble gases to partition into it, thereby stripping the water. Purging water through the sampling-string too quickly under a vacuum can lead to bubble formation, effectively degassing the water. The converse of these situations can also occur; a bubble that contains partitioned gasses can be trapped within the sample volume resulting in dissolved gas concentrations higher then expected.
- Sampling quality is of utmost importance for accurate dissolved gas measurements; several precautions can be taken to reduce the risk of bubble interference. First, several liters of water are purged through the sampling-string to flush it. Second, while purging the system, a tool (wrench or other metal object) is used to tap the tubing of the sample string along its entire length. This helps dislodges air bubbles from the inside of the copper tube and connected equipment, allowing them to flush out of the system. Third, a visual inspection is made throughout the purging process for bubble formation; using the clear flexible tubing portion of the sampling-string. Fourth, a valve is used downstream of the sampling tube to provide backing pressure if bubbles are present. This can occur when samples are collected from depth, the reduction in hydrostatic pressure as the sample is brought up can cause bubble formation to occur. By watching the water flow through the plastic tubing and slowly turning the valve provided, bubble formation can usually be eliminated.
- In our experience, the best pumps for dissolved gas sampling are electric submersibles that can be regulated to produce a low flow (e.g. the Redi-Flo II or similar.)
- Dedicated bladder pumps can be a problem especially if they employ a teflon bladder. The teflon is fairly permeable to gases, especially helium.
- If it is not possible to use a low flow submersible pump, we recommend that you discuss the issue with the lab before sampling (801-585-5214)

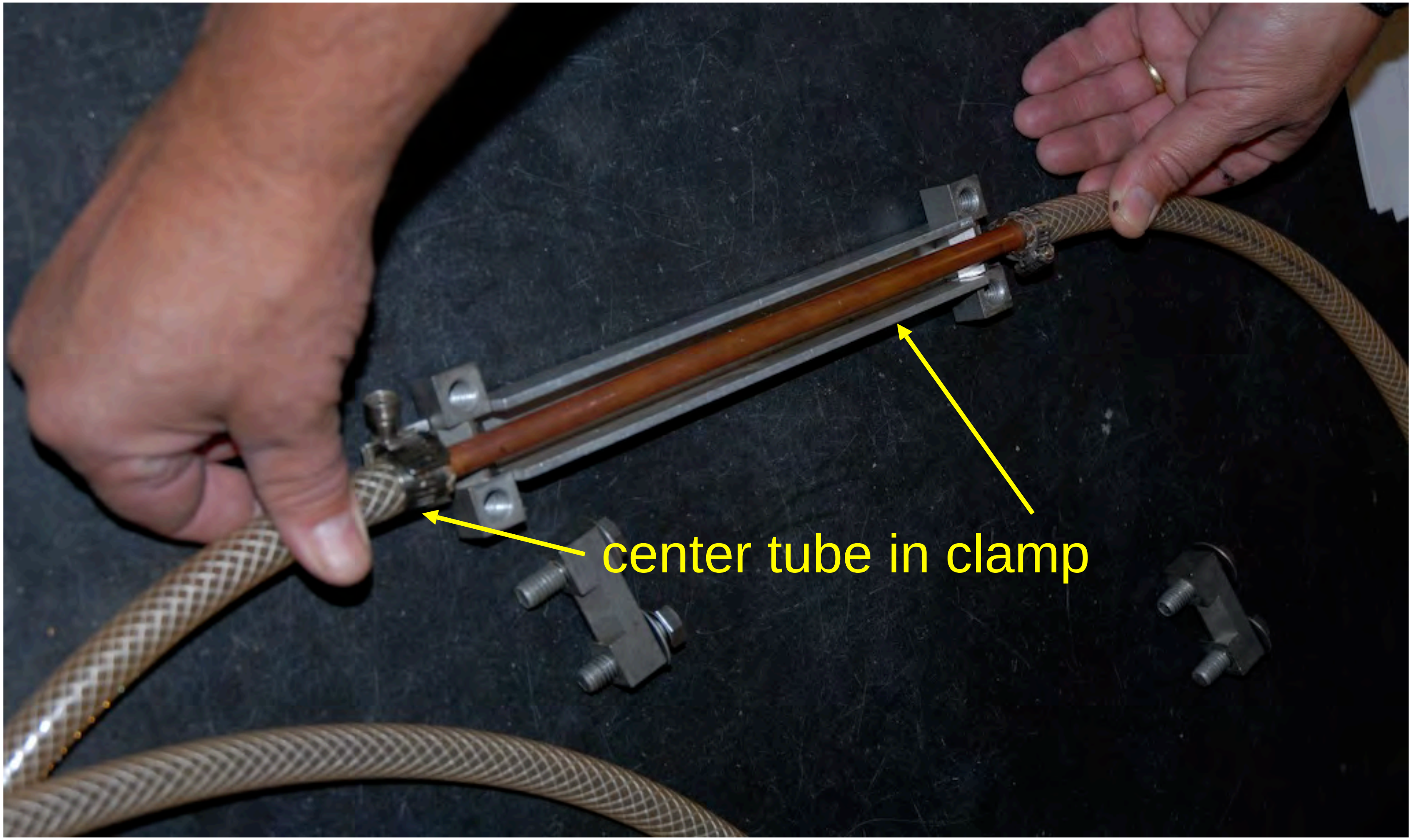
Sampling Procedure

- Place the metal pinch clamps in the holder and secure them using a short screw (10-32) - one screw for each clamp. Using the screw is not absolutely essential, but helps especially if sampling alone. NOTE: Not all of our clamps have hole in the bottom for this.

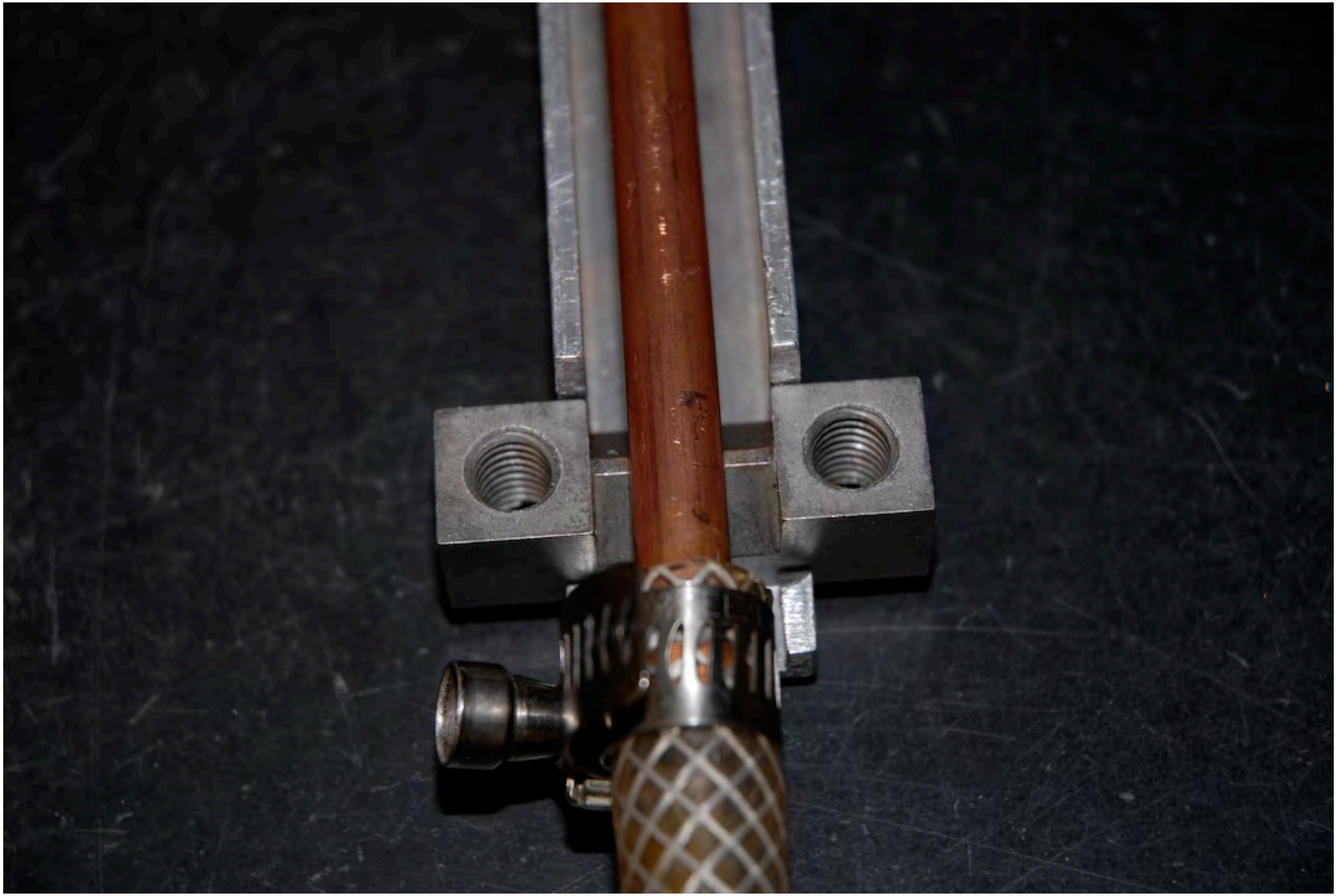


- Insert the copper tube into the plastic hose about 2 cm and secure using the hose clamps as shown.

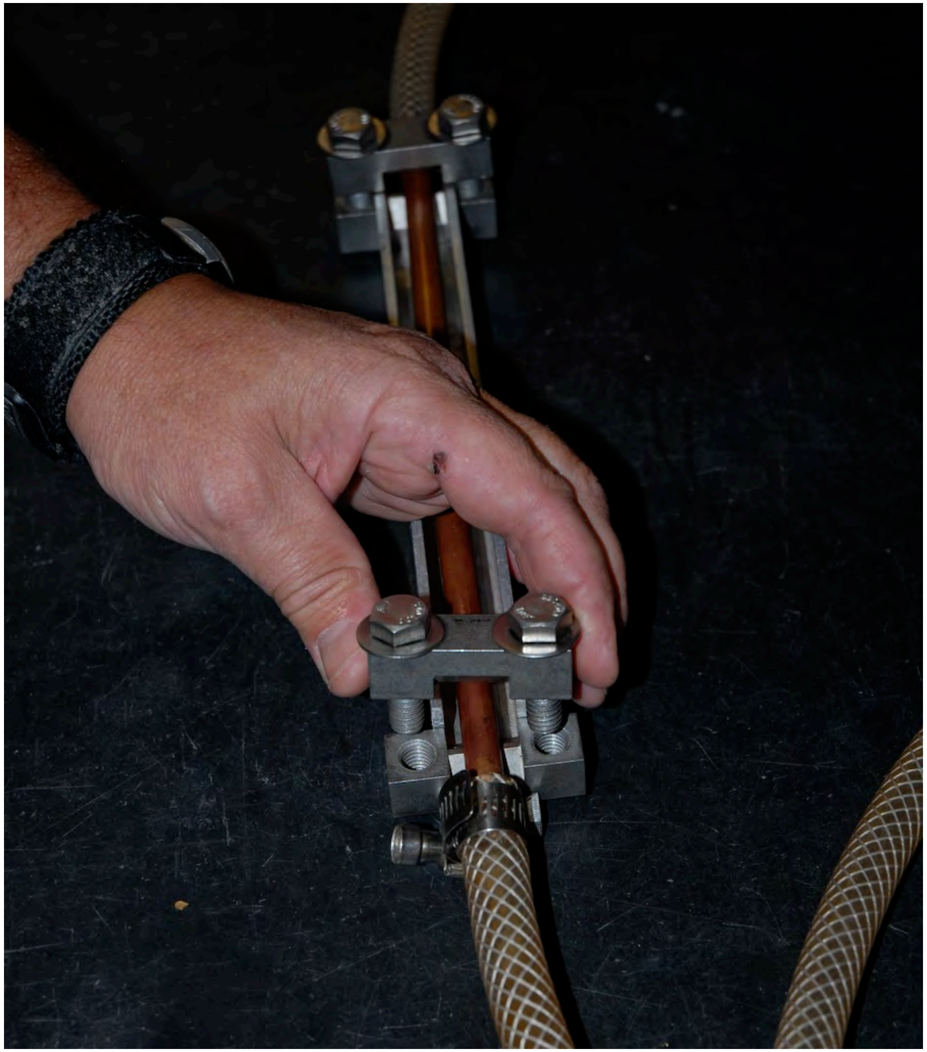
- Remove the upper portion of the both pinch clamps.
- Center the copper tube (in both directions) within the clamp holder as shown.



- Centering the copper tube in the clamp is very important.

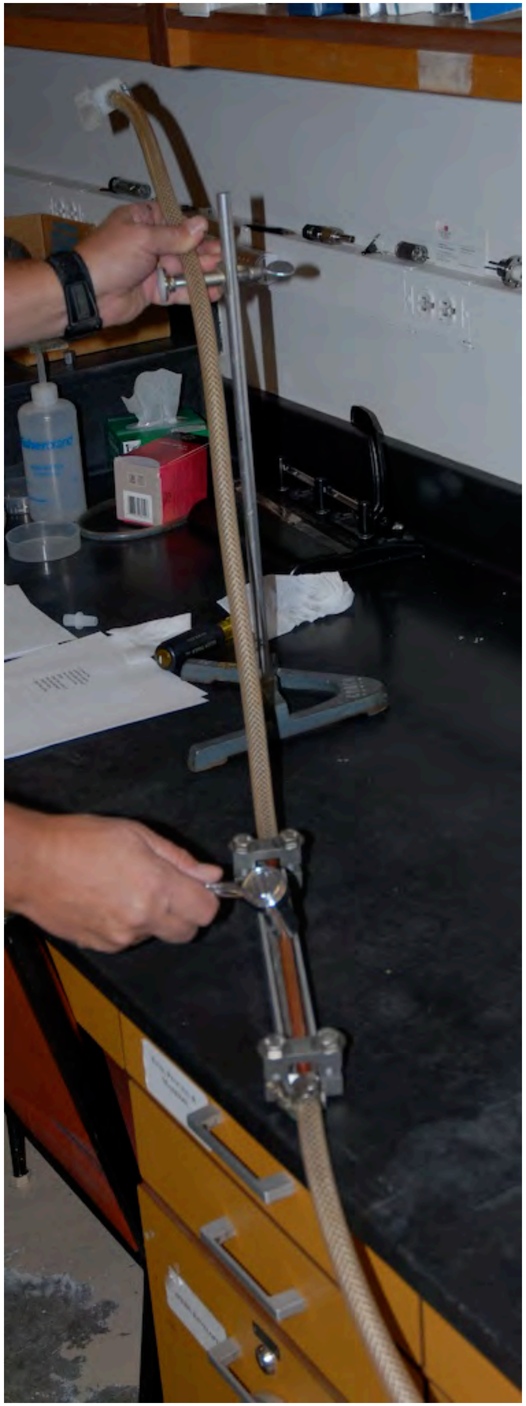


- Replace the upper portion of the pinch clamps and tighten using fingers only (do not yet deform the copper tube by excessive tightening).



- Make sure tubing is connected to sample tube.
- Open the valve on the downstream plastic tube.
- Start the pump and varify that water is flowing through system.

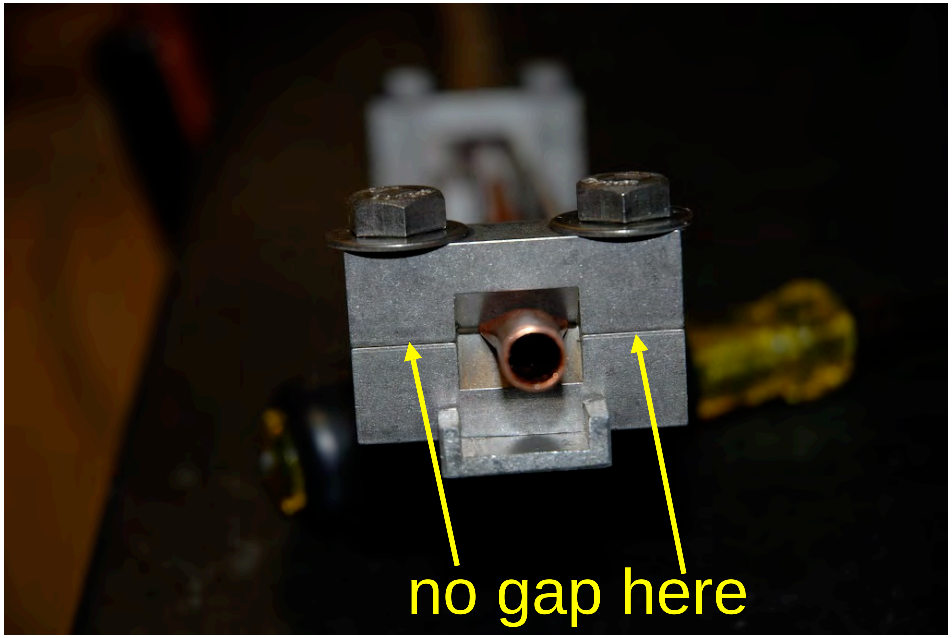
- While keeping the downstream end of the copper tube elevated relative to the upstream end (as shown) tap the tube with wrench to help dislodge bubbles.
- Maintain the orientation of the tube such that the downstream end is always elevated relative to the upstream end during the remainder of sampling procedure (until the clamps are closed.)



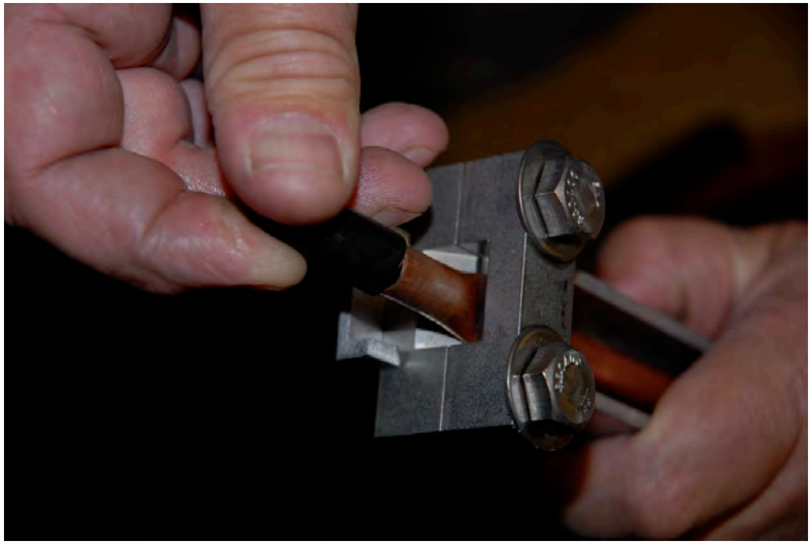
- Purge approximately 1 liter of water through the tube and watch for bubbles in the downstream plastic tube.
- Partially close the valve on the downstream tube. This will elevate the pressure inside the copper tube and will help eliminate bubbles.

- Once the copper tube is purged and NO bubbles can be observed in the downstream plastic tube, begin to close the downstream pinch clamp
- Caution - If you cannot eliminate the bubbles by further closing of the valve, it is unlikely that the sample will yield acceptable results.
- Close the downstream pinch clamp by turning 1 bolt about 1 turn, and then switch to the other bolt (i.e. alternate so that the clamp closes on the tube uniformly without a shearing - scissor-like - motion.)

- While keeping the pump operating, close the upstream clamp in a similar manner as before.
- Once both clamps are closed, the pump can be turned off.
- Note: The metal clamps contain a precision gap between the sealing surfaces. You should tighten the clamps completely such that no gap exists near the bolts as shown. (The precision gap will prevent the copper tube from shearing off.) You should tighten the bolts as much as reasonably possible using a wrench that is approximately 20 cm long. Over tightening the bolts is generally better than under tightening them (but don’t hurt yourself of break the bolts!)



- Remove the plastic hoses and make sure that the ends of the copper tube are filled with water.
- Fill the plastic caps with water and install them on the copper tube as shown. (With the ends of the copper tube filled with water, any leakage across the clamped surface will be reduced.
- Remove the clamped copper tube from the holder.



- Carefully label the copper tubes. This can be done directly using a sharpie, but it is then a good idea to cover the marking with clear tape.
- Treat the sample with care. The ends are delicate and if they break off the sample will probably leak, and/or we will not be able to attach it to the extraction line in the lab.

Additional Comments

- Samples in properly-sealed copper tubes have a very long shelf life (years) and do not require refrigeration.
- Do NOT allow the samples to freeze. There is NO (hopefully) headspace inside the copper tube and freezing will often break the tube.
- FedEx triangular “map” boxes make fairly good shipping containers.

Shipping Address

Dissolved Gas Lab
University of Utah
115 South 1460 East, Room 420
Salt Lake City, UT 84112-0102

Phone 801-585-5214
Fax   801-581-5560

Attachment C

Tritium Collection

Tritium Collection
from natural waters for low level tritium analysis

Sample Bottles

Although glass bottles with a PolySeal® cap are preferred, their breakage during collection or transportation is a legitimate concern. Therefore, we only recommend using glass bottles where the suspected tritium content is low (<1 TU). Generally, for most sampling environments, we recommend the use of LDPE bottles instead. All bottles should meet the U.S. Department of Transportation Spec DOT-2 for shipment. Our lab routinely uses 500 cc (16oz.) Nalgene® plastic bottles for sample collection but any comparable bottle will work fine. Generally two 500 cc samples are collected per site; one of the 500 cc bottles is used during the extraction process. The duplicate bottle is useful as a back-up sample. Bottles should be clean and dry, preferably factory fresh. No leakage is permissible; therefore bottles must be leak tight and have quality caps. Test this by holding a filled bottle upside down and squeezing hard. If it is possible to cause leakage, use different bottles. Remember large pressure changes are possible during shipment.

Sample Collection

For the best possible results, always observe the following:

1. During sample collection, a ban on luminescent dials should be observed. These so called “beta lights” contain a small amount of tritium which can interfere with an accurate sample collection.
2. Although glass bottles are preferred, they are very susceptible to breakage during transport. Therefore we prefer to use quality, plastic bottles instead. Nalgene® wide-mouth bottles work well. Collect samples using a 1-liter sample bottle.
3. Using formation water, rinse out the bottle several times.
4. While minimizing the bubbles trapped in the bottle, fill it all the way to the top and screw on the lid. It is best if this can be done underwater. Turn bottle up side down and check for bubbles. Make sure only small bubbles are present.
5. It is not necessary to preserve water samples for tritium analysis, add nothing to the water sample.
6. Make sure the cap is tight, and then rap the lid with black electrical tape. This is not used as an addition seal, but rather is used to prevent the lid from mechanically backing off during shipment.
7. Record sample collection date and time.
8. Although extreme temperature changes should be avoided, it is not necessary to store / ship samples on ice. Do not freeze samples
9. Package for shipping using a sturdy box, which allows for adequate package material. NOTE: If you use glass, each bottle should be bubble-wrapped or placed in its own cardboard compartment within the container. Double boxing with packing in between is also encouraged. Camping coolers, used in place of cardboard boxes, provide an extra degree of protection and can be returned upon request.

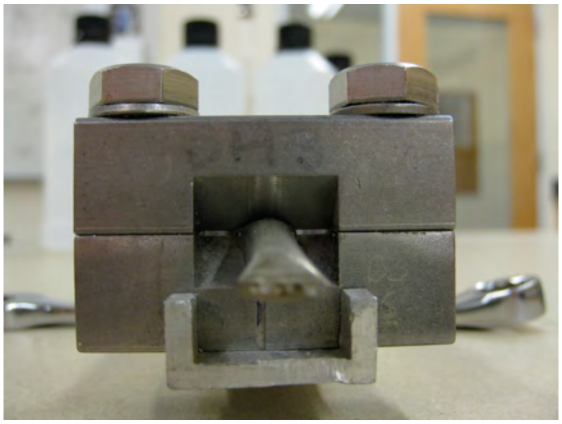
Attachment D

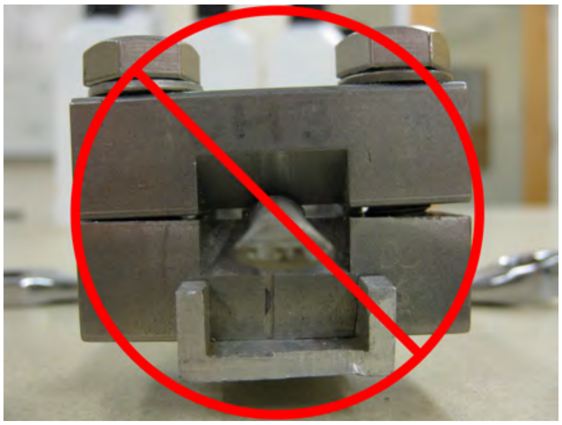
Using Pinch-Off Clamps for Copper Tubing

Using Pinch-off Clamps

When installed correctly clamping metal tubing will provide a very leak tight seal. Samples collected in this manner have a very long shelve life, on the order of years. However, in order to assure a leak tight seal, the following instructions should be followed.

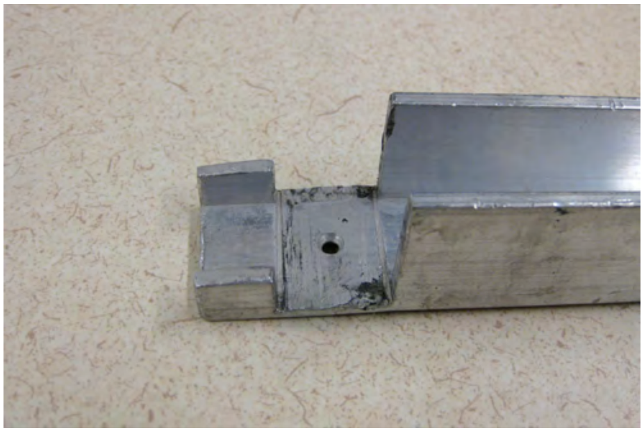
- Pinch-off clamps work best with soft metal tubing. Generally refrigeration grade copper tubing is used. Our lab also uses nickel tubing for some applications.
- Clamps should be placed on the tubing about 1½” to 2” from the tubing end. (**<u>IMPORTANT</u>**: This is needed to avoid complications when attaching the sample tube to the vacuum line for gas extraction. Care should also be taken to avoid marring or de-forming the tube ends.) Or in the “pre-crimp” area of the sampler
- To aid in clamp positioning, a sampling jig should be used. (See “Using Sampling Jigs” below)
- The tubing should be centered in the clamp such that when the tubing is collapsed during clamping, all of the sealing surface of the sample tube is in contact with the “knife” edge of the pinch-off clamp.
- Tighten the clamp by alternating between the two hex nuts. The two halves of the clamp should come together squarely. This will help ensure a proper seal in the sample tube (see figures below).
- The clamp should be tightened as tight as possible. The clamp has been designed with a precision gap in the sealing surface which prevents the user from over tightening the clamp. For a proper seal the two shoulders of the clamp halves should come together with out a gap (see figures below) .

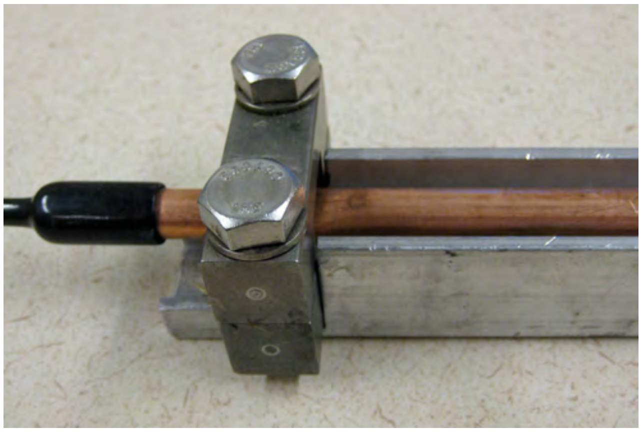


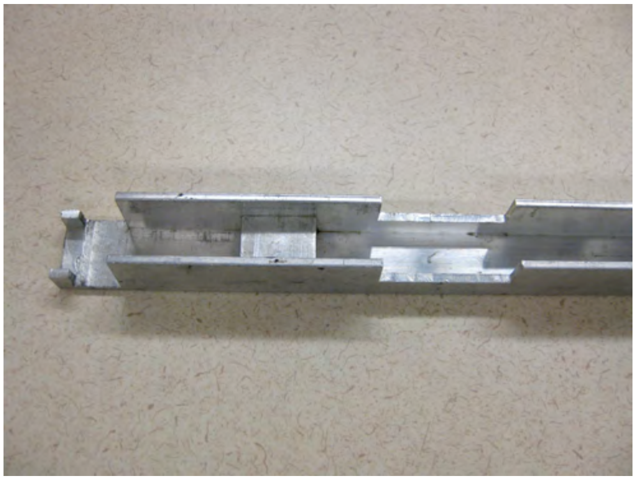


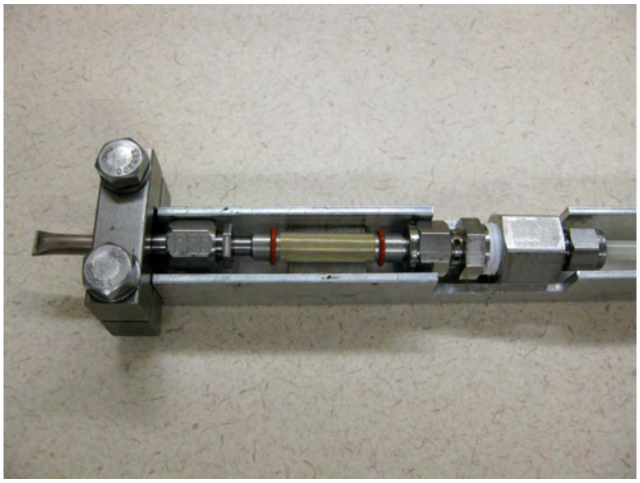
Using Sampling Jig

Jigs are designed to aid in the placement of the clamps and provide support during the clamping process. We use two types of jigs depending on the sampling type. Sampling jigs are sent out with the sampling equipment and should be used for every sample to insure proper clamp placement.









Appendix C: Mineral Constituents Concentrations

Table C-1. Mineral Analytical Results

Well	Date Sampled	Weighted Avg. Scrn Depth , ft	pH	EC, dS/m	NO3-N, mg/L	TDS, mg/L	Alk., meq/L	Cl, meq/L	Ca (Total), mg/L	Mg (Total), mg/L	Na (Total), mg/L	Zn (Total), mg/L	Mn (Total), mg/L	Fe (Total), mg/L	Hardness, mg/L as CaCO3	S (Total), mg/L	B (Total), mg/L	Se (Total), mg/L	Temp. C	DO, mg/L	ORP
N101	6/1/2011	224	7.96	0.69	3.28	390	4.8	1.22	47.5	35.4	45.9	0.01	<0.02	0.05	264	11.2	1.71	0.5	20.4	NA	NA
N102	9/29/2011	340	8.29	0.70	2.82	400	4.7	1.23	47.2	34.1	47.3	0.02	<0.02	<0.02	258	10.7	1.67	<0.5	18.1	5.4	467
N103	5/31/2011	172	7.74	1.15	12.92	690	8.3	1.68	75	67.8	80	<0.01	<0.02	<0.02	465	16.2	1.94	1.3	17.9	NA	NA
N104	8/3/2011	268	7.92	0.90	6.655	520	5.9	1.64	48.2	58.1	63.8	0.02	<0.02	<0.02	359	15.2	1.53	0.8	24.4	NA	NA
N105	8/3/2011	151	7.78	1.16	12.32	680	8	1.87	85.6	65	71.3	<0.01	<0.02	<0.02	481	14.6	2.58	1.3	25.7	NA	NA
N106	9/29/2011	240	8.06	1.13	10.1	680	6.9	2.35	87.9	63.3	61.8	<0.01	<0.02	0.03	479	22.5	2.28	1.2	18.6	12.5	468
N107	8/3/2011	230	7.72	1.16	10.22	680	2.4	2.4	85.7	62.5	75.2	0.01	<0.02	<0.02	470	21.6	2.64	<0.5	24.1	NA	NA
N108	9/29/2011	132	8.10	0.93	6.43	560	5.7	1.75	62.2	45.5	75.3	0.02	<0.02	0.03	342	18	2.6	1	18.5	9.9	470
N109	9/29/2011	220	8.32	1.01	14.3	600	8.1	0.64	44.3	82.4	61.1	0.04	<0.02	0.02	448	7.3	0.7	<0.5	20.2	7.3	444
N110	9/27/2011	236	8.25	1.74	14.88	1090	11.8	3.28	73.8	120.3	153.1	1.07	<0.02	0.11	678	33.8	1.36	8.8	19.3	6.2	439
N111	9/27/2011	193	8.31	1.59	11.58	960	11.8	2.51	62.7	111.7	132.5	<0.01	<0.02	<0.02	615	23.7	1.28	4	19.3	4.7	444
N113	9/30/2011	330	8.39	0.84	0.79	480	6.1	1.16	26.1	51.7	86.3	<0.01	<0.02	<0.02	277	17.6	1.14	2.6	20.0	0.5	431
N116	9/27/2011	418	8.30	1.16	5.15	680	8.2	1.55	39.9	83	97.2	<0.01	<0.02	<0.02	440	25.1	0.9	23	18.9	5.5	431
N117	6/1/2011	323	8.05	0.90	3.97	520	6.7	1.17	30.2	58.6	85.9	0.06	<0.02	<0.02	316	17.7	0.89	3.2	18.2	NA	NA
N118	9/27/2011	424	8.46	1.04	1.9	610	7.1	1.95	33.2	67.1	93.6	<0.01	0.03	<0.02	358	21.4	1.04	11.7	19.3	5.1	430
N119	9/30/2011	337	8.25	1.31	14.6	760	9	2.15	92.4	67.2	107.6	<0.01	<0.02	<0.02	506	14.9	2.78	6.9	18.3	14.1	486
N120	9/30/2011	373	8.22	0.97	7.07	560	6.1	2.09	75.8	52.7	58.6	0.1	<0.02	0.08	405	14	2.09	1.4	18.7	7.8	471
N121	5/31/2011	301	8.06	0.86	5.41	480	5.6	1.85	65.7	44.9	52.6	0.3	<0.02	<0.02	348	12.6	1.71	1.4	17.7	NA	NA
N122	5/31/2011	363	7.79	1.03	7.98	600	7	1.91	75.2	56.8	68.2	0.65	<0.02	<0.02	420	13.5	1.87	8.9	17.6	NA	NA
N123	9/30/2011	136	8.18	0.88	5.19	490	6	1.66	57.5	45.9	58	<0.01	<0.02	<0.02	332	9.7	2.06	3.2	19.3	2.4	476
N124	9/30/2011	324	8.24	1.11	9.48	630	7.9	1.87	84.1	62.3	67.5	<0.01	<0.02	<0.02	465	11.4	2.39	5.4	20.2	9.1	472
N125	9/29/2011	164	8.25	1.02	6.14	610	7.2	1.46	59.7	60.3	85.3	0.02	<0.02	<0.02	396	18.7	1.72	0.9	19.6	5.0	461
N126	9/27/2011	317	8.28	0.92	3.5	530	6	1.52	38.7	54.3	82.4	<0.01	<0.02	0.02	319	19.3	0.89	13.8	19.9	5.9	438
N127	9/27/2011	310	8.22	1.27	11.38	740	8.7	2.01	60.1	82.4	104	<0.01	<0.02	<0.02	488	20.9	1.24	5.9	19.1	6.5	440
N128	10/4/2011	N/A	8.28	0.39	0.21	200	2.9	0.61	27.7	20.9	22.6	<0.01	<0.02	0.04	155	2.9	1.24	<0.5	17.1	10.0	458
N129	10/4/2011	N/A	8.29	0.35	0.12	160	2.8	0.15	18.8	31.2	10.2	<0.01	<0.02	<0.02	175	7.6	<0.20	<0.5	11.6	12.0	478

Appendix D: CFC, Tritium and Noble Gas Results

Table D-1. Stable Isotopes and CFC Results

Well	δ^{15}N vs. Air	δ^{18}O	δD (H-2, Deterium)	CFC-111 (year)	CFC-112 (year)	CFC-113 (year)	CFC Average	CFC Average Age (from 2012)	Field Notes
N101	7.09	-5.4	-45.0	1982.7	Contamination	Contamination	1982.7	29	
N102	7.65	-5.49	-42.5	1982.5	N/A	1984.0	1983.3	29	
N103	3.70	-5.7	-44.7	1981.2	Contamination	Contamination	1981.2	31	
N104	3.71	-5.51	-42.7	1975.8	1981.7	1981.8	1979.8	32	
N105	5.30	-5.93	-44.2	1987.0	1992.5	Contamination	1989.8	22	
N106	5.2	-5.64	-43.3	1985.2	N/A	N/A	1985.2	27	
N107	5.19	-6	-44.7	1984.5	1989.8	Contamination	1987.1	25	
N108	4.52	-5.62	-43.3	1985.0	N/A	1987.3	1986.2	26	Small bubbles coming out of the sample tube while filling cfc bottles.
N109	2.97	-5.62	-42.6	1993.5	N/A	1988.5	1991	21	
N110	4.8	-6.35	-46.2	1984.7	1991.3	1983.7	1986.6	25	
N111	3.81	-6.18	-45.1	1974.7	1984.0	1979.2	1979.3	33	
N113	17	-7.61	-51.8	1959.8	1960.5	1968.0	1962.8	49	
N116	6.87	-7.35	-50.3	1973.5	1977.2	1969.5	1973.4	39	
N117	6.04	-7.1	-52.3	1967.0	1971.2	1970.1	1969.4	43	
N118	9.1	-7.16	-50.2	1966.7	1966.2	N/A	1966.4	46	
N119	3.37	-5.6	-42	1977.0	N/A	N/A	1977	35	Bubbles apparent in water while filling CFC bottles
N120	5.8	-5.6	-42.9	1957.5	1971.8	1969.5	1966.3	46	Air bubbles present in water while filling CFCs.
N121	5.76	-5.4	-44.7	Contamination	Contamination	Contamination	N/A	N/A	
N122	4.82	-5.2	-43.8	1987.5	Contamination	Contamination	1987.5	25	
N123	6.51	-4.98	-40	1980.2	1986.5	1990.7	1985.8	26	
N124	4.07	-5.45	-42.6	1982.0	N/A	N/A	1982	30	
N125	5.02	-4.75	-38.5	1975.5	N/A	1980.8	1978.2	34	
N126	5.8	-7.22	-51.1	1964.5	1972.0	1966.8	1967.8	44	
N127	5.18	-6.54	-47	1970.2	1990.5	1975.0	1978.6	33	
N128	6.06	-4.7	-38.6	2004.7	2001.8	N/A	2003.2	9	
N129	2.45	-4.69	-36	2002.5	2002.0	N/A	2002.3	10	

Notes:

1. CFC values for N128 and 129 are past peak
2. Contamination means CFC values far above peak for atmospheric record

Table D-2. Tritium and Noble Gas Results

Well	Ar total (ccSTP/g)	Ne total (ccSTP/g)	Kr total (ccSTP/g)	Xe total (ccSTP/g)	He4 (ccSTP/g)	R/Ra	Tritium (TU)	Tritium (error +/-)	Calculated Age - using Ne only (yrs)	using Ne (error +/-)	Calculated Age - using EA (yrs)	EA Age (error +/-)	Rterr - assumed	ΔNe (%)	Notes (Tritium)
N101	0.000387	2.94E-07	8.2E-08	1.13E-08	7.18E-08	1.018301	2.19	0.10	-3.26	14.46	-3.04	9.14	2.01E-07	54.522	Looks modern
N102	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N103	0.000352	1.91E-07	7.78E-08	1.14E-08	4.34E-08	1.088109	2.96	0.13	8.84	3.01	7.75	2.35	2.01E-07	-1.0776	Slight stripping, looks OK
N104	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N105	0.00046	4.29E-07	9.46E-08	1.2E-08	1.04E-07	1.040686	2.50	0.11	-32.37	35.41	-33.03	35.74	2.01E-07	126.307	Good gas model fit, He low by 9%
N106	0.000532	4.94E-07	1.05E-07	1.3E-08	1.19E-07	1.073529	2.46	0.11	-12.56	28.98	5.17	8.46	2.01E-07	158.805	Good gas model fit, He low by 7%
N107	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N108	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N109	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N110	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N111	0.000476	4.48E-07	9.7E-08	1.19E-08	1.11E-07	1.029306	1.95	0.09	-33.32	34.12	-10.67	29.07	2.01E-07	138.272	Good gas model fit, He low by 5%
N113	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N116	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N117	0.000487	4.06E-07	9.37E-08	1.24E-08	1.02E-07	0.993598	0.59	0.10	‡	‡	‡	‡	2.01E-07	111.972	Excess air, water appears mixed modern (R/Ra=1) with older water (low TU)
N118	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N119	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N120	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N121	0.000614	6.4E-07	1.12E-07	1.38E-08	1.76E-07	1.216034	2.28	0.11	42.77	2.61	44.48	2.04	2.01E-07	231.639	Excess air; age looks OK
N122	0.000323	1.7E-07	7.55E-08	1.04E-08	3.76E-08	1.154764	2.35	0.11	13.84*	2.94*	1.37*	4.03*	2.01E-07	-9.8825	Sample appears stripped, poor gas model fit, age is estimate only
N123	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N124	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N125	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N126	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N127	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N128	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N129	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table D-3. CFC Data - First Group

SAMPLE ID	CFC-11 (pmoles/kg)	CFC-12 (pmoles/kg)	CFC-113 (pmoles/kg)	Salinity (‰)	Recharge Elev. (m)	Recharge Temp (C)	Pwater	Elev. correction	KRT_11	KRT_12	KRT_113	eq. air conc_11 (ppt)	eq. air conc_12 (ppt)	eq. air conc_113 (ppt)	CFC-11 Rech. year	CFC-12 Rech. year	CFC-113 Rech. year
N101-1	2.401272373	2.534400141	1.312477554	0	28	20.4	0.0236	0.973049716	0.01265	0.00347	0.003702	195.021	750.364	364.3619	1983	Contamination	Contamination
N101-2	2.380451259	2.531119347	1.281710051	0	28	20.4	0.0236	0.973049716	0.01265	0.00347	0.003702	193.33	749.392	355.8204	1982.5	Contamination	Contamination
N101-3	2.384734193	2.531907915	1.276686377	0	28	20.4	0.0236	0.973049716	0.01265	0.00347	0.003702	193.678	749.626	354.4258	1982.5	Contamination	Contamination
N103-1	2.499554957	2.137287496	1.564180341	0	24	17.9	0.0202	0.976934546	0.01417	0.00384	0.004199	180.555	569.765	381.2713	1981	Contamination	Contamination
N103-2	2.546861446	2.196381177	1.633253029	0	24	17.9	0.0202	0.976934546	0.01417	0.00384	0.004199	183.972	585.518	398.1078	1981.5	Contamination	Contamination
N103-3	2.478386137	2.131716806	1.447692198	0	24	17.9	0.0202	0.976934546	0.01417	0.00384	0.004199	179.026	568.28	352.8771	1981	Contamination	Contamination
N104-1	2.224785249	1.452956774	0.174941436	0	20	15	0.0168	0.980818062	0.01629	0.00435	0.0049	139.281	340.775	36.40269	1976.5	1982	1983.5
N104-2	2.057559367	1.410067713	0.134318704	0	20	15	0.0168	0.980818062	0.01629	0.00435	0.0049	128.812	330.716	27.94971	1975.5	1981.5	1981.5
N104-3	2.024638737	1.41701763	0.125076562	0	20	15	0.0168	0.980818062	0.01629	0.00435	0.0049	126.751	332.346	26.02656	1975.5	1981.5	1980.5
N105-1	3.885052515	2.176173296	1.030992653	0	20	15	0.0168	0.980818062	0.01629	0.00435	0.0049	243.221	510.398	214.5341	1987.5	1991.5	Contamination
N105-2	3.761444977	2.192585118	1.081585731	0	20	15	0.0168	0.980818062	0.01629	0.00435	0.0049	235.482	514.247	225.0618	1987	1993	Contamination
N105-3	3.736212114	2.204207777	1.03780059	0	20	15	0.0168	0.980818062	0.01629	0.00435	0.0049	233.903	516.973	215.9508	1986.5	1993	Contamination
N107-1	3.023699326	2.074181059	8.338096504	0	20	15	0.0168	0.980818062	0.01629	0.00435	0.0049	189.296	486.477	1735.033	1982	1990	Contamination
N107-2	3.324817842	2.049360162	5.639736001	0	20	15	0.0168	0.980818062	0.01629	0.00435	0.0049	208.148	480.655	1173.545	1984.5	1989.5	Contamination
N107-3	3.7950726	3.236975109	6.195961058	0	20	15	0.0168	0.980818062	0.01629	0.00435	0.0049	237.588	759.197	1289.287	1987	Contamination	Contamination
N117-1	0.507306726	0.638357622	0.027876394	0	15	18.2	0.0206	0.977614415	0.01397	0.00379	0.004135	37.1326	172.179	6.895998	1967	1972.5	1971
N117-2	0.509208327	0.500339625	0.023283755	0	15	18.2	0.0206	0.977614415	0.01397	0.00379	0.004135	37.2718	134.953	5.759882	1967	1970	1969.5
N117-3	0.527584484	0.531350381	0.024956596	0	15	18.2	0.0206	0.977614415	0.01397	0.00379	0.004135	38.6169	143.317	6.173705	1967	1971	1970
N121-1	5.610349615	4.036185596	14.81906278	0	22	17.7	0.02	0.977424419	0.0143	0.00387	0.004243	401.301	1066.54	3573.151	Contamina	Contamination	Contamination
N121-2	5.635938135	4.026661422	14.3622499	0	22	17.7	0.02	0.977424419	0.0143	0.00387	0.004243	403.132	1064.02	3463.005	Contamina	Contamination	Contamination
N121-3	5.731622275	4.037044105	14.54643201	0	22	17.7	0.02	0.977424419	0.0143	0.00387	0.004243	409.976	1066.76	3507.414	Contamina	Contamination	Contamination
N122-1	3.526014143	4.406899862	111.0431382	0	22	17.6	0.0198	0.977550009	0.01437	0.00389	0.004265	251.003	1159.5	26632.41	1988	Contamination	Contamination
N122-2	3.391971408	4.26667394	111.1677532	0	22	17.6	0.0198	0.977550009	0.01437	0.00389	0.004265	241.461	1122.61	26662.29	1987	Contamination	Contamination
N122-3	3.477982618	4.411685038	110.7389948	0	22	17.6	0.0198	0.977550009	0.01437	0.00389	0.004265	247.583	1160.76	26559.46	1987.5	Contamination	Contamination

Table D-4. CFC Data - Second Group

SAMPLE ID	CFC-11 (pmoles/kg)	CFC-12 (pmoles/kg)	CFC-113 (pmoles/kg)	Salinity (‰)	Surface Elev, Ft	Recharge Elev. (m)	Recharge Temp (C)	Pwater	Elev. correction	KRT_11	KRT_12	KRT_113	eq. air conc_1 1 (ppt)	eq. air conc_1 2 (ppt)	eq. air conc_11 3 (ppt)	CFC-11 Rech. year	CFC-12 Rech. year	CFC-113 Rech. year
N102-1	2.611281993	2.228720914	0.166540914	0.0004	94	28	18.09	0.020466	0.976160947	0.01405	0.00381	0.004158	190.448	599.308	41.02718	1982.5	Contamination	1984.5
N102-2	2.628266642	2.231755069	0.151884142	0.0004	94	28	18.09	0.020466	0.976160947	0.01405	0.00381	0.004158	191.687	600.124	37.4165	1982.5	Contamination	1983.5
N102-3	2.606593163	2.213159669	0.156143454	0.0004	94	28	18.09	0.020466	0.976160947	0.01405	0.00381	0.004158	190.106	595.123	38.46578	1982.5	Contamination	1984
N106-1	2.863698059	3.175047648	36.46373852	0.00068	78	24	18.62	0.021158	0.976042324	0.01371	0.00373	0.004047	214.045	872.675	9231.213	1985	Contamination	Contamination
N106-2	2.91511615	3.198194464	36.46522884	0.00068	78	24	18.62	0.021158	0.976042324	0.01371	0.00373	0.004047	217.889	879.037	9231.591	1985	Contamination	Contamination
N106-3	2.959422064	3.316575788	37.1124213	0.00068	78	24	18.62	0.021158	0.976042324	0.01371	0.00373	0.004047	221.2	911.574	9395.435	1985.5	Contamination	Contamination
N108-1	2.865282615	2.20411162	0.225550559	0.00056	100	30	18.47	0.020961	0.975451865	0.0138	0.00375	0.004078	212.824	602.467	56.69943	1985	Contamination	1987
N108-2	2.826139687	2.109656774	0.227864355	0.00056	100	30	18.47	0.020961	0.975451865	0.0138	0.00375	0.004078	209.916	576.649	57.28107	1984.5	Contamination	1987
N108-3	2.952506908	2.369892945	0.248334655	0.00056	100	30	18.47	0.020961	0.975451865	0.0138	0.00375	0.004078	219.303	647.781	62.42695	1985.5	Contamination	1988
N109-1	3.609148131	2.114927309	0.246289885	0.0006	91	28	20.19	0.02333	0.973404677	0.01277	0.0035	0.00374	290.309	620.791	67.64498	1993.5	Contamination	1988.5
N109-2				0.0006	91	28	20.19	0.02333	0.973404677	0.01277	0.0035	0.00374	0	0	0	-	-	-
N109-3	3.611130338	2.171778126	0.241453661	0.0006	91	28	20.19	0.02333	0.973404677	0.01277	0.0035	0.00374	290.469	637.479	66.31668	1993.5	Contamination	1988.5
N110-1	2.657398929	1.763432884	0.126983708	0.00109	54	16	19.31	0.02209	0.975971329	0.01328	0.00362	0.003908	204.97	498.472	33.29264	1984	1991	1983
N110-2	2.795097587	1.78131304	0.13738765	0.00109	54	16	19.31	0.02209	0.975971329	0.01328	0.00362	0.003908	215.591	503.526	36.02035	1985	1991.5	1983.5
N110-3	2.770388353	1.775307909	0.162895265	0.00109	54	16	19.31	0.02209	0.975971329	0.01328	0.00362	0.003908	213.686	501.828	42.70794	1985	1991.5	1984.5
N111-1	1.542157084	1.340423905	0.073208072	0.00096	52	16	19.27	0.022035	0.976098042	0.01331	0.00363	0.003916	118.719	378.24	19.15263	1975	1984	1978.5
N111-2	1.48721745	1.317262953	0.081680832	0.00096	52	16	19.27	0.022035	0.976098042	0.01331	0.00363	0.003916	114.49	371.705	21.36927	1974.5	1983.5	1979
N111-3	1.497161638	1.355567046	0.091190283	0.00096	52	16	19.27	0.022035	0.976098042	0.01331	0.00363	0.003916	115.256	382.513	23.85712	1974.5	1984.5	1980
N113-1	0.200882593	0.159543081	0.017114969	0.00048	46	14	20.02	0.023086	0.975262411	0.01287	0.00352	0.003772	16.0065	46.4281	4.652463	1962	1962	1968
N113-2	0.122932586	0.123943574	0	0.00048	46	14	20.02	0.023086	0.975262411	0.01287	0.00352	0.003772	9.79536	36.0684	0	1959.5	1960	-
N113-3	0.098860639	0.111053982	0	0.00048	46	14	20.02	0.023086	0.975262411	0.01287	0.00352	0.003772	7.87729	32.3175	0	1958	1959.5	-
N116-1	1.372175897	0.996519461	0.023004484	0.00068	48	15	18.86	0.021479	0.976798123	0.01356	0.00369	0.003998	103.613	276.374	5.890792	1974	1977.5	1970
N116-2	1.268026715	0.930653485	0	0.00068	48	15	18.86	0.021479	0.976798123	0.01356	0.00369	0.003998	95.7486	258.107	0	1973	1976.5	-
N116-3	1.324099741	0.976073692	0.019826086	0.00068	48	15	18.86	0.021479	0.976798123	0.01356	0.00369	0.003998	99.9826	270.704	5.076895	1973.5	1977.5	1969
N118-1	0.417767478	0.256773647	0	0.00061	40	12	19.3	0.022076	0.976487377	0.01329	0.00363	0.00391	32.1915	72.5146	0	1966	1965.5	-
N118-2	0.519240791	0.294483542	0	0.00061	40	12	19.3	0.022076	0.976487377	0.01329	0.00363	0.00391	40.0107	83.1642	0	1967.5	1966.5	-
N118-3	0.477914521	0.30213991	0	0.00061	40	12	19.3	0.022076	0.976487377	0.01329	0.00363	0.00391	36.8262	85.3264	0	1966.5	1966.5	-
N119-1	1.958941205	2.547142667	22.85817113	0.00076	76	23	18.29	0.020725	0.976547274	0.01392	0.00378	0.004116	144.141	690.331	5687.043	1977	Contamination	Contamination
N119-2	1.977646103	2.597629982	22.99599209	0.00076	76	23	18.29	0.020725	0.976547274	0.01392	0.00378	0.004116	145.518	704.014	5721.333	1977	Contamination	Contamination
N119-3	1.97013546	2.626322292	22.64176727	0.00076	76	23	18.29	0.020725	0.976547274	0.01392	0.00378	0.004116	144.965	711.79	5633.203	1977	Contamination	Contamination
N120-1	0.095909092	0.56487046	0.022070513	0.00056	68	21	18.71	0.021278	0.976281308	0.01365	0.00371	0.004029	7.19648	155.79	5.611688	1957.5	1971.5	1969.5
N120-2	0.097883275	0.582720252	0.022386715	0.00056	68	21	18.71	0.021278	0.976281308	0.01365	0.00371	0.004029	7.34461	160.713	5.692086	1957.5	1972	1969.5
N120-3				0.00056	68	21	18.71									-	-	-
N123-1	2.253778245	1.467708167	0.301432403	0.00049	63	19	19.32	0.022104	0.975634761	0.01328	0.00362	0.003906	173.976	415.186	79.09621	1980.5	1986	1990.5
N123-2	2.212093571	1.486591825	0.303016654	0.00049	63	19	19.32	0.022104	0.975634761	0.01328	0.00362	0.003906	170.758	420.528	79.51192	1980	1986.5	1990.5
N123-3	2.223302303	1.533900361	0.31040657	0.00049	63	19	19.32	0.022104	0.975634761	0.01328	0.00362	0.003906	171.623	433.911	81.45104	1980	1987	1991
N124-1	2.306778306	2.15561224	3.396090214	0.00063	63	19	20.21	0.023359	0.974379523	0.01276	0.0035	0.003737	185.529	632.6	932.7444	1982	Contamination	Contamination
N124-2	2.35455611	2.244943779	3.517880048	0.00063	63	19	20.21	0.023359	0.974379523	0.01276	0.0035	0.003737	189.372	658.816	966.1943	1982	Contamination	Contamination
N124-3	2.339714201	2.213756965	3.412231736	0.00063	63	19	20.21	0.023359	0.974379523	0.01276	0.0035	0.003737	188.178	649.663	937.1777	1982	Contamination	Contamination
N125-1	1.631728659	4.523444135	0.097613584	0.00061	63	19	19.55	0.022422	0.97531617	0.01314	0.00359	0.003861	127.31	1291.88	25.91957	1975.5	Contamination	1980.5
N125-2	1.646707575	4.679720131	0.101582988	0.00061	63	19	19.55	0.022422	0.97531617	0.01314	0.00359	0.003861	128.479	1336.51	26.97358	1975.5	Contamination	1981
N125-3	1.638600912	4.555561227	0.099340343	0.00061	63	19	19.55	0.022422	0.97531617	0.01314	0.00359	0.003861	127.846	1301.05	26.37808	1975.5	Contamination	1981
N126-1	0.30706234	0.534814516	0.015678902	0.00053	52	16	19.92	0.022943	0.975189757	0.01293	0.00354	0.003791	24.3602	155.03	4.24131	1964.5	1971.5	1967.5
N126-2	0.327379637	0.600336204	0.013646333	0.00053	52	16	19.92	0.022943	0.975189757	0.01293	0.00354	0.003791	25.972	174.024	3.691479	1964.5	1972.5	1966.5
N126-3	0.311039855	0.571494523	0.013333758	0.00053	52	16	19.92	0.022943	0.975189757	0.01293	0.00354	0.003791	24.6757	165.663	3.606924	1964.5	1972	1966.5
N127-1	0.816334225	1.772460414	0	0.00074	52	16	19.11	0.021816	0.976316727	0.0134	0.00365	0.003948	62.3763	496.822	0	1970	1991	-
N127-2	0.700051915	1.740883699	0.027741054	0.00074	52	16	19.11	0.021816	0.976316727	0.0134	0.00365	0.003948	53.4911	487.971	7.197677	1969	1990	1971.5
N127-3	0.985711084	2.090670676	0.074021554	0.00074	52	16	19.11	0.021816	0.976316727	0.0134	0.00365	0.003948	75.3184	586.017	19.20559	1971.5	Contamination	1978.5
N128-1	3.358654225	2.117627484	0.190686446	0.0002	200	61	17.13	0.019263	0.97357199	0.01469	0.00397	0.004371	234.816	548.522	44.80714	2012	2001.5	1985
N128-2	3.427351732	2.164501893	0.192221522	0.0002	200	61	17.13	0.019263	0.97357199	0.01469	0.00397	0.004371	239.619	560.664	45.16785	2010.5	2002	1985
N128-3	3.900002747	2.949929953	0.286754661	0.0002	200	61	17.13	0.019263	0.97357199	0.01469	0.00397	0.004371	272.664	764.111	67.38107	1991.5	Contamination	1988.5
N129-1	4.879050551	2.941826287	0.374654234	0.00016	218	66	11.55	0.013422	0.978770553	0.01944	0.00509	0.005955	256.472	590.471	64.27939	2003.5	Above Peak	1988
N129-2	4.958556129	2.957798706	0.34789712	0.00016	218	66	11.55	0.013422	0.978770553	0.01944	0.00509	0.005955	260.652	593.677	59.68868	2002	Above Peak	1987.5
N129-3	4.944538134	2.924668189	0.337260338	0.00016	218	66	11.55	0.013422	0.978770553	0.01944	0.00509	0.005955	259.915	587.027	57.86372	2002	Above Peak	1987

Table D-4. Tritium and Noble Gas Results

Well	Ar total (ccSTP/g)	Ne total (ccSTP/g)	Kr total (ccSTP/g)	Xe total (ccSTP/g)	He4 (ccSTP/g)	R/Ra	Tritium (TU)	Tritium (error +/-)	Calculated Age - using Ne only (yrs)	using Ne (error +/-)	Calculated Age - using EA (yrs)	EA Age (error +/-)	Rterr - assumed	ΔNe (%)	Notes (Tritium)
N101	0.000387	2.94E-07	8.2E-08	1.13E-08	7.18E-08	1.018301	2.19	0.10	-3.26	14.46	-3.04	9.14	2.01E-07	54.522	Looks modern
N102	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N103	0.000352	1.91E-07	7.78E-08	1.14E-08	4.34E-08	1.088109	2.96	0.13	8.84	3.01	7.75	2.35	2.01E-07	-1.0776	Slight stripping, looks OK
N104	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N105	0.00046	4.29E-07	9.46E-08	1.2E-08	1.04E-07	1.040686	2.50	0.11	-32.37	35.41	-33.03	35.74	2.01E-07	126.307	Good gas model fit, He low by 9%
N106	0.000532	4.94E-07	1.05E-07	1.3E-08	1.19E-07	1.073529	2.46	0.11	-12.56	28.98	5.17	8.46	2.01E-07	158.805	Good gas model fit, He low by 7%
N107	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N108	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N109	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N110	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N111	0.000476	4.48E-07	9.7E-08	1.19E-08	1.11E-07	1.029306	1.95	0.09	-33.32	34.12	-10.67	29.07	2.01E-07	138.272	Good gas model fit, He low by 5%
N113	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N116	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N117	0.000487	4.06E-07	9.37E-08	1.24E-08	1.02E-07	0.993598	0.59	0.10	‡	‡	‡	‡	2.01E-07	111.972	Excess air, water appears mixed modern (R/Ra=1) with older water (low TU)
N118	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N119	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N120	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N121	0.000614	6.4E-07	1.12E-07	1.38E-08	1.76E-07	1.216034	2.28	0.11	42.77	2.61	44.48	2.04	2.01E-07	231.639	Excess air; age looks OK
N122	0.000323	1.7E-07	7.55E-08	1.04E-08	3.76E-08	1.154764	2.35	0.11	13.84*	2.94*	1.37*	4.03*	2.01E-07	-9.8825	Sample appears stripped, poor gas model fit, age is estimate only
N123	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N124	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N125	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N126	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N127	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N128	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N129	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Appendix E: Well Construction Information

Table E-1. Well Construction Details

Well	Date Sampled	Top Screen	Screen 1 Length	Average Screen Depth, ft	Screen 2	Screen 2 Length	Average Screen Depth, ft	Screen 3	Screen 3 Length	Average Screen Depth, ft	Screen 4	Screen 4 Length	Average Screen Depth, ft	Screen 5	Screen 5 Length	Average Screen Depth, ft	Screen 6	Screen 6 Length	Average Screen Depth, ft	Weighted Avg. Scrn. Depth , ft	Total Screen Length, ft
N101	6/1/2011	216-232	16	224																224	16
N102	9/29/2011	320-360	40	340																340	40
N103	5/31/2011	153-191	38	172																172	38
N104	8/3/2011	180-210	30	195	250-260	10	255	290-340	50	315										268	90
N105	8/3/2011	141-161	20	151																151	20
N106	9/29/2011	220-260	40	240																240	40
N107	8/3/2011	200-260	60	230																230	60
N108	9/29/2011	122-141	19	131.5																132	19
N109	9/29/2011	200-240	40	220																220	40
N110	9/27/2011	184-204	20	194	268-288	20	278													236	40
N111	9/27/2011	188-198	10	193																193	10
N113	9/30/2011	320-340	20	330																330	20
N116	9/27/2011	210-230	20	220	285-295	10	290	355-365	10	360	490-500	10	495	560-570	10	565	585-605	20	595	418	80
N117	6/1/2011	296-334	38	315	342-354	12	348													323	50
N118	9/27/2011	310-340	30	325	350-370	20	360	422-460	38	441	470-520	50	495							424	138
N119	9/30/2011	140-150	10	145	174-184	10	179	412-442	30	427	496-501	5	498.5							337	55
N120	9/30/2011	150-160	10	155	222-234	12	228	280-288	8	284	450-496	46	473							373	76
N121	5/31/2011	175-195	20	185	230-250	20	240	450-472	22	461										301	62
N122	5/31/2011	250-272	22	261	286-364	78	325	394-402	8	398	422-478	56	450							363	164
N123	9/30/2011	126-146	20	136																136	20
N124	9/30/2011	314-334	20	324																324	20
N125	9/29/2011	139-159	20	149	169-189	20	179													164	40
N126	9/27/2011	150-340	190	245	370-490	120	430													317	310
N127	9/27/2011	182-202	20	192	302-352	50	327	452-462	10	457										310	80

Appendix F: Agency Policies on Private Well Water Quality

Effective water resource management

YOLO COUNTY

FLOOD CONTROL &
WATER CONSERVATION
DISTRICT

March 8, 2011

To: Potential Volunteer Well Owners

From: Max Stevenson, Yolo County Flood Control MAX

RE: Groundwater Quality Testing

The Flood Control District, in cooperation with the cities of Woodland, Davis, and the Yolo County Farm Bureau received a grant to test for nitrate in groundwater both under the cities and nearby county areas. The test results will be used in a study.

We would greatly appreciate your help in allowing a one-time test of your well. The results from your well will be provided to you free and will contain valuable information for you.

Some volunteer well owners have asked about government regulations. We contacted four agencies during February of 2011 and asked about regulation of water quality in private wells. All responded that ***they do not regulate the water quality of private wells.*** Only public water supplies are regulated.

Attached please find their written confirmation that they do not regulate private wells. List of agencies contacted:

- Yolo County Environmental Health Department
- California Department of Pesticide Regulation
- California Department of Public Health, Division of Drinking Water and Environmental Management
- California State Water Resources Control Board, Groundwater Ambient Monitoring and Assessment Program

If you have any questions please call me at 530-662-0265.

34274 State Highway 16
Woodland, CA 95695-9371
(530) 662-0265
FAX (530) 662-4982
www.ycfcwcd.org

Tim O'Halloran
General Manager

Yolo County Environmental Health Department Response

Max Stevenson

From: Wayne Taniguchi [Wayne.Taniguchi@yolocounty.org]
Sent: Tuesday, March 08, 2011 11:08 AM
To: Max Stevenson
Subject: RE: Confirmation of Yolo Co Env. Health policy on private wells

Hi Max.

Our regulatory role for the individual wells remains the same since the 2004. I believe the response from Mr. To addresses those areas

Thanks,

Wayne Y. Taniguchi, R.E.H.S.
Supervising Environmental Health Specialist
Yolo County Health Department
Environmental Health Division
(530) 666-8646 office
(916) 375-3475 office
(530) 669-1448 fax
wayne.taniguchi@yolocounty.org

From: Max Stevenson [mailto:mstevenson@ycfcwcd.org]
Sent: Tuesday, March 08, 2011 9:46 AM
To: Wayne Taniguchi
Subject: RE: Confirmation of Yolo Co Env. Health policy on private wells

Hi Wayne,

Just checking in. Yolo County is the last agency yet to officially respond, I think you said we are waiting on the lawyers? Would it be helpful if I called someone at the County?

Max Stevenson
Yolo County Flood Control and Water Conservation District
www.ycfcwcd.org
530-662-0265 office
530-681-6004 cell

From: Max Stevenson
Sent: Thursday, February 24, 2011 4:23 PM
To: 'Wayne.Taniguchi@yolocounty.org'
Cc: Tim O'Halloran; 'Cindy Tuttle'
Subject: Confirmation of Yolo Co Env. Health policy on private wells

Wayne,

Below is a copy of a letter and email exchange clarifying the 2004 policy of Yolo County Environmental Health toward private well MCL exceedances. Per our conversation today, it would be very helpful if you could confirm that the policy is the same today. We are starting a new round of groundwater sampling and wish to inform our volunteer well owners on the current details of County policy.

Thank you very much.

-Max

Max Stevenson
Yolo County Flood Control and Water Conservation District
www.ycfcwcd.org
530-662-0265 office
530-681-6004 cell

April 30, 2004
File No. 03-1-062

Mr. Tom To
Director of Environmental Health
Yolo County Environmental Health Department
10 Cottonwood Street
Woodland, CA 95695

SUBJECT: **CONFIRMATION OF YOLO COUNTY ENVIRONMENTAL HEALTH DEPARTMENT POLICY ON WATER QUALITY RESULTS THAT EXCEED THE MCL IN PRIVATE WELLS**

Dear Mr. To:

This letter is to confirm our conversation from January 13, 2004, regarding Yolo County Environmenta Health Department (YCEHD) response to water quality results that exceed the Maximum Contaminant Level (MCL) for samples collected from a private domestic or irrigation well. My notes from this conversation indicate that YCEHD has no authority over private wells and would only offer suggestion to the well owner on how to improve their water quality.

Please reply by email or telephone if you concur or want to add clarification to my understanding of YCEHD's response if results for constituents in a private domestic or irrigation well exceed the MCLs by the State of California for public water supply wells. This letter, with your approval, will be includ along with letters to other agencies with authority over groundwater quality in Yolo County, in the rep for the Yolo County Flood Control and Water Conservation District AB 303 Grant. My inquiry to loca and state agencies was prompted by concerns expressed by private well owners when they were approached with a request for permission to sample the water quality in their domestic or irrigation we Your response will provide these and other private well owners with an understanding of the possible consequences if contaminants are detected in their well.

Your reply by email (dcannon@lsce.com) or telephone (530.661.0109) is requested by June 1, 2004 to allow this letter to be included in the report. We appreciate your consideration of this request. Please if you have any questions.

Sincerely,

LUHDORFF AND SCALMANINI
CONSULTING ENGINEERS

Debbie Cannon
Senior Hydrogeologist

Debbie Cannon

From: Tom To [mailto:Tom.To@yolocounty.org]
Sent: Thursday, May 06, 2004 1:58 PM
To: dcannon@lsce.com
Subject: MCL in private wells

Debbie,

I received your letter of April 30, 2004 confirming the role of Environmental Health (EH) on private wells that exceed MCL. It is correct that EH does not regulate private wells and only provide recommendation for corrections on MCL matters. However, EH does have a regulatory role on MCL if the private well serves water to the public. The 'public' can be a renter, a business with outside employees or a fountain providing water to the public. Hope this clarification helps.

Tom

California Department of Pesticide Regulation Response

Max Stevenson

From: Mark Pepple [mpepple@cdpr.ca.gov]
Sent: Tuesday, March 08, 2011 8:05 AM
To: Max Stevenson
Cc: Lisa Ross
Subject: Re: DPR private well policy 2004 update

Max,

This is in response to your request for an update of how the Department of Pesticide Regulation (DPR)responds to reports of pesticides detected in wells at levels that exceed maximum contaminant levels (MCLs). For clarification, DPR does not regulate nitrates, so would not monitor for, nor respond to, reports of nitrates exceeding an MCL.

The Pesticide Contamination Prevention Act (Food and Agricultural Code sections 13141-13152) requires all state and local agencies to report to DPR the results of all well monitoring for pesticides. Since DPR considers the Yolo County Flood Control and Water Conservation District
(District) to be a local agency, the District would be required to report to DPR any results of well sampling the District does for pesticides.

DPR's response to reports of pesticides exceeding MCLs would depend on the level detected, the regulatory status of the pesticide detected, and the location of the detection. In any case, DPR does not regulate the use of public or private wells. We only regulate pesticides that may be detected in those wells or used around them. The Department of Public Health regulates public water system wells. We are not aware of any agency that regulates the use of private wells after they are constructed.

Although we are in the process of making some minor changes to the DPR policy for responding to pesticide detections, the policy is essentially the same as in 2004. We will send you the updated policy when we have it finished.

Feel free to contact me if you have any questions.

Mark

>>> Max Stevenson <mstevenson@ycfcwcd.org> 2/28/2011 11:54 AM >>>
Dear Mark,

Thank you for the conversation this morning. Appended below are 4 pages of correspondence from 2004 regarding DPR policy on water quality in private wells. Can you please confirm for me that the policy is the same? Or if it has changed, could you let me know how?

Thank you for your time.

-Max Stevenson

Max Stevenson
Yolo County Flood Control and Water Conservation District www.ycfcwcd.org
530-662-0265 office
530-681-6004 cell

[cid:image001.png@01CBD73E.51956300]

[cid:image002.png@01CBD73E.51956300]
[cid:image003.png@01CBD73E.51956300]
[cid:image004.png@01CBD73E.51956300]

California Department of Public Health, Division of Drinking Water and Environmental Management

Response

Max Stevenson

From: Mazzera, David (CDPH-DDWEM) [David.Mazzera@cdph.ca.gov]
Sent: Wednesday, March 02, 2011 2:57 PM
To: Max Stevenson
Subject: RE: CDPH regulation of private wells

Max,

I received confirmation faster than I anticipated. As indicated previously by Dr. Steven Book in response to your letter dated April 30th, 2004, CDPH regulates public water systems and not private wells. Thus, the policy remains the same as previously indicated.

Dave Mazzera, Ph.D.
Research Scientist
Division of Drinking Water and Environmental Management
California Department of Public Health
ph. 916-449-5556

From: Max Stevenson [mailto:mstevenson@ycfcwcd.org]
Sent: Tuesday, March 01, 2011 5:00 PM
To: Mazzera, David (CDPH-DDWEM)
Subject: CDPH regulation of private wells

Dave,

Below is a copy of a letter and email exchange confirming the 2004 policy of California Department of Public Health (CDPH previously Department of Health Services) toward private well MCL exceedances.

Per our conversation today, it would be very helpful if you could confirm that the policy is the same today. We are starting a new round of groundwater sampling and wish to inform our volunteer well owners on the current details of CDPH policy.

Thank you very much.

-Max

Max Stevenson
Yolo County Flood Control and Water Conservation District
www.ycfcwcd.org
530-662-0265 office
530-681-6004 cell

April 30, 2004
File No. 03-1-062

Mr. Steven Book
Toxicologist
Division of Drinking Water and Environmental Management
California Department of Health Services
1616 Capitol Avenue, MS 7416
P.O. Box 997413
Sacramento, CA 95899-7413

SUBJECT: **CONFIRMATION OF DEPARTMENT OF HEALTH SERVICES POLICY ON WATER QUALITY RESULTS THAT EXCEED THE MCL IN PRIVATE WELLS**

Dear Mr. Book:

This letter is to confirm our conversation from January 13, 2004, regarding California Department of Health Services, Division of Drinking Water and Environmental Management (DDWEM) response to water quality results that exceed the Maximum Contaminant Level (MCL) from a private domestic or irrigation well. My notes from this conversation indicate that DDWEM does not regulate private wells. Action resulting from widespread detections of analytes that exceed the MCL in private wells would be that water purveyors operating nearby public water supply wells would be required to monitor for the contaminant.

Please reply email or telephone if you concur or want to add clarification to my understanding of DDWEM's response if results for constituents in a private domestic or irrigation well exceed the MCLs set by the State of California for public water supply wells. This letter, with your approval, will be included, along with letters to other agencies with authority over groundwater quality in Yolo County, in the report for the Yolo County Flood Control and Water Conservation District AB 303 Grant. My inquiry to local and state agencies was prompted by concerns expressed by private well owners when they were approached with a request for permission to sample the water quality in their domestic or irrigation well. Your response will provide these and other private well owners with an understanding of the possible consequences if contaminants are detected in their well.

Your reply by email (dcannon@lsce.com) or telephone (530.661.0109) is requested by June 1, 2004 to allow this letter to be included in the report. We appreciate your consideration of this request. Please call if you have any questions.

Sincerely,

LUHDORFF AND SCALMANINI
CONSULTING ENGINEERS

Debbie Cannon
Senior Hydrogeologist

Debbie Cannon

From: Book, Steven (DHS) [sbook@dhs.ca.gov]
Sent: Tuesday, May 18, 2004 10:54 AM
To: dcannon@lsce.com
Subject: contaminants in private wells

To: Debbie Cannon

Your letter of April 30, 2004 (File No. 03-1-062) is correct: DHS regulates public water systems and not private wells.

Steven Book, Ph.D.
DHS' Drinking Water Program
email: sbook@dhs.ca.gov
phone: (916) 449-5556
fax: (916) 449-5656
mail: California Department of Health Services/Drinking Water Program /MS 7416/P.O. Box 997413/Sacramento, CA 95899-7413
overnight courier: California Department of Health Services/Drinking Water Program /MS 7416/1616 Capitol Avenue, Suite 74.243/Sacramento, CA 95814

Visit our website at http://www.dhs.ca.gov/ps/ddwem/default.htm

California State Water Resources Control Board, Groundwater Ambient Monitoring and Assessment Program

Response

Max Stevenson

From: Mariela Carpio-Obeso [mcarpio-obeso@waterboards.ca.gov]
Sent: Monday, February 28, 2011 12:19 PM
To: John Borkovich; Max Stevenson
Subject: Re: Fwd: well owner water quality testing brochure
Attachments: DomWell_23x85_Final_043010.pdf

Follow Up Flag: Follow up
Flag Status: Completed

Max

Please, see the attachment. If you have further questions, do not hesitate to contact us
Thanks

Mariela Paz Carpio-Obeso

>>> John Borkovich 2/28/2011 12:08 PM >>>
Mariela

Could you please fwd a pdf of the pamphlet to Max? Thank you

>>> Max Stevenson <mstevenson@ycfcwcd.org> 2/28/2011 8:57 AM >>>
Hi John,

Nice talking with you this morning. If you could send me a pdf of the brochure you send to well owners, I would appreciate it.

-Max

Max Stevenson
Yolo County Flood Control and Water Conservation District
www.ycfcwcd.org
530-662-0265 office
530-681-6004 cell

Free domestic well water quality testing is being offered by the State Water Board's GAMA Domestic Well Project.

La Junta Estatal del Agua está ofreciendo pruebas gratuitas para monitorear la calidad del agua de su pozo, a través del Programa de Evaluación de Monitoreo Ambiental en Aguas Subterráneas (GAMA[1]), bajo el Proyecto de Pozos Domésticos.

[1]Siglas en Inglés

How can I tell if the water from my well is safe?

The taste and appearance of well water is not always a reliable method to evaluate its quality. To assess if your water is safe, you need to have water samples collected from your well and tested by a certified laboratory.

How can domestic well water become polluted?

Groundwater pollution can originate from various sources including: naturally occurring chemicals, as well as fertilizers, pesticides, septic systems, livestock waste, chemical spills, and fuel from leaking underground tanks.

Who is responsible for my private "domestic" well water?

You as the well owner are responsible for your domestic well. Health agencies recommend that private domestic water well supplies be tested on an annual basis.

What is the GAMA Domestic Well Project?

The Domestic Well Project is part of the State Water Board's Groundwater Ambient Monitoring and Assessment "GAMA" Program. We are conducting free, one-time domestic well water quality testing for well owners who volunteer. This testing effort provides domestic well owners and users with specific water quality data and helps us in the assessment of California groundwater quality.

TABLE: Chemicals Typically Tested

CONSTITUENT
• **Bacteria** (e.g. Total and Fecal Coliform)
• **General Minerals** (e.g. Sodium Bicarbonate)
• **Inorganics** (e.g. Metals, Nitrate)
• **Organics** (e.g. Volatile Organic Compounds)
• **Additional Chemicals may also be tested**

How are samples collected and how will I get the results?

- The well owner assists water board staff locate the well and pressure tank.
- Water from your well pressure tank may need to be drained by staff before sampling.
- Water samples are collected by staff from a faucet as close to the well as possible.
- Water samples are transported to a laboratory for analysis.
- Well water test results are sent to the well owner.
- Well sampling and water testing are performed at no cost to the well owner.

How do I sign-up to participate?

To have your domestic well water tested:

- Complete the attached registration card by filling in the required information
- Cut along the dotted line and remove the registration card from this brochure
- Place a postage stamp on the front of the registration card
- Place the completed and stamped registration card in the mail

As our resources permit, we will contact you by telephone to schedule a time to collect samples from your well. Priority will be given to those who have well construction information (Well Completion Report).

For more information on the GAMA Domestic Well Project, go to www.waterboards.ca.gov/gama or call (916) 341-5858

¿Cómo puedo saber si el agua de mi pozo es saludable?

El sabor y la apariencia del agua potable no es un método confiable para evaluar su calidad. Para saber si su agua es saludable usted necesita que el agua de su pozo sea muestreada y analizada por un laboratorio certificado.

¿Cómo puede llegar a contaminarse el agua de un pozo?

La contaminación del agua subterránea puede originarse por varias fuentes que incluyen: la naturaleza del químico, el uso de fertilizantes, plaguicidas, sistemas sépticos, desechos provenientes del ganado, derrames accidentales de sustancias químicas y fugas de tanques de combustible subterráneos.

¿Quién es responsable del agua de mi pozo?

Usted como el dueño del pozo es responsable de él. Instituciones de salud recomiendan que el agua de los pozos privados sea analizada una vez por año.

¿Qué es el Proyecto GAMA Pozos Domésticos?

El Proyecto para la Evaluación del Agua de los Pozos Domésticos es parte del Programa de Evaluación de Monitoreo Ambiental en Aguas Subterráneas, de la Junta Estatal del Agua. Este Proyecto ofrece pruebas gratuitas, para analizar la calidad del agua del pozo de los dueños que gusten participar en el programa. Este muestreo se llevará a cabo una sola vez. Además de proporcionarle a los dueños de los pozos y sus usuarios, con información específica acerca de la calidad del agua, este esfuerzo nos ayudará a hacer una evaluación general de la calidad del agua subterránea de California.

TABLA 1. Componentes químicos a analizar.

COMPONENTE
• **Bacterias** (ej. Coliformes Fecales y totales)
• **Minerales** (ej. Bicarbonato de Sodio)
• **Sustancias Inorgánicas** (ej. Metales, Nitratos)
• **Sustancias Orgánicas** (ej. Compuestos Orgánicos Volátiles)
• **Pruebas adicionales pueden ser seleccionadas**

¿Cómo se recolectan las muestras y cómo recibiré los resultados?

- El dueño del pozo ayudará al personal de la Junta Estatal del Agua a localizar el pozo y el tanque de presión.
- Agua proveniente de su tanque de presión puede ser drenada por el personal de la Junta antes de tomar la muestra.
- Las muestras de agua se recolectan lo más cerca posible al pozo, preferiblemente de un grifo de agua fría que se encuentre antes de los filtros o sistemas de tratamiento de agua.
- Las muestras de agua se transportan a un laboratorio para ser analizadas.
- Se le envía al dueño del pozo una copia de los resultados de las pruebas.
- La toma de la muestra y el análisis del agua son sin costo para el dueño del pozo.

¿Cómo puedo participar en el Proyecto?

Para que se evalúe la calidad del agua de su pozo usted deberá:

- Completar y llenar la tarjeta de inscripción anexa con la información necesaria.
- Cortar en la línea punteada y desprender la tarjeta de este folleto.
- Colocar una estampilla en el frente de la tarjeta y
- Depositarla en un buzón de correos.

Hasta donde los recursos lo permitan, nosotros nos pondremos en contacto con usted para programar la toma de las muestras en su pozo y le notificaremos por teléfono unos cuantos días antes de nuestra llegada. Se le dará prioridad a aquellos que cuenten con información acerca de la construcción del pozo (Informe de Terminación del Pozo).

Para mayor información sobre el Proyecto GAMA Pozos Domésticos visite www.waterboards.ca.gov/gama, o llame (916) 341-5858

CUT ALONG DOTTED LINE

I agree, as owner or tenant in possession of the property r below, that State Water Boards employees, agents, or c may have access to the property for collecting water sam knowledge that the samples will be analyzed for one or mo cal or biological constituents and that the copy of the report provided to me will illustrate the concentration of co sampled for and will not indicate or preclude the presenc contaminants. I further acknowledge that the analytical be a public record and as such may be used in water qual or investigations. I understand that the State Water Boa require or provide service to correct the drinking water privately owned wells.

- ☐ **YES**, I am the well owner and would like to particip in the GAMA Domestic Well Project (Well Owner).
- ☐ **YES**, I am the tenant and have permission from the well owner to participate.
- ☐ **YES**, this well is used for drinking water
- ☐ **YES**, I have well construction information (Well Completion Report).
- ☐ **NO**, I do not wish to participate at this time, but I would like additional information on how to safeguard my domestic well water.

Signature: ______________________

Name: ______________________

Mailing Address: ______________________

City, Zip: ______________________

Well Location Address: (if different from mailing) ______________________

Daytime Phone: ______________________

ID Number: (from top of mailing label) ______________________

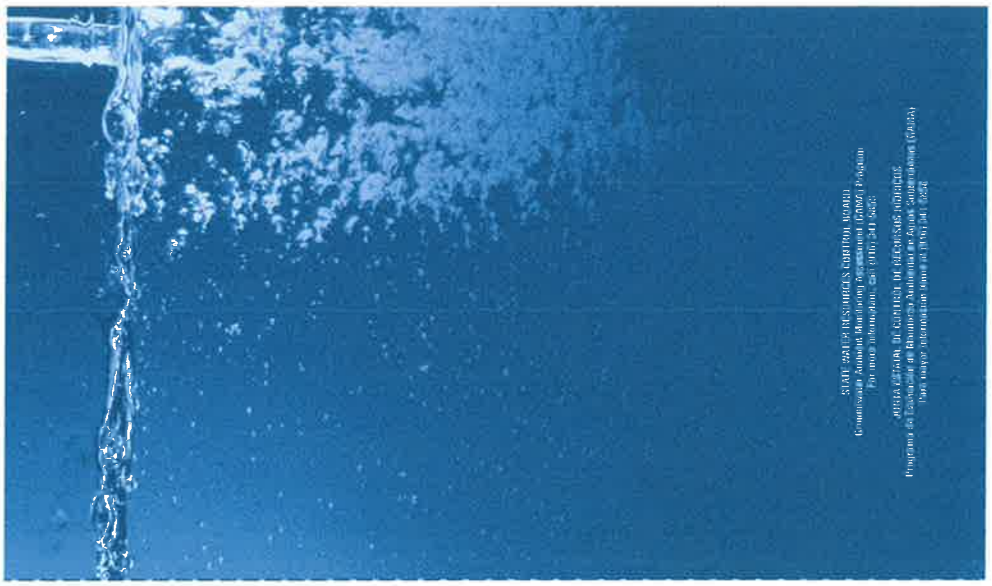
Comments: ______________________

Wells will be tested as resources allow.

Please return registration card by:

STATE WATER RESOURCES CONTROL BOARD
GAMA Domestic Well Project
P.O. Box 2231
Sacramento, CA 95812
Attn: Division of Water Quality

Printed on Recycled Paper.



PLACE STAMP HERE

Post Office will not deliver mail without postage.

STATE WATER RESOURCES CONTROL BOARD
GAMA Domestic Well Project
P.O. Box 2231
Sacramento, CA 95812
Attn: Division of Water Quality

PLACE STAMP HERE

Post Office will not deliver mail without postage.

STATE WATER RESOURCES CONTROL BOARD
GAMA Domestic Well Project
P.O. Box 2231
Sacramento, CA 95812
Attn: Division of Water Quality

CUT ALONG DOTTED LINE

I agree, as owner or tenant in possession of the property referenced below, that State Water Boards employees, agents, or contractors may have access to the property for collecting water samples. I acknowledge that the samples will be analyzed for one or more chemical or biological constituents and that the copy of the analytical report provided to me will illustrate the concentration of constituents sampled for and will not indicate or preclude the presence of other contaminants. I further acknowledge that the analytical report will be a public record and as such may be used in water quality studies or investigations. I understand that the State Water Boards cannot require or provide service to correct the drinking water quality of privately owned wells.

- ☐ **YES**, I am the well owner and would like to participate in the GAMA Domestic Well Project (Well Owner).
- ☐ **YES**, I am the tenant and have permission from the well owner to participate.
- ☐ **YES**, this well is used for drinking water
- ☐ **YES**, I have well construction information (Well Completion Report).
- ☐ **NO**, I do not wish to participate at this time, but I would like additional information on how to safeguard my domestic well water.

Signature: ______________________

Name: ______________________

Mailing Address: ______________________

City, Zip: ______________________

Well Location Address: (if different from mailing) ______________________

____

____

Daytime Phone: ______________________

ID Number: (from top of mailing label) ______________________

Comments: ______________________

____

____

____

____

Wells will be tested as resources allow.

Please return registration card by:

Appendix G: Non-Disclosure Agreement with CDPH

YOLO COUNTY

FLOOD CONTROL &
WATER CONSERVATION
DISTRICT

OFFICE COPY

May 12, 2010

Gary Yamamoto
Division of Drinking Water and
Environmental Management
California Department of Public Health
P.O. Box 997377
MS 7400
Sacramento, CA 95899-7377

Re: Yolo Nitrate Well Location Data

Dear Mr. Yamamoto:

Enclosed are two original signed non-disclosure agreements. Please return one to me after it has been fully executed.

Thank you.

Sincerely,

Max Stevenson
Water Resources Associate

Enclosures

34274 State Highway 16
Woodland, CA 95695-9371
(530) 662-0265
FAX (530) 662-4982
www.ycfcwcd.org

Tim O'Halloran
General Manager

CALIFORNIA DEPARTMENT OF PUBLIC HEALTH
DIVISION OF DRINKING WATER AND ENVIRONMENTAL MANAGEMENT

CONFIDENTIALITY AGREEMENT

WHEREAS the California Department of Public Health, Division of Drinking Water and Environmental Management (hereafter "CDPH") received a request for records from a federal, state, or local agency, namely Yolo County Flood Control And Water Conservation District (YCFCWCD) (hereafter "Requesting Party"); and

WHEREAS CDPH has determined that the requested records, or portions thereof, are confidential and exempt from disclosure to the public.

THEREFORE, CDPH and Requesting Party hereby agree that CDPH will disclose to Requesting Party the records described in Attachment A subject to the following terms and conditions.

1. Non-Disclosure: Requesting Party agrees to treat the records described in Attachment A as confidential and exempt from disclosure to the public, allowing access to the records only to those persons who are employed, retained, or otherwise under the control of the Requesting Party, who are listed in Attachment C, and who have signed Attachment D. Requesting Party agrees to protect the records described in Attachment A from disclosure to others to the greatest degree allowed by law.

2. Use: Requesting Party agrees to use the records described in Attachment A for the purpose(s) described in Attachment B and for no other purpose. If such use will include a display or representation of the geographical location of a drinking water source or treatment facility, the information will be displayed in such a manner that the exact location of the source or facility, within a radius of one mile, cannot be determined, and the use of the display or representation is otherwise subject to the provisions of this Confidentiality Agreement.

3. Approval: Requesting Party agrees that no reports, publications, maps, or other representations of the records, and/or information contained therein, described in Attachment A will be released to any person who is not employed, retained, or otherwise under the control of the Requesting Party, who is not listed in Attachment C or who has not signed Attachment D without the prior written approval of an authorized representative of CDPH.

4. Notice: Requesting Party agrees to notify CDPH promptly of any requests for disclosure of any records described in Attachment A and to coordinate with CDPH in its response to those requests.

5. Amendments: CDPH and Requesting Party agree that this Agreement and its Attachments may not be amended, except in writing signed by authorized representatives of CDPH and Requesting Party.

6. Continuity of Obligations: Requesting Party agrees that its obligations under this Agreement shall continue until the parties agree in writing to the contrary.

7. Destruction: Requesting Party agrees to destroy the records disclosed by CDPH in Attachment A as soon as Requesting Party is finished using them and to notify CDPH when they have been destroyed.

8. Indemnification: Requesting Party agrees to defend, indemnify, and hold harmless CDPH, its officers, employees, and agents against any and all claims and actions that may arise as a result of any breach of this Agreement by Requesting Party or any person listed in Attachment C.

9. Remedies: Requesting Party agrees that CDPH may pursue any and all legal remedies that may be available as a result of any breach of this Agreement by Requesting Party or any person listed in Attachment C. In addition, Requesting Party agrees that, in the event of a breach, CDPH may deny future requests for records made by Requesting Party.

10. Governing Law: CDPH and Requesting Party agree that this Agreement shall be governed by and construed in accordance with the laws of the State of California.

By their signatures below, CDPH and Requesting Party represent that they have authority to execute this Agreement and to bind the party on whose behalf their execution is made.

REQUESTING PARTY

Printed Name of Authorized Representative: Tim O'Halloran
Title: General Manager
Signature: [signature]
Date: 5-12-2010

CDPH

Printed Name of Authorized Representative: Gary H. Yamamoto
Title: Division Chief

Signature: ______________________________
Date: ________________________

ATTACHMENT A

DESCRIPTION OF RECORDS

The following records will be disclosed to Requesting Party subject to the terms and conditions of the attached Agreement.

As ordered by the Yolo County Public Health Department, the nitrate tests are identified by PS Code. This work was performed by the MONTEREY COUNTY PUBLIC HEALTH LABORATORY, under contract with Yolo County. The PS codes for which location information are needed are given below. Please provide coordinate datum and units, and other metadata, along with the location data.

PS-CODES
5700541-001
5700784-001
5700816-001
5700827-001
5700769-001
5700770-001
5700817-001
5700720-001
5700518-001
5700745-001
5700600-001
5700541-001
5700827-002
5700752-001
5700797-002
5700643-001
5700745-002
5700510-002
5700724-001
5700827-002
5700575-001
5700575-002
5700608-002
5700714-002
5700817-001
5700729-001
5700702-001
5700813-001
5700580-001
5700820-001

5700584-001
5700591-001
5700546-001
5700539-001
5700623-002
5700701-001
5700773-001
5700532-001
5700769-001
5700716-001
5700827-001
5700799-001
5700745-001
5700672-001
5700672-001
5700814-001
5700827-002
5700802-001
5700543-001
5700588-001
5700774-001
5700591-001
5700827-002
5700722-001
5700565-004
5700565-002
5700565-003
5700584-001
5700817-001
5700813-001
5700580-001
5700700-001
5700700-002
5700821-001
5700707-001
5700751-001
5700817-001
5700713-001
5700776-001
5700727-001
5700728-001
5700507-001
5700571-003
5700769-001
5700827-001
5700745-002
5700745-001
5700827-002
5700745-002
5700551-001

5700555-001
5700555-002
5700554-001
5700787-001
5700562-001
5700553-001
5700552-001
5700741-001
5700757-001
5700555-001
5700565-002
5700565-003
5700568-001
5700568-002
5700798-001
5700615-001
5700615-002
5700745-002
5700724-001
5700521-001
5700804-001
5700528-001
5700791-001
5700763-001
5700673-001
5700512-001
5700509-001
5700510-001
5700815-001
5700723-001
5700817-001
5700712-001
5700712-002
5700560-001
5700504-001
5700828-003
5700537-001
5700542-001
5700769-001
5700745-001
5700827-001
5700653-001
5700672-001
5700642-001
5700652-001
5700767-001
5700827-002
5700649-001
5700745-002
5700577-001

5700769-001
5700827-001
5700816-001
5700770-001
5700745-001
5700784-001
5700518-002
5700817-001
5700720-001
5700600-001
5700745-002
5700558-001
5700643-001
5700797-001
5700752-001
5700827-002
5700724-001
5700745-002
5700714-002
5700608-002
5700580-001
5700813-001
5700820-001
5700584-001
5700591-001
5700532-001
5700539-001
5700546-002
5700701-001
5700773-001
5700623-002
5700769-001
5700827-001
5700672-001
5700716-001
5700799-001
5700745-001
5700702-001
5700817-001
5700729-001
5700814-001
5700543-001
5700575-002
5700813-001
5700580-001
5700820-001
5700588-001
5700774-001
5700584-001
5700591-001

5700722-001
5700802-001
5700565-002
5700565-003
5700575-001
5700745-002
5700798-001
5700700-001
5700700-002
5700817-001
5700751-001
5700727-001
5700507-001
5700828-001
5700827-002
5700571-002
5700827-001
5700769-001
5700745-001
5700707-001
5700821-001
5700615-001
5700615-002
5700554-001
5700560-001
5700553-001
5700787-001
5700562-001
5700551-001
5700555-001
5700741-001
5700552-001
5700757-001
5700776-001
5700728-001
5700506-001
5700745-002
5700636-003
5700565-002
5700565-003
5700568-001
5700568-002
5700724-001
5700724-002
5700724-002
5700577-001
5700712-001
5700504-001
5700815-001
5700817-001

5700653-001
5700672-001
5700723-001
5700565-004
5700537-001
5700769-001
5700672-001
5700542-001
5700673-002
5700509-001
5700521-001
5700528-001
5700791-001
5700804-001
5700506-001
5700510-001
5700577-001
5700763-001
5700642-001
5700769-002
5700827-001
5700767-001
5700652-001
5700649-001
5700745-002
5700827-001
5700745-002
5700745-001
5700769-001
5700827-001
5700816-001
5700720-001
5700518-002
5700817-001
5700784-001
5700769-001
5700770-001
5700600-001
5700558-001
5700778-001
5700827-002
5700643-001
5700745-002
5700752-001
5700797-001
5700575-002
5700575-001
5700558-001
5700506-001
5700724-001

5700745-
5700761-001
5700608-002
5700714-002
5700549-001
5700761-001
5700672-001
5700769-001
5700827-001
5700745-001
5700716-001
5700799-001
5700824-001
5700814-001
5700817-001
5700702-001
5700729-001
5700722-001
5700745-001
5700506-001
5700802-001
5700558-001
5700623-002
5700701-001
5700773-001
5700539-001
5700546-001
5700532-001
5700543-001
5700778-001
5700580-001
5700820-001
5700584-001
5700588-001
5700813-001
5700591-001
5700827-002
5700745-002
5700761-001
5700636-003
5700798-001
5700565-002
5700565-003
5700549-001
5700827-001
5700821-001
5700707-001
5700751-001
5700817-001
5700565-004

5700769-001
5700827-001
5700615-001
5700615-002
5700745-002
5700700-001
5700700-002
5700820-001
5700714-002
5700813-001
5700549-001
5700571-001
5700828-003
5700728-001
5700727-001
5700636-002

ATTACHMENT B

USE OF RECORDS

The records described in Attachment A will be used for the following purpose(s) and for no other purpose:

More than 10 municipal water supply wells have been lost in Yolo County due to nitrate contamination. Replacement of each well costs between $1.5 and $3 million. The City of Woodland, City of Davis, UC Davis, County of Yolo, and the Yolo County Flood Control and Water Conservation District are all working on the problem of Nitrate in groundwater. The Yolo County Health Department has been collecting nitrate data since 2007, but they do not have easy access to the well locations. Locations of the wells are critical for any analysis of nitrate contamination patterns. Additionaly, the District received a State funded AB303 grant for additional nitrate sampling. The District would like to map the nitrate concentration from the hundreds of wells already sampled, and use this infomormation to plan future sampling.

Any public reporting of the data will be in the form of regional and subregional contour maps, covering 100,000 acres or more. Tabular data will be presented in summary with parameters such as mean, maximum, and minimum concentrations. No individual wells will be displayed in an identifying manner.

Printed map size: between 4 x 6 inches and 3 x 4 feet
Projected map size: up to 30 feet wide
Map area coverage: minimum 100,000 acres (about 1/6 of the County), maximum coverage is the entire County around 650,000 acres.
Map scale: variable, depends on ratio of area covered to printed or projected size

ATTACHMENT C

LIST OF PERSONS AUTHORIZED TO ACCESS THE RECORDS

The following persons, and no others, are authorized to access the records described in Attachment A. (List each person's name, title, and employer.)

YCFCWCD Water Resources Associate- Max Stevenson

YCFCWCD Special Projects Coordinator- Greg Anderson

Charlie Thomsen, Consultant

Name of Student Intern: ______________________

ATTACHMENT D

AGREEMENT BY PERSONS AUTHORIZED TO ACCESS THE RECORDS

I hereby certify that I have read the attached Confidentiality Agreement between CDPH and Requesting Party and, as a condition to accessing the records described in Attachment A, I agree to be bound by all of its terms and conditions to the same extent as Requesting Party.

Printed Name: Max Stevenson
Employer: YCFCWCD
Title: WATER RESOURCES ASSOCIATE
Signature: [illegible]
Date: 4-21-2010

Printed Name: Greg Anderson
Employer: YCFCWCD
Title: SPECIAL PROJECTS COORDINATOR
Signature: [illegible]
Date: 4-21-2010

Printed Name: Charlie Thomsen
Employer: ______
Title: ______
Signature: [illegible]
Date: 4/26/2010

Printed Name: ______
Employer: ______
Title: ______
Signature: ______
Date: ______

Prepared by

Brown AND Caldwell

Davis
1590 Drew Avenue, Suite 210
Davis, CA 95618
Phone: 530.747.0650
Fax: 530.297.7148

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Yolo County Flood Control & Water Conservation District