WORKING TO UNDERSTAND GROUNDWATER QUALITY IN THE NORTHERN SACRAMENTO VALLEY

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INTRODUCTION

The previous article in this informational series on groundwater topics discussed basic principles pertaining to groundwater quality and provided an overview of current groundwater quality monitoring activities underway in the north valley. This article is a continuation of the discussion on groundwater quality and highlights some findings from ongoing water quality monitoring programs in the north valley.

USE OF DEDICATED MONITORING WELLS

Northern District, Department of Water Resources (DWR) collaborates with counties, water purveyors, Lawrence Livermore National Laboratory (LLNL), and the United States Geological Survey (USGS) to monitor groundwater quality in dedicated monitoring wells throughout the Northern Sacramento Valley. Figure 1 shows, at present, 45 dedicated monitoring wells in the north valley and Figure 2 shows how the monitoring wells are constructed to sample groundwater from discrete aquifer intervals.

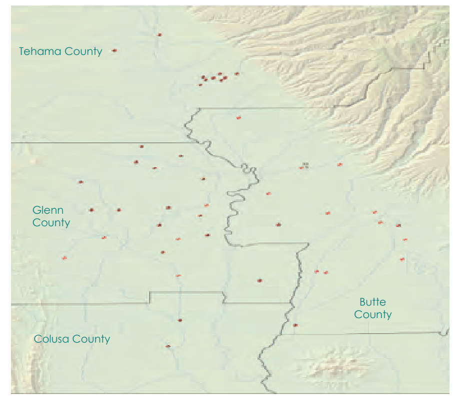

Figure 1. Dedicated monitoring wells in the northern Sacramento Valley sampled for water quality.

IMPORTANT GROUNDWATER CHARACTERISTICS

Simple physical and chemical attributes

Temperature, pH, and electrical conductivity (EC) are commonly measured. Groundwater temperature is generally higher than surface water and becomes warmer with depth due to the earth's natural thermal gradient of about 1.5°F per 100 feet. Monitoring groundwater temperature gives insight as to how groundwater might be managed to compliment surface water supplies and provides insight about different aquifer systems. The pH of groundwater indicates whether a water source is alkaline, neutral, or acidic. EC is a simple indicator of the level of dissolved minerals in groundwater. EC and pH are inexpensive water quality characteristics that are helpful to recognize change and to assess suitability.

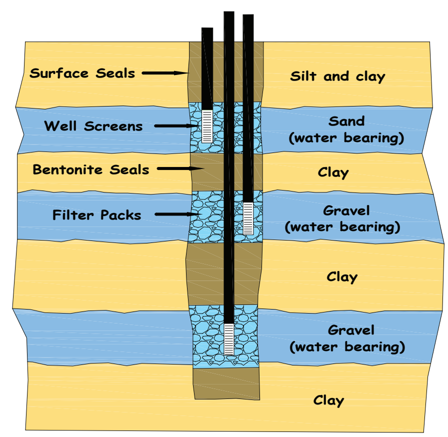

Figure 2. Example of discrete aquifer sampling with dedicated monitoring wells.

Mineral composition

Minerals or salts from geological materials in discrete aquifers are dissolved in groundwater and exist mostly as disassociated cations and anions. The major cations are calcium (Ca), magnesium (Mg), sodium (Na), and to a lesser extent potassium (K). The primary anions are bicarbonate or carbonate (HCO_3 and CO_3), chloride (Cl), and sulfate (SO_4). Boron (H_3BO_3) and nitrate (NO_3) are also present in groundwater as anions but at lower concentrations. Over long periods of time, the mineral composition of the groundwater will change due to the capacity of the clays, silts, and organic materials to adsorb and release cations and anions. Understanding the mineral composition is valuable to assess groundwater suitability for a variety of uses. Analysis of minerals constituents may also help discern discrete aquifer systems and to form management strategies to protect freshwater aquifer systems from saline aquifer systems.

Isotopes of Natural Occurring Elements

Natural occurring elements may have two or more atomic structures that are referred to as isotopes. Oxygen, carbon, hydrogen, and helium, are all natural occuring elements with isotopes. They can be used for age dating of groundwater and help understand recharge areas and hydrologic connections between aquafier systems.

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Hydrogen-3 (tritium) is a naturally occurring isotope at very low levels in the atmosphere with a relative short half-life of 12.3 years. Levels of tritium in the atmosphere have been elevated significantly in the past 50 years. Levels of tritium in precipitation that percolates into groundwater can be used to distinguish "modern recharge" (less than 50 years in age), from "pre-modern" recharge (greater than 50 years in age). Similarly, carbon-14 (^{14}C) is also present in the atmosphere and falls to the earth with precipitation. However, its half-life is 5,730 years enabling it to be used to identify groundwater that has been stored in discrete aquifers for 1,000 to 50,000 years. Another isotope used in groundwater age dating is the helium isotope (^{4}He). It results from the decay of naturally occurring uranium and thorium. High levels of ^{4}He also indicate groundwater older than 10,000 years.

Oxygen has three isotopes (^{16}O, ^{17}O, and ^{18}O). Oxygen-16 is the most common atom with 16 protons and 16 neutrons in its nucleus. Oxygen-18 (^{18}O) also has 16 protons in the nucleus but instead has 18 neutrons in its nucleus. The additional neutrons increase the mass of the atom. The amount of ^{18}O found in precipitation varies depending on temperature, elevation, and latitude. Because of its larger mass, ^{18}O atoms tend to "drop out" with precipitation at lower elevations. Precipitation in higher mountain watersheds has less ^{18}O atoms than at the valley floor. The relative differences in the number of ^{18}O atoms in groundwater may provide an isotopic characteristic that helps understand the extent that groundwater recharge of discrete aquifers occurs from stream flow originating in the higher watersheds and rainfall occurring in the valley.

Trace elements and human induced constituents

Trace metals may occur naturally in groundwater or possibly associated with human activities. Other examples of potential human induced constituents are synthetic chemicals, nitrates, and antibiotics. Understanding their extent is important to assure healthy drinking water supplies.

HIGHLIGHTED FINDINGS

Selected findings from ongoing groundwater quality monitoring in the northern Sacramento Valley are presented in this section. Specifically, results from investigations into mineral composition and age dating of groundwater are highlighted. Studies of other groundwater quality characteristics are underway but findings are not included in this article.

Mineral Composition of Groundwater

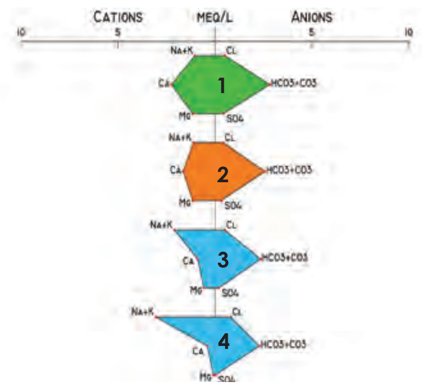

Figure 3. Stiff diagram showing the vertical change in mineral composition of groundwater sampled from a quadruple-completion monitoring well .

Figure 3 is a "Stiff Diagram" depicting the mineral composition of groundwater detected in four different aquifer intervals from a monitoring well west of the Sacramento River in Glenn County.

A Stiff Diagram is one graphical method of displaying the types and concentrations of the major cations and anions in the groundwater. The types and concentrations of cations are plotted on the left axes and anions are plotted on the right axes. The green polygon(#1) depicts the general mineral composition associated with the shallow alluvial groundwater from about 30 to 100 feet below the ground surface. The orange polygon (#2) represents the groundwater mineral composition associated with the Tehama Formation from about 170 to 280 feet below ground surface. The upper blue polygon (#3) represents groundwater from a deeper portion of the Tehama Aquifer between 400 and 510 feet. The lower blue polygon (#4) is from a highly confined portion of a deep aquifer from 920 to 1000 feet. Field analysis of lithologic samples to determine the geologic formation associated with this deep aquifer was inconclusive. Detailed analysis of the sand grains within this aquifer is being conducted to more accurately identify the associated geologic formation.

At this dedicated monitoring well, the mineral composition of groundwater in the northern Sacramento is relatively low in total dissolved cations and anions in all four discrete groundwater zones. The sum of the cations (Ca, Mg, and Na) and anions (HCO_3, CO_3, Cl, and SO_4) each total to about 5.0 meq/l (milliequivalents per liter), and poses very little if any limitation for use as a domestic, industrial, or irrigation supply. However, the mineral composition of the groundwater does vary with depth as illustrated by differently shaped polygons in Figure 3. The mineral composition of groundwater from the upper two zones (polygons 1 and 2) show balanced proportions of calcium (Ca), magnesium (Mg), and sodium cations and a predominance of bicarbonate and carbonate anions. In contrast, the mineral composition in the deeper groundwater (polygons 3 and 4) shows a predominance of sodium (Na) and lower levels of calcium (Ca) and magnesium (Mg), while bicarbonate and carbonate anions remain predominant.

In terms of assessing suitability, Sodium (Na) dominated waters tend to have less hardness associated with them, which may have benefits to some domestic and industrial uses but sodium dominated waters in other parts of

California have been shown to contribute to reduced soil tilth and slower water infiltration characteristics when used for irrigation.

Aside from assessing groundwater suitability for use, the Stiff Diagram in Figure 3 depicts the mineral composition of groundwater from discrete aquifer zones that can serve as a baseline to monitor change. When Stiff Diagrams are developed to characterize the mineral composition of groundwater sampled from numerous dedicated groundwater monitoring wells throughout the northern Sacramento Valley (Figure 4), unique differences and correlations in mineral composition of groundwater can help provide a better understanding of the extent of the aquifer systems beneath the Sacramento Valley.

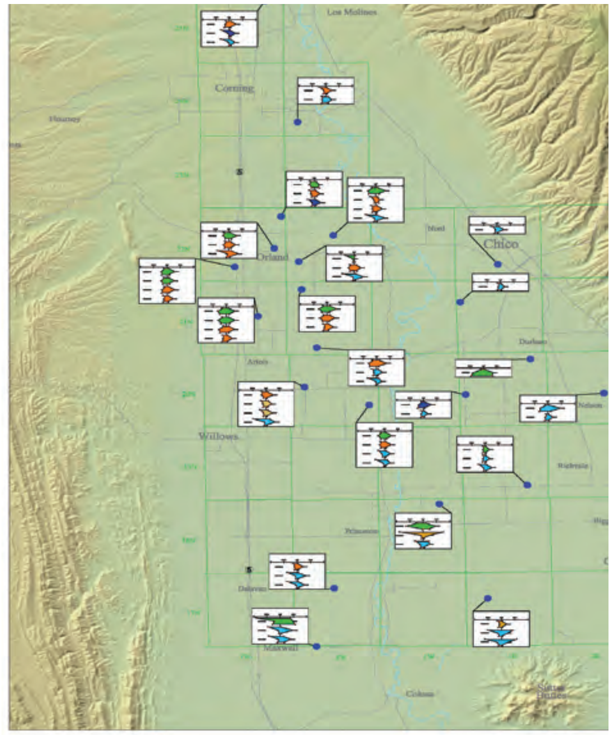

Figure 4. Stiff diagrams showing the spatial distribution and mineral composition of groundwater in the northern Sacramento Valley sampled from multi-completion monitoring wells.

Using Isotopes to "Age" Groundwater

Below, Figure 5 shows the sample locations and the estimated age for groundwater sampled from the Tehama and lower Tuscan Formations at different sites in the north valley. The range of age dating accuracy varies significantly depending upon the analysis method. The age results reported for "modern" water (<100 yrs. old) can be accurate within a couple of years. The age results associated with "pre-modern" water (100 – 9000 yrs old) may only be accurate to within a couple thousand years; while the "paleo" water (>10,000 yrs old), is only accurate in the range of tens of thousands of years. Test results in Figure 5 indicate that the "age" of the groundwater samples ranges from less than 100 years to tens of thousands of years. In general, the more shallow wells in the lower Tuscan Formation along the eastern margin of the valley have the "youngest" water and the deeper wells in the western and southern portions of the valley have the "oldest" water. The youngest groundwater in the lower Tuscan Formation is probably nearest to recharge areas. Samples of groundwater from the Tehama Formation ranged from less than 100 years to about 3000 years old.

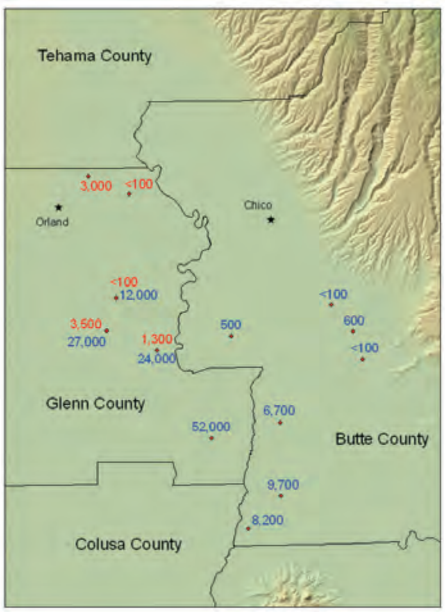

Figure 5. Sample locations and estimated age of the groundwater at various monitoring sites in the north valley. Age is estimated in years; dark blue values represent groundwater in lower Tuscan Formation and red values represent groundwater in Tehama Formation.

GROUNDWATER INFORMATIONAL SERIES

Some of the past articles in this series are listed below and are available at http://cetehama.ucdavis.edu:

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This article is the last in a series of five to be published in 2006/07 discussing topics related to groundwater and water wells in the northern Sacramento Valley.

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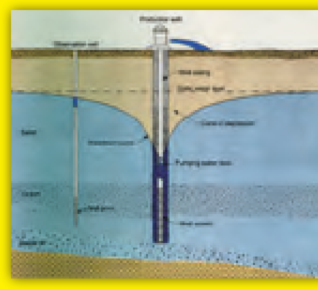

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