Geohydrologic Characterization of Southern Sonoma Valley to Support Water Management, Sonoma County, California

Donald Sweetkind[1], Geoff Cromwell[2], Nicholas Teague[3], and Andrew Rich[4]

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Abstract

The U.S. Geological Survey and Sonoma County Water Agency (SCWA) are engaged in a cooperative project to characterize the hydrogeology of southern Sonoma Valley, a groundwater basin in the northern California Coast Ranges where groundwater represents about 60% of the valley's water supply. The basin lies near the Sonoma volcanic field and major transverse faults of the San Francisco Bay region, resulting in a complex aquifer system comprising volcanic and sedimentary rocks and unconsolidated sediments that are cut by faults and overlain to the south by recent Bay Muds of San Francisco Bay. Geologic sections were constructed using geologic maps and lithologic data from over 1,500 water wells compiled by SCWA to describe the subsurface geologic configuration relative to groundwater pumping wells. This work suggests an aquifer system extending to about 900 feet below land surface (ft bls), consisting of upper and lower aquifer units separated by an intermediate unit with lower hydraulic conductivity, overlying and partly interfingering with a complex suite of volcanic rocks. SCWA constructed a four-layer hydrostratigraphic model of the basin using spatial trends in the lithologic data. The hydrostratigraphic layers defined by SCWA include multiple mapped geologic formations because of heterogeneity and complex interfingering between stratigraphic units. Water from selected wells was analyzed for specific conductance, major and minor ions, nutrients, stable isotopes, carbon isotopes, and tritium. Well data were categorized by completed perforation interval into shallow wells ($<$ 200 ft bls), mid-depth wells (200–500 ft bls), and deep wells ($>$ 500 ft bls). Shallow wells typically have water types related to recent mountain-front recharge, and, near the tidal marshlands north of San Pablo Bay, have high chloride and total dissolved solid concentrations associated with modern saline-water intrusion. Mid-depth and deep wells have water with poor water-quality, likely influenced by connate water from consolidated marine sediments, or a mixture of water from consolidated sediments and thermal water. This cooperative basin characterization of subsurface geology, hydrostratigraphy, and water chemistry will enable SCWA to make strategic water management decisions in Sonoma Valley.

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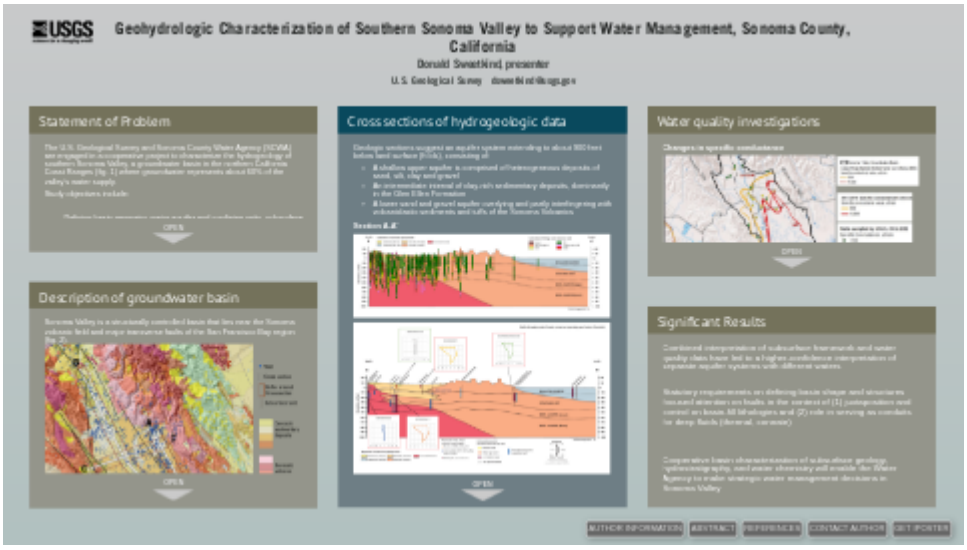

Donald Sweetkind, presenter

U.S. Geological Survey dsweetkind@usgs.gov

PRESENTED AT:

STATEMENT OF PROBLEM

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Study objectives include:

- Defining basin geometry, major aquifer and confining units, subsurface lithologic variations, and structures that may impact the hydrologic system
- Define water quality, identify sources of poor water-quality, and describe groundwater movement
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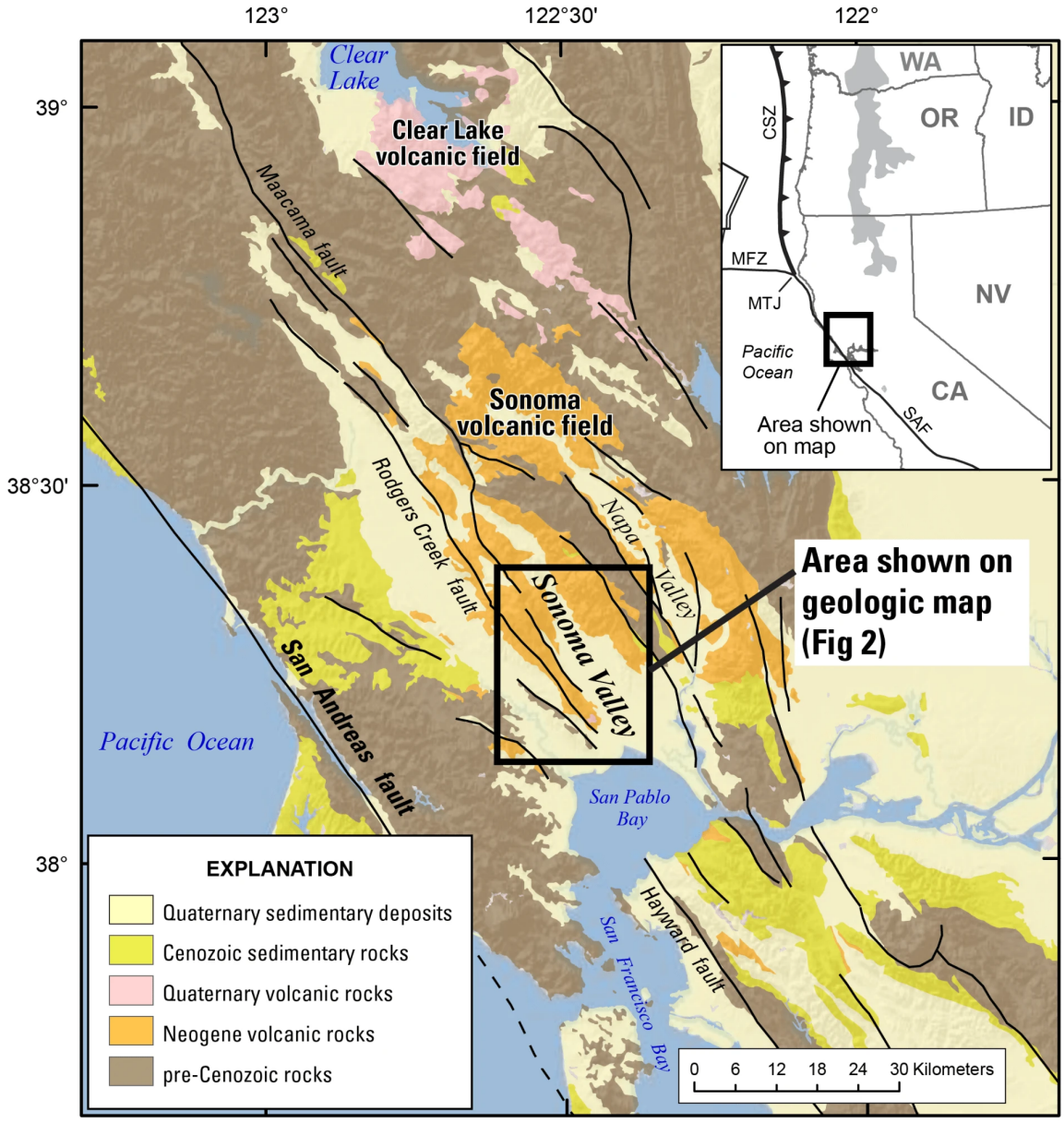

Fig. 1 Index map of study area. Abbreviations on small index: CSZ, Cascadia Subduction Zone; MFZ, Mendocino Fracture Zone; MTJ, Mendocino Triple Junction; SAF, San Andreas fault. Map from Sweetkind and others (2011).

Groundwater resource assessments require conceptualization of the hydrologic system and the subsurface geologic framework. Motivated, in part, by the ongoing drought, California adopted legislation in 2014, known as the Sustainable Groundwater Management Act (SGMA), which requires local agencies in 127 groundwater basins/subbasins statewide to form Groundwater Sustainability Agencies, and to develop and implement Groundwater Sustainability Plans (GSP) for managing groundwater. As part of SGMA, groundwater sustainability agencies are required to develop a hydrogeologic conceptual models (HCM) to support the long-term sustainability of California's groundwater basins. The HCM is intended to provide an understanding of the general physical characteristics related to regional hydrology, land use, geology and geologic structure, water quality, principal aquifers, and principal aquitards of the basin setting.

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DESCRIPTION OF GROUNDWATER BASIN

Sonoma Valley is a structurally controlled basin that lies near the Sonoma volcanic field and major transverse faults of the San Francisco Bay region (fig. 2).

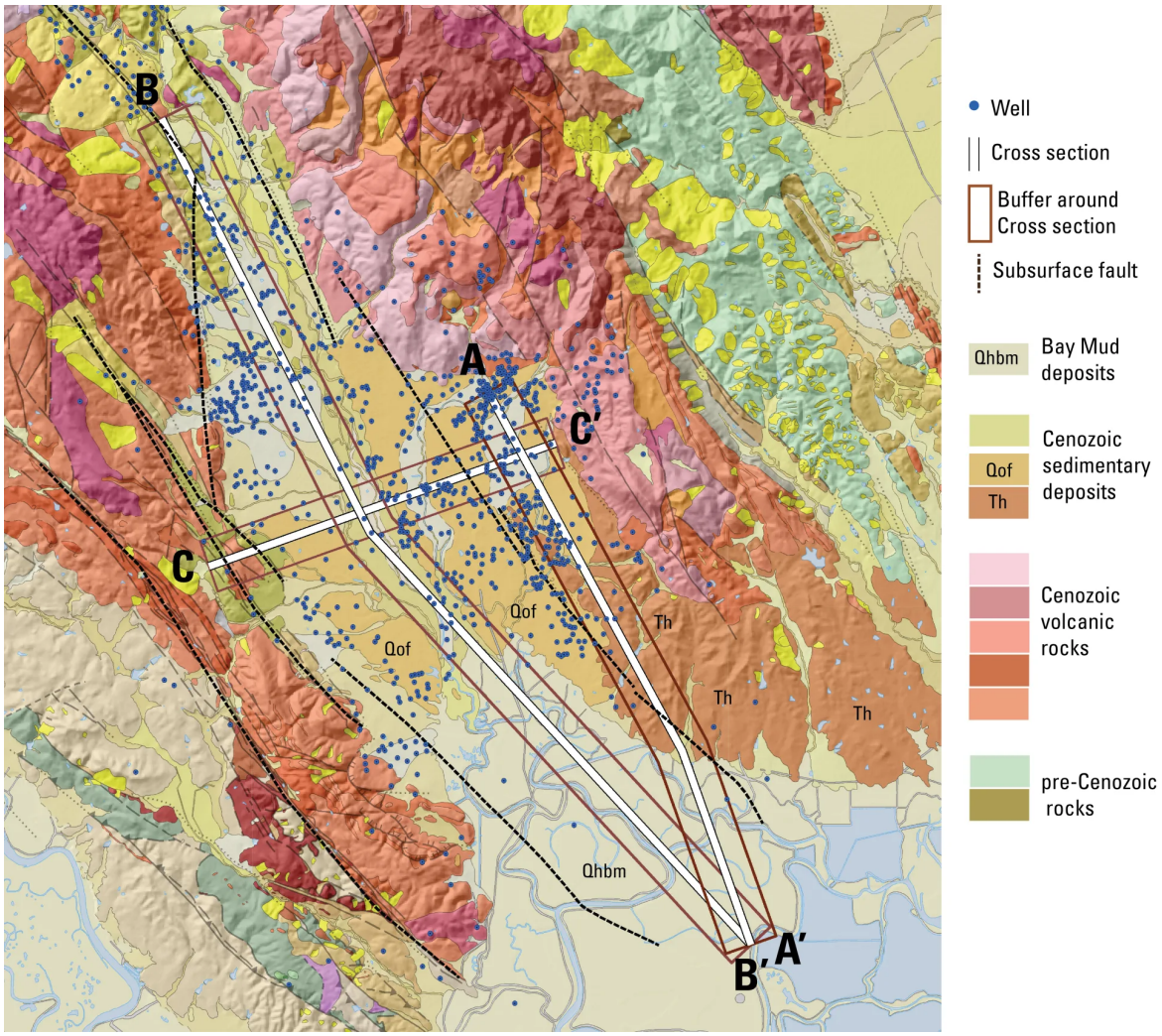


Fig. 2 Geologic map of southern part of Sonoma Valley, showing lines of section. Map created from digital geologic data from Wagner and Gutierrez (2010).

Major rock types include (1) highly deformed pre-Cenozoic basement rocks; (2) Cenozoic sediments and sedimentary rocks; (3) heterogeneous Cenozoic volcanic rocks and tuffs; and (4) Quaternary alluvial deposits and Bay Mud deposits. The structural and volcanic setting of the basin results in a complex aquifer system comprising volcanic and sedimentary rocks and unconsolidated sediments that are cut by faults and overlain to the south by recent Bay Muds of San Francisco Bay (fig. 2).

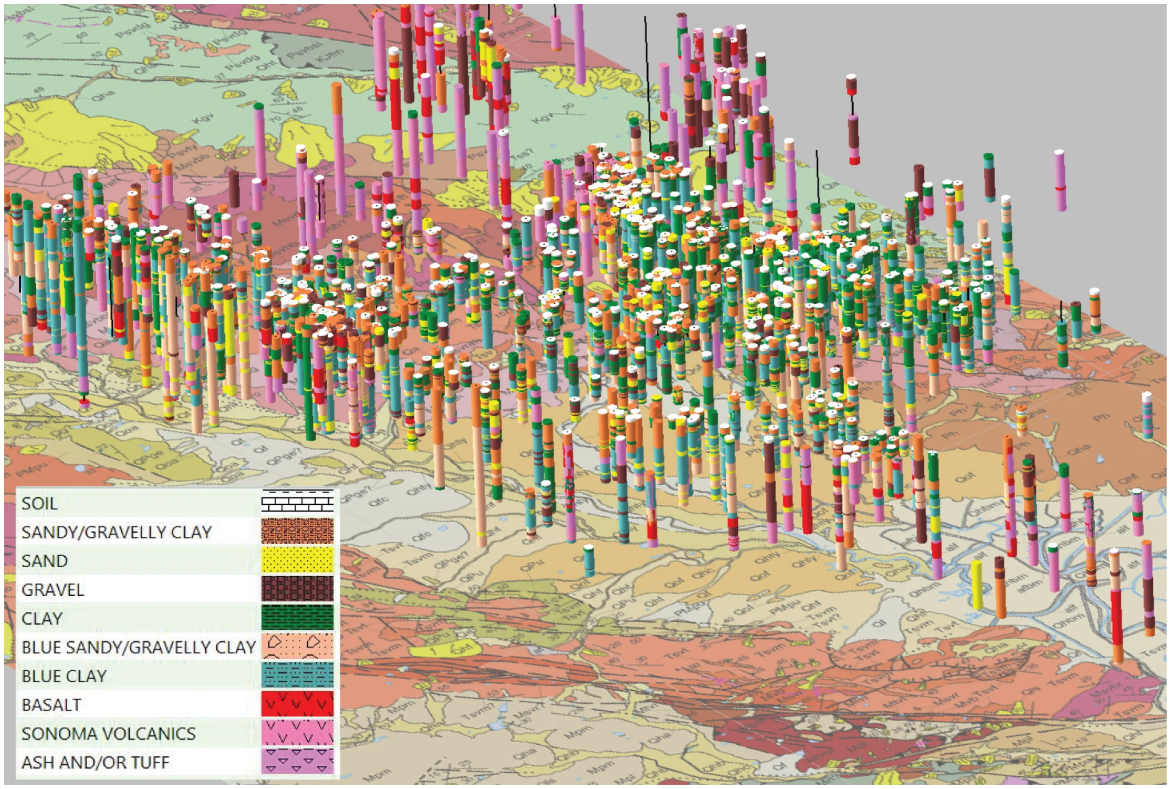


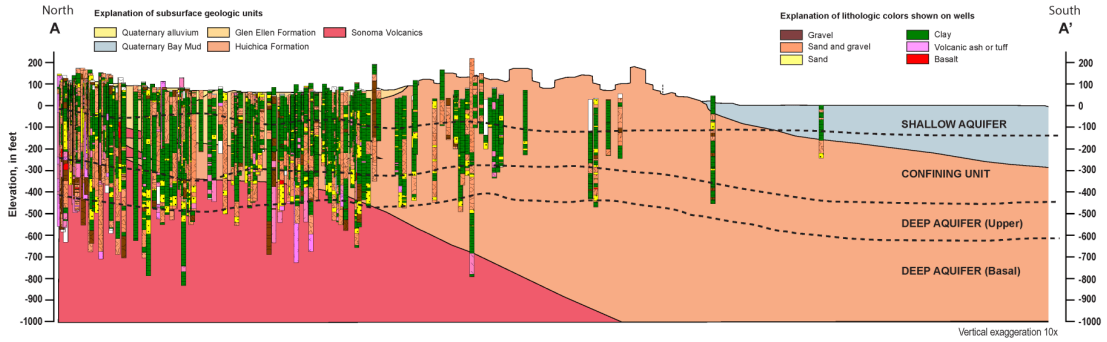
Fig. 3 Perspective view,of southern part of Sonoma Valley, showing classified downhole lithologic data from wells. Wells appear as vertical cylinders with downhole lithology symbolized by colors. View is from above and from the southwest. Wells are hung in 3D space from land surface which is turned off in this view. Geologic map is inserted for reference at an arbitrary elevation below the well data; colors on this map differ from the map shown in fig. 2 because of the effects of directional illumination and transparency in the 3D view.

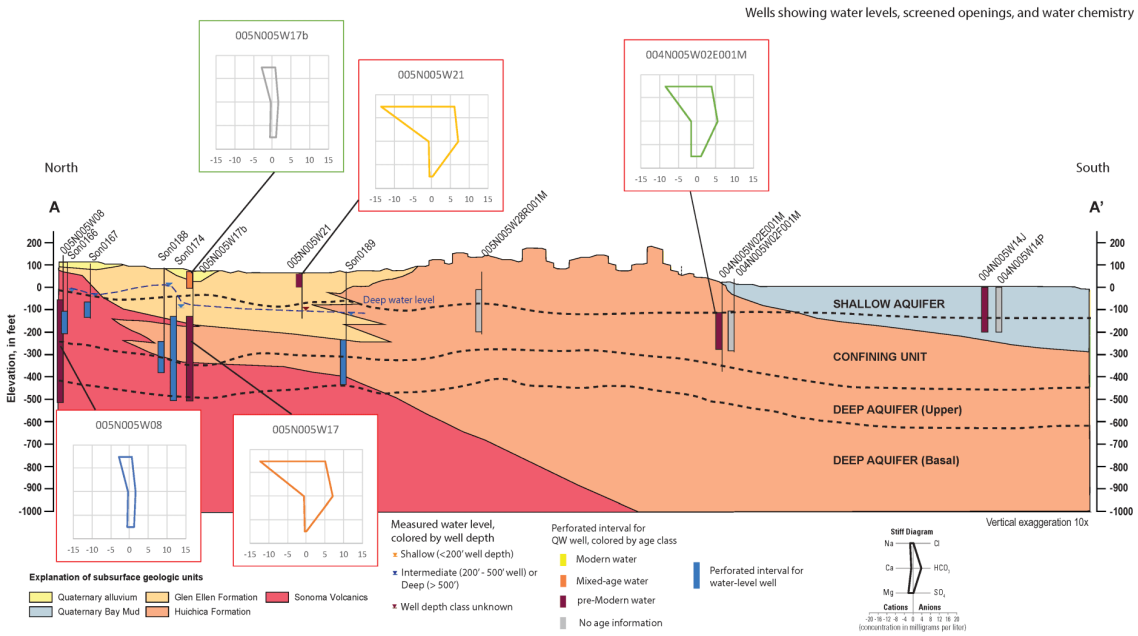
The distribution of volcanic rock types and fine- and coarse-grained sediments in Sonoma Valley are illustrated in a perspective view (fig. 3), looking from above to the northeast, of reported downhole lithologic data from 1,530 well logs. The lithologic description in each well log was regularized into one of into 10 lithologic descriptors.

CROSS SECTIONS OF HYDROGEOLOGIC DATA

Hydrogeologic conceptual model is built from integration of geologic data (inferred subsurface geology, downhole lithologic logs) and hydrologic data (well perforation depth, water level, age, and chemistry).

Section A-A' (described below)





General description of cross sections

Three cross sections were constructed using geologic maps and lithologic data from over 1,500 water wells to describe the subsurface geologic configuration relative to water wells sampled for water-table elevation and water chemistry. The sections support subsurface characterization by showing subsurface aquifer layers, profiles through a 3D lithologic model, lithology in wells, and geochemistry data from selected wells. Cross sections are partly diagrammatic; not all faults and geologic units shown on the geologic map are shown on the sections. Sediment/volcanic contacts attempt to honor borehole data but are largely diagrammatic. Wells within 500 m of the line of section are projected onto the section.

Geologic sections suggest an aquifer system extending to about 900 feet below land surface (ft bls), consisting of: (1) A shallow upper aquifer is comprised of heterogeneous deposits of sand, silt, clay and gravel; (2) An intermediate interval of clay-rich sedimentary deposits, dominantly in the Glen Ellen Formation, and (3) A lower sand and gravel aquifer overlying and partly interfingering with volcaniclastic sediments and tuffs of the Sonoma Volcanics.

Aquifer and confining unit model layers for use in the numerical model generally honor spatial trends of lithologic variability as observed in well data, but for computational stability model layers were constructed to be sub-parallel to land surface and the water table surface. The hydrostratigraphic layers defined for the model thus include multiple mapped geologic formations. The heterogeneity and complex interfingering between stratigraphic units is addressed in the numerical model through horizontal subdivision of model units by geology-based properties.

The major-ion compositions of groundwater samples from wells were characterized by using Stiff diagrams that depict the concentrations of major ions in meq/L and indicate relative proportions of major ions. Analyses with similarly shaped diagrams represent groundwater of similar chemical characteristics with respect to major ions. Changes in the width of the diagrams indicate differences in the concentration of dissolved constituents.

Following Farrar and others (2006), the wells were categorized into four main categories: (1) shallow wells—entire perforated or open interval above 200 ft below land surface (bls), (2) mid-depth wells—entire perforated or open interval between 200 and 500 ft bls, (3) deep wells—entire perforated or open interval below 500 ft bls, and (4) unknown depth wells—the depth of the perforated or open interval is unknown.

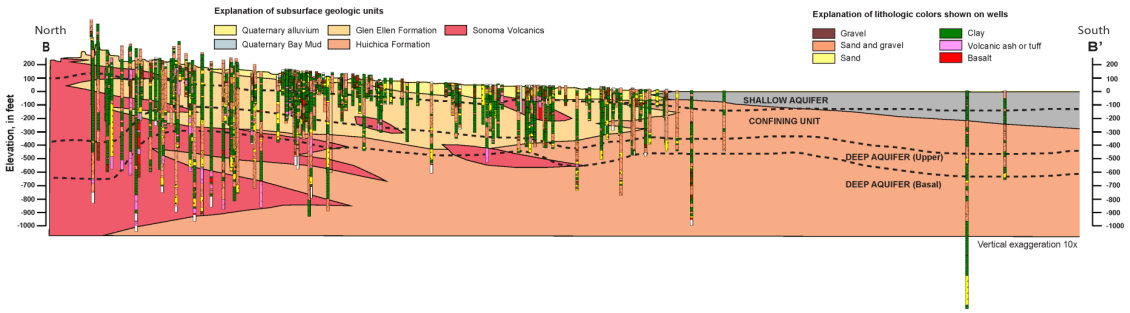
Description of individual sections

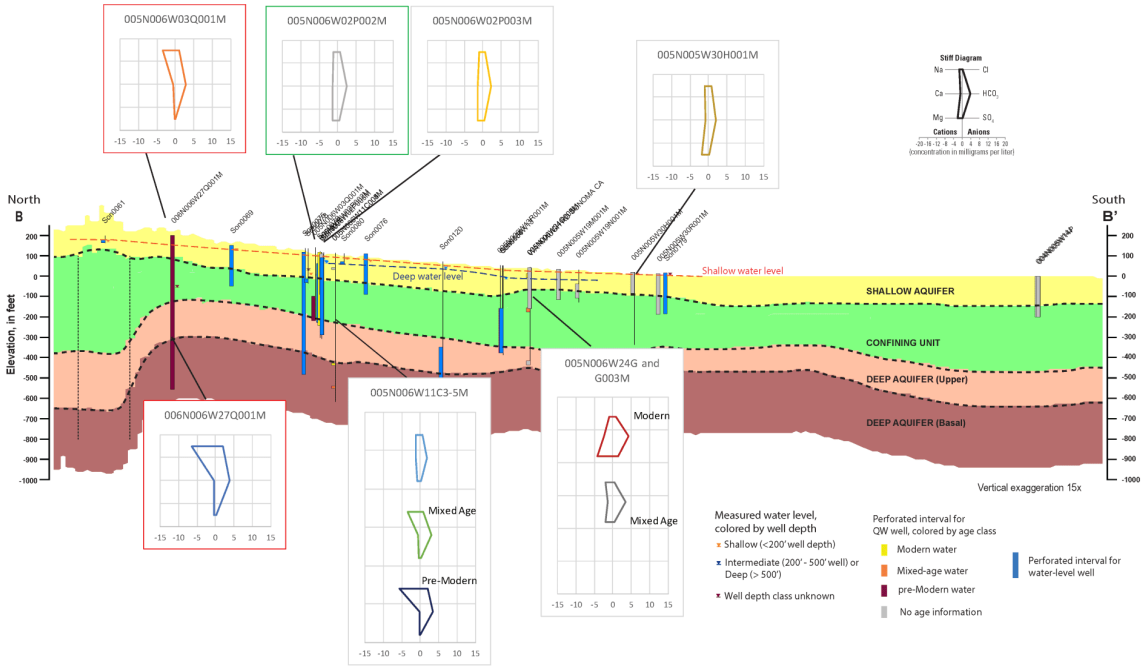
Section A-A'

Cross section A-A’ is a NW-SE section along the east side of the basin extending from the base of the uplands underlain by volcanic rocks on the north to the tidal flats underlain by Bay Mud on the south. Wells 005N005W-W17 and -W21 display relatively high concentrations of iodide, boron, and other constituents in water suggestive of connate water as the source of salinity to wells in this area. The East Side fault (not shown but parallel to the line of section) may play a role as a conduit for deep fluids.

Section B-B'

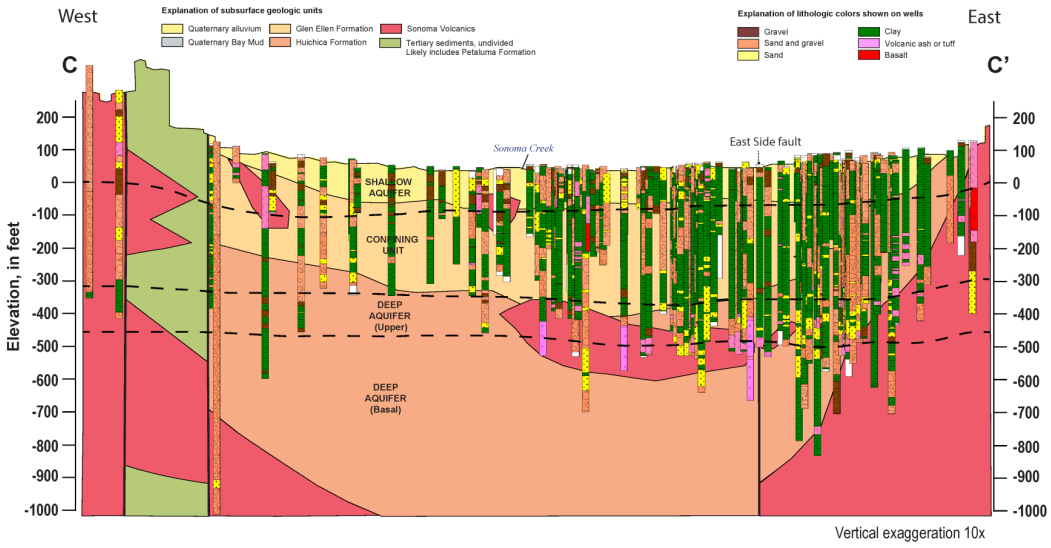
Cross section B-B’ is a long NW-SE section along the axis of the basin and topographic valley. The section extends from the narrow northwest part of the basin dominated by tuffaceous and volcaniclastic sediments to the broader southeastern part of the basin where sediments of the Glen Ellen and Huichica Formations are overlain by shallow alluvium and, in the south, Bay Mud.

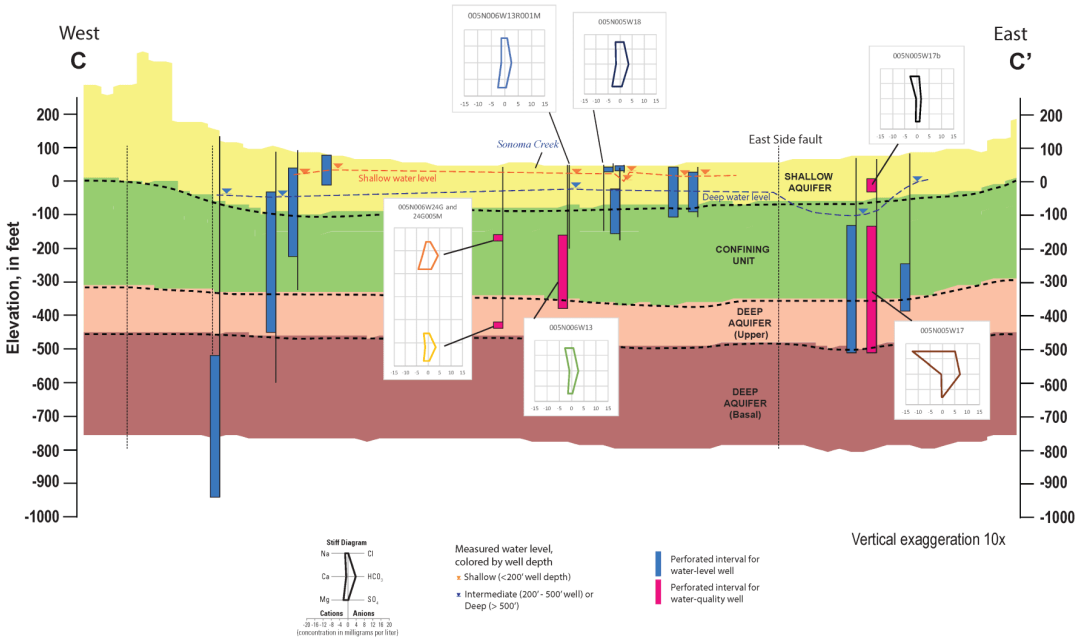




Section C-C'

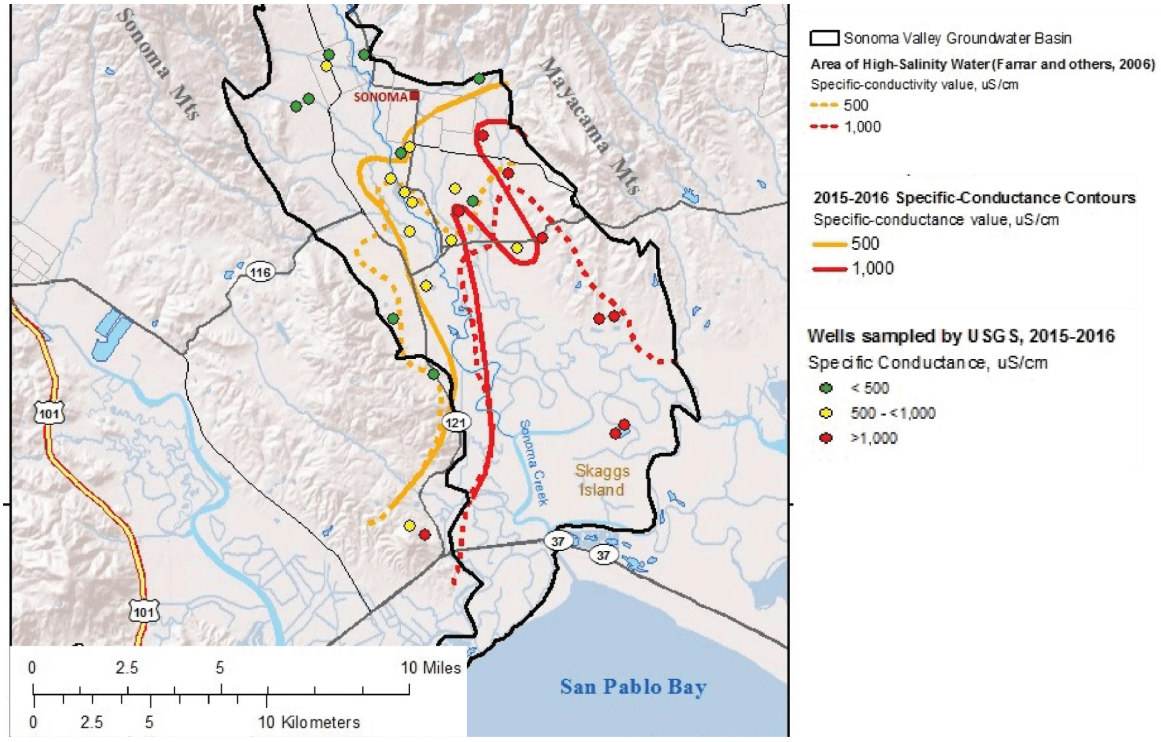
Cross section C-C’ is an E-W section through the center of the southern part of the basin and crosses basin-bounding faults at the east and west ends of the section. Water levels on the east side of the section show a cone of depression around wells pumping groundwater from the deeper units.




West
C
East
C'
Elevation, in feet
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
005N006W13R001M
005N005W18
005N005W17b
Sonoma Creek
East Side fault
Shallow water level
Deep water level
SHALLOW AQUIFER
CONFINING UNIT
DEEP AQUIFER (Upper)
DEEP AQUIFER (Basal)
005N006W24G and 24G005M
005N006W13
005N005W17
Vertical exaggeration 10x
Stiff Diagram
Na
Cl
Ca
HCO3
Mg
SO4
Cations
Anions
(concentration in milligrams per liter)
Measured water level, colored by well depth
Shallow (<200' well depth)
Intermediate (200' - 500' well) or Deep (> 500')
Perforated interval for water-level well
Perforated interval for water-quality well

WATER QUALITY INVESTIGATIONS

Changes in specific conductance



Contours of equal specific conductivity (SC) values, made from conductivity measurements from 37 wells and 2 springs, show that high-salinity water (SC greater than or equal to 1,000 µS/cm) is present south of Sonoma. The SC contours show that shallow wells containing high-salinity water seem to be constrained to the southern part of the study area, near the tidal marshlands.

The areas of high-salinity water in the mid-depth and deep wells show that high-salinity water extends north from the marshlands near San Pablo Bay, but trace-element, stable-isotope, and age-dating (tritium and carbon-isotope) data suggest that high-salinity water in deep wells may be brines from consolidated marine sediments; deep, high-salinity, thermal water; or mixtures of both – rather than young seawater intrusion. The areas of high-salinity water in the mid-depth and deep wells correspond to areas of groundwater draw-down and may represent inflow of deeper waters to pumping wells, perhaps augmented by upward flow along the East Side fault zone.

SIGNIFICANT RESULTS

Combined interpretation of subsurface framework and water quality data have led to a higher-confidence interpretation of separate aquifer systems with different waters

Statutory requirements on defining basin shape and structures focused attention on faults in the context of (1) juxtaposition and control on basin-fill lithologies and (2) role in serving as conduits for deep fluids (thermal, connate)

Basin characterization of subsurface geology, hydrostratigraphy, and water chemistry will enable the Water Agency to make strategic water management decisions in Sonoma Valley

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ABSTRACT

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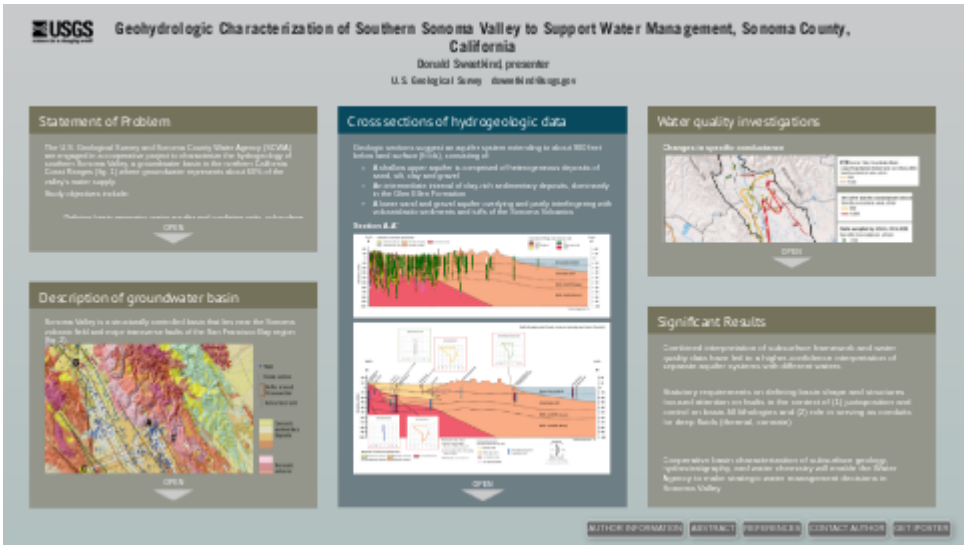

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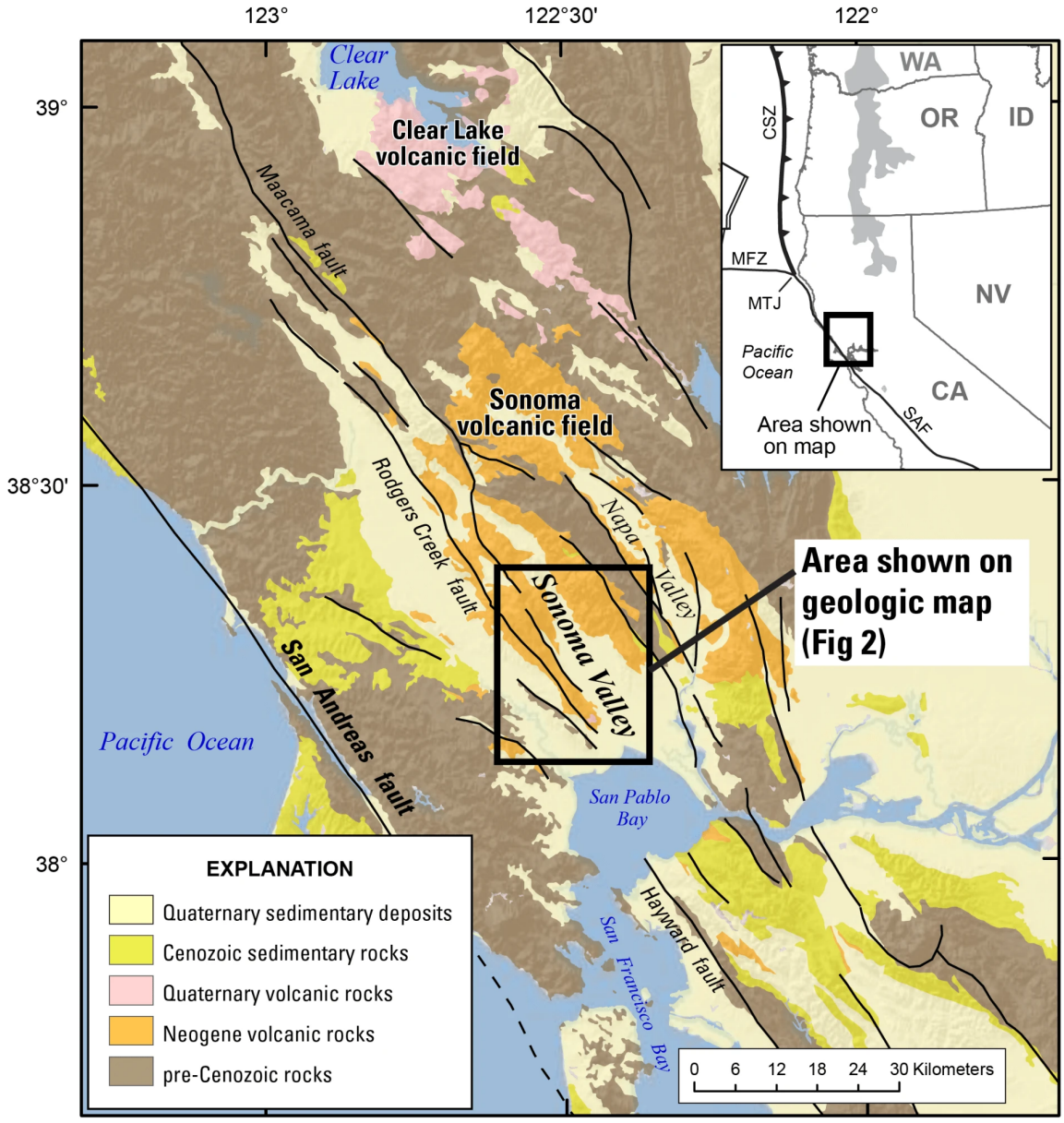

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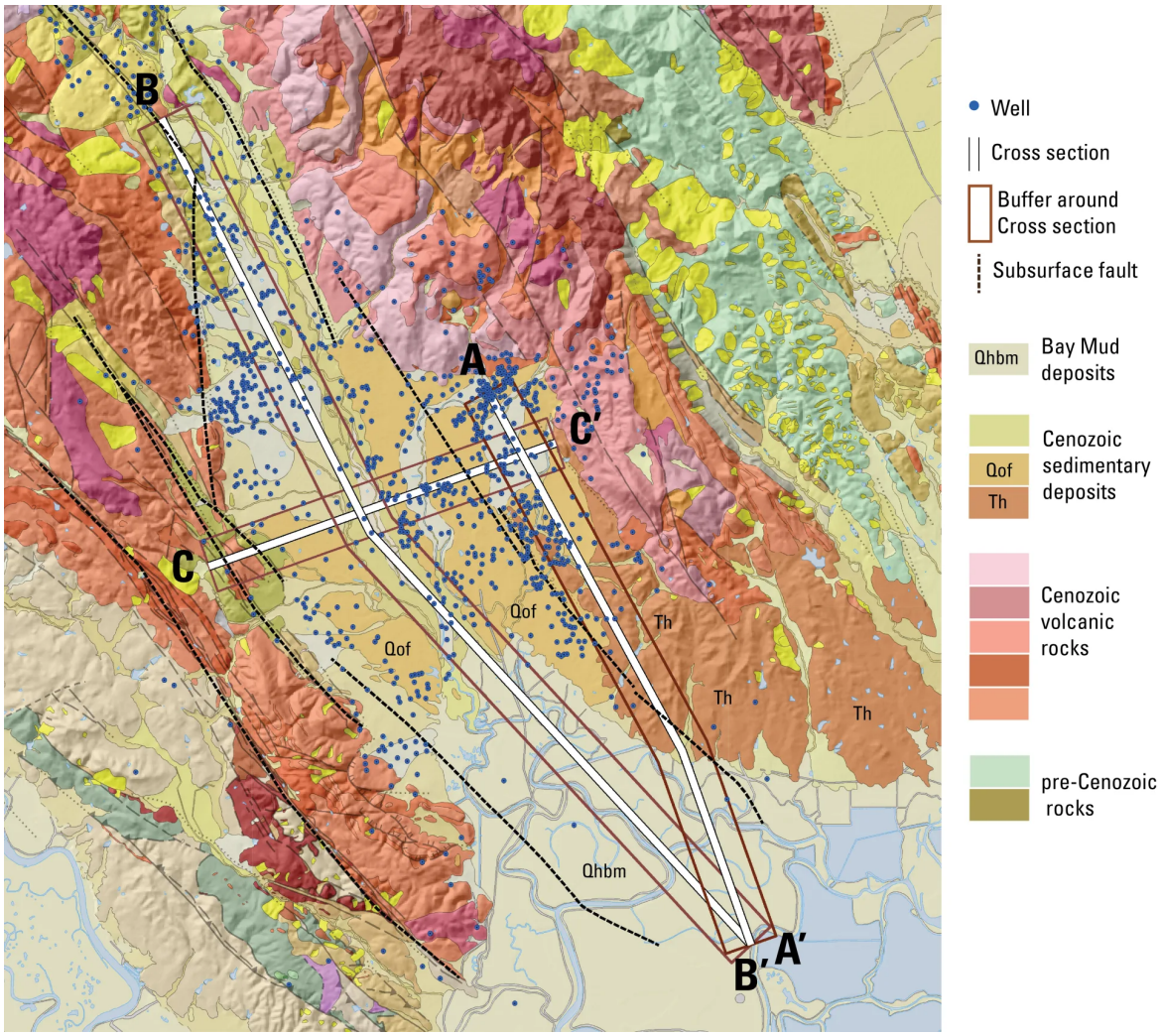

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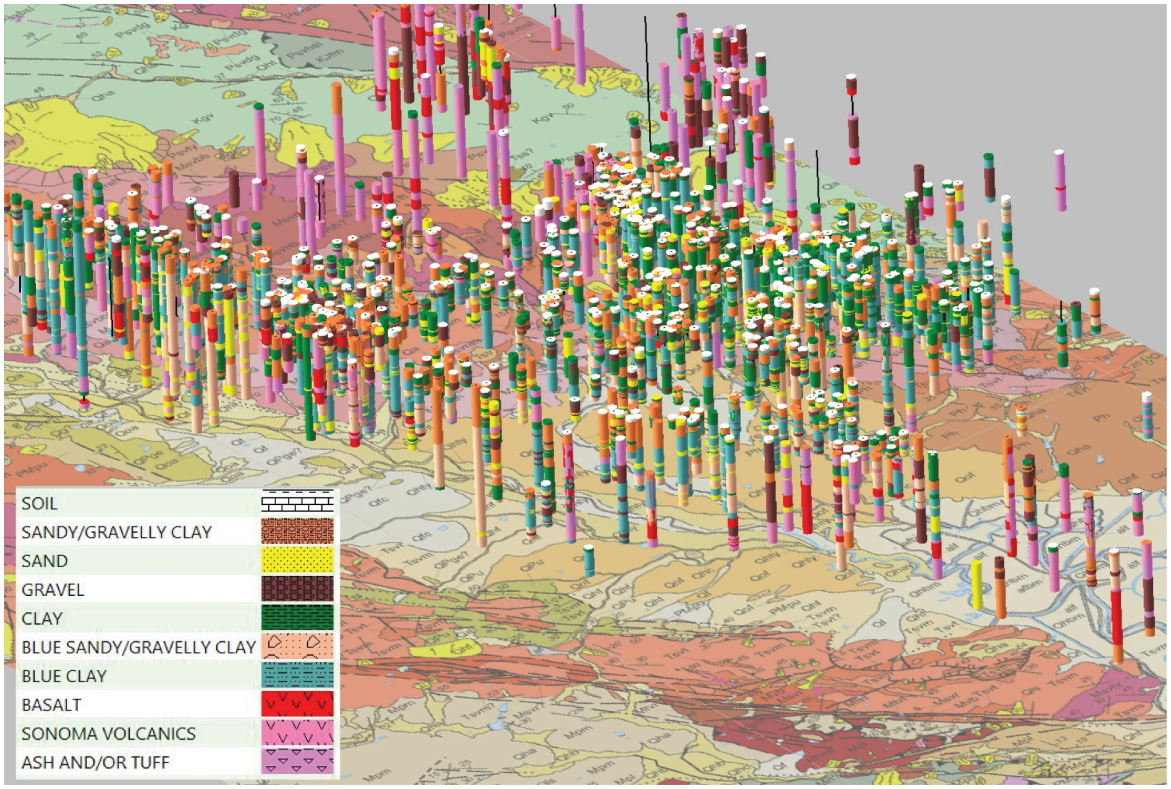

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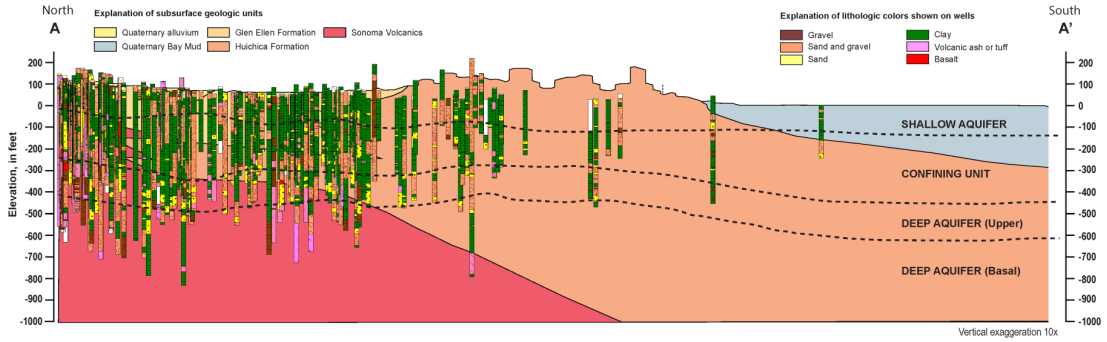

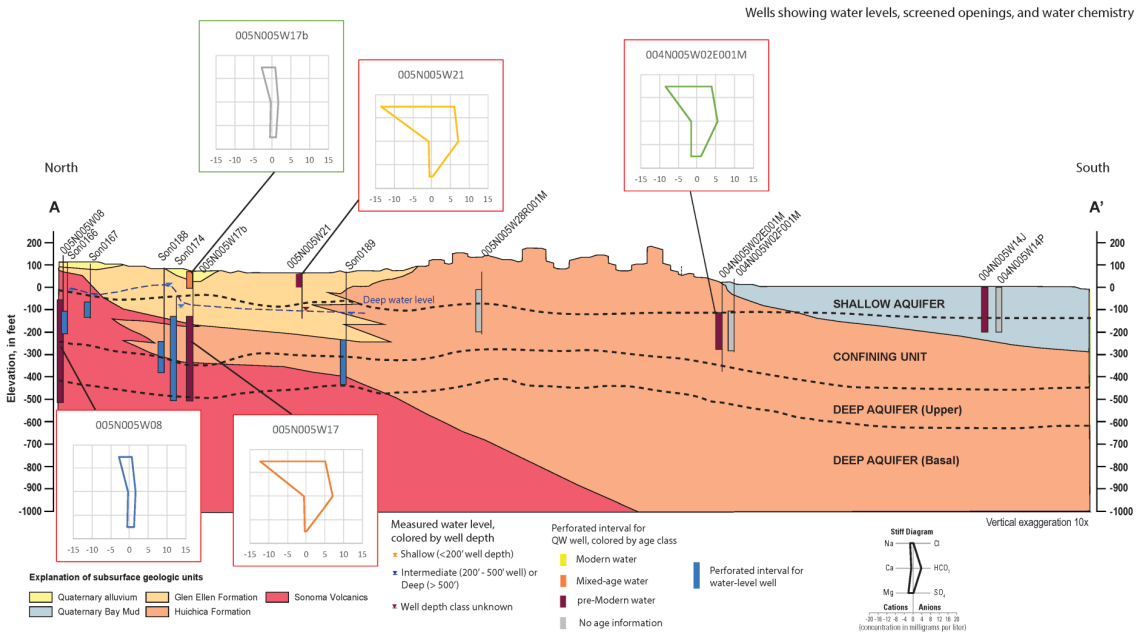

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Geologic sections suggest an aquifer system extending to about 900 feet below land surface (ft bls), consisting of: (1) A shallow upper aquifer is comprised of heterogeneous deposits of sand, silt, clay and gravel; (2) An intermediate interval of clay-rich sedimentary deposits, dominantly in the Glen Ellen Formation, and (3) A lower sand and gravel aquifer overlying and partly interfingering with volcaniclastic sediments and tuffs of the Sonoma Volcanics.

Aquifer and confining unit model layers for use in the numerical model generally honor spatial trends of lithologic variability as observed in well data, but for computational stability model layers were constructed to be sub-parallel to land surface and the water table surface. The hydrostratigraphic layers defined for the model thus include multiple mapped geologic formations. The heterogeneity and complex interfingering between stratigraphic units is addressed in the numerical model through horizontal subdivision of model units by geology-based properties.

The major-ion compositions of groundwater samples from wells were characterized by using Stiff diagrams that depict the concentrations of major ions in meq/L and indicate relative proportions of major ions. Analyses with similarly shaped diagrams represent groundwater of similar chemical characteristics with respect to major ions. Changes in the width of the diagrams indicate differences in the concentration of dissolved constituents.

Following Farrar and others (2006), the wells were categorized into four main categories: (1) shallow wells—entire perforated or open interval above 200 ft below land surface (bls), (2) mid-depth wells—entire perforated or open interval between 200 and 500 ft bls, (3) deep wells—entire perforated or open interval below 500 ft bls, and (4) unknown depth wells—the depth of the perforated or open interval is unknown.

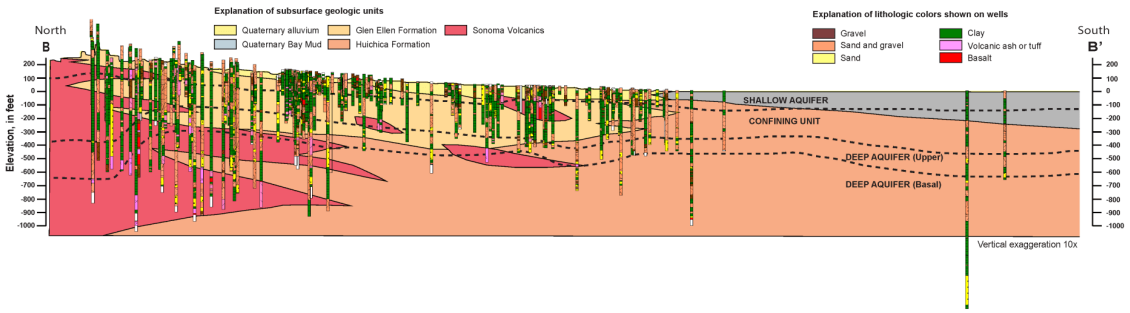
Description of individual sections

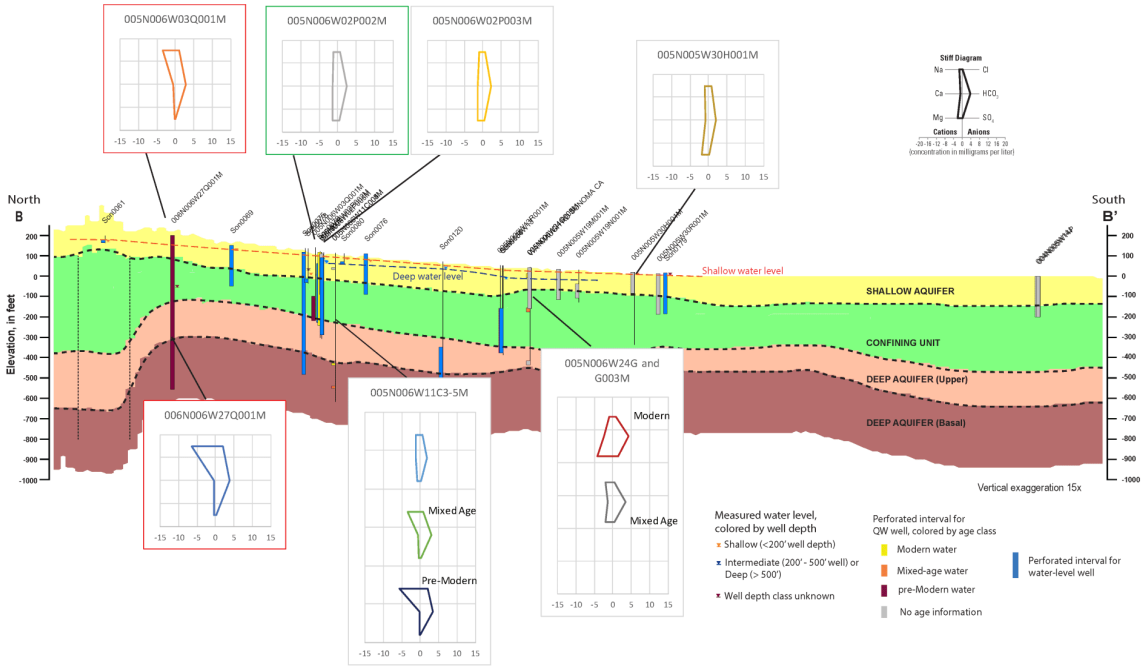
Section A-A'

Cross section A-A’ is a NW-SE section along the east side of the basin extending from the base of the uplands underlain by volcanic rocks on the north to the tidal flats underlain by Bay Mud on the south. Wells 005N005W-W17 and -W21 display relatively high concentrations of iodide, boron, and other constituents in water suggestive of connate water as the source of salinity to wells in this area. The East Side fault (not shown but parallel to the line of section) may play a role as a conduit for deep fluids.

Section B-B'

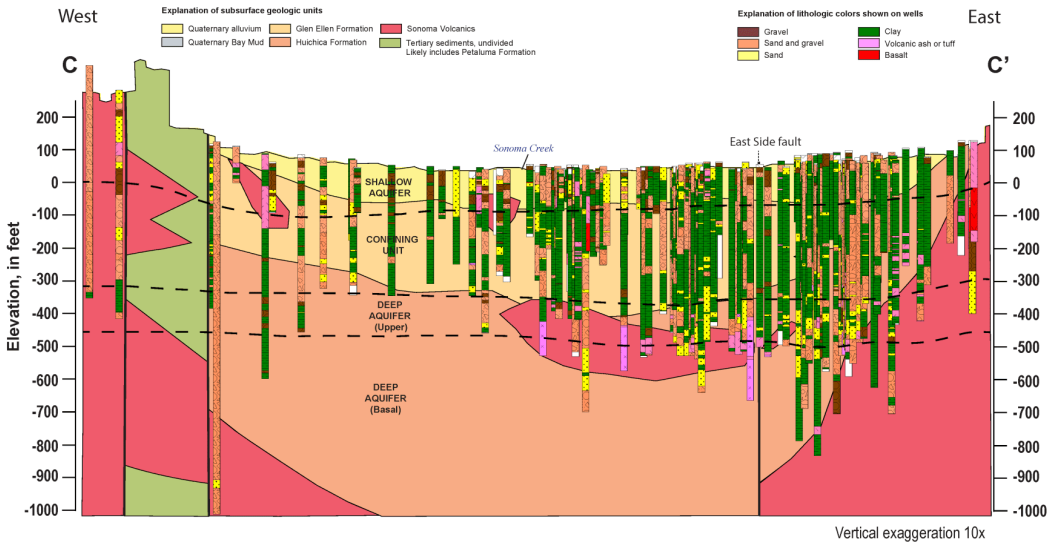
Cross section B-B’ is a long NW-SE section along the axis of the basin and topographic valley. The section extends from the narrow northwest part of the basin dominated by tuffaceous and volcaniclastic sediments to the broader southeastern part of the basin where sediments of the Glen Ellen and Huichica Formations are overlain by shallow alluvium and, in the south, Bay Mud.

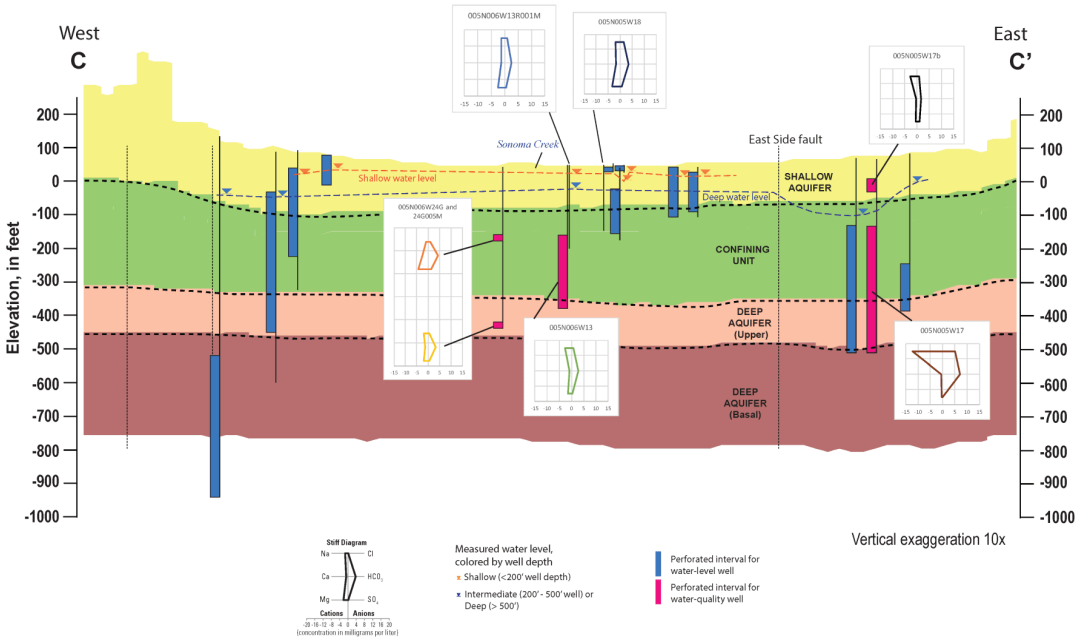




Section C-C'

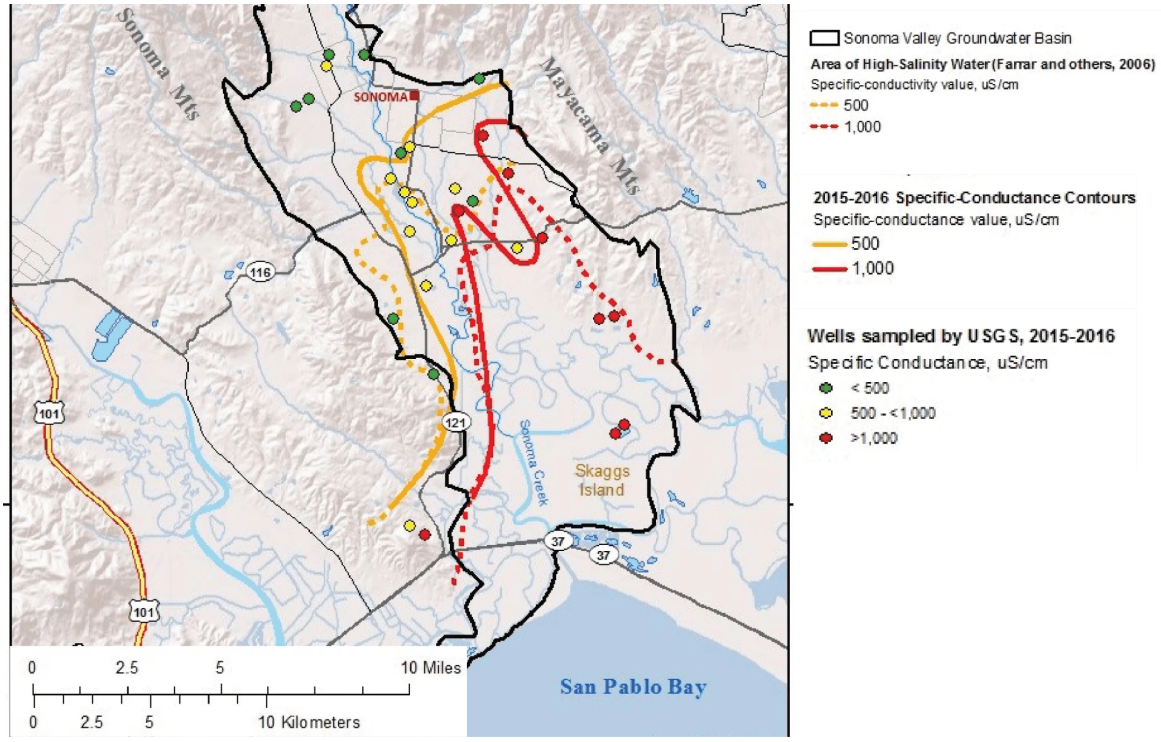
Cross section C-C’ is an E-W section through the center of the southern part of the basin and crosses basin-bounding faults at the east and west ends of the section. Water levels on the east side of the section show a cone of depression around wells pumping groundwater from the deeper units.




West
C
East
C'
Elevation, in feet
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
005N006W13R001M
005N005W18
005N005W17b
Sonoma Creek
East Side fault
Shallow water level
Deep water level
SHALLOW AQUIFER
CONFINING UNIT
DEEP AQUIFER (Upper)
DEEP AQUIFER (Basal)
005N006W24G and 24G005M
005N006W13
005N005W17
Vertical exaggeration 10x
Stiff Diagram
Na
Cl
Ca
HCO3
Mg
SO4
Cations
Anions
(concentration in milligrams per liter)
Measured water level, colored by well depth
Shallow (<200' well depth)
Intermediate (200' - 500' well) or Deep (> 500')
Perforated interval for water-level well
Perforated interval for water-quality well

WATER QUALITY INVESTIGATIONS

Changes in specific conductance



Contours of equal specific conductivity (SC) values, made from conductivity measurements from 37 wells and 2 springs, show that high-salinity water (SC greater than or equal to 1,000 µS/cm) is present south of Sonoma. The SC contours show that shallow wells containing high-salinity water seem to be constrained to the southern part of the study area, near the tidal marshlands.

The areas of high-salinity water in the mid-depth and deep wells show that high-salinity water extends north from the marshlands near San Pablo Bay, but trace-element, stable-isotope, and age-dating (tritium and carbon-isotope) data suggest that high-salinity water in deep wells may be brines from consolidated marine sediments; deep, high-salinity, thermal water; or mixtures of both – rather than young seawater intrusion. The areas of high-salinity water in the mid-depth and deep wells correspond to areas of groundwater draw-down and may represent inflow of deeper waters to pumping wells, perhaps augmented by upward flow along the East Side fault zone.

SIGNIFICANT RESULTS

Combined interpretation of subsurface framework and water quality data have led to a higher-confidence interpretation of separate aquifer systems with different waters

Statutory requirements on defining basin shape and structures focused attention on faults in the context of (1) juxtaposition and control on basin-fill lithologies and (2) role in serving as conduits for deep fluids (thermal, connate)

Basin characterization of subsurface geology, hydrostratigraphy, and water chemistry will enable the Water Agency to make strategic water management decisions in Sonoma Valley

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ABSTRACT

The U.S. Geological Survey and Sonoma County Water Agency (SCWA) are engaged in a cooperative project to characterize the hydrogeology of southern Sonoma Valley, a groundwater basin in the northern California Coast Ranges where groundwater represents about 60% of the valley's water supply. The basin lies near the Sonoma volcanic field and major transverse faults of the San Francisco Bay region, resulting in a complex aquifer system comprising volcanic and sedimentary rocks and unconsolidated sediments that are cut by faults and overlain to the south by recent Bay Muds of San Francisco Bay. Geologic sections were constructed using geologic maps and lithologic data from over 1,500 water wells compiled by SCWA to describe the subsurface geologic configuration relative to groundwater pumping wells. This work suggests an aquifer system extending to about 900 feet below land surface (ft bls), consisting of upper and lower aquifer units separated by an intermediate unit with lower hydraulic conductivity, overlying and partly interfingering with a complex suite of volcanic rocks. SCWA constructed a four-layer hydrostratigraphic model of the basin using spatial trends in the lithologic data. The hydrostratigraphic layers defined by SCWA include multiple mapped geologic formations because of heterogeneity and complex interfingering between stratigraphic units. Water from selected wells was analyzed for specific conductance, major and minor ions, nutrients, stable isotopes, carbon isotopes, and tritium. Well data were categorized by completed perforation interval into shallow wells (< 200 ft bls), mid-depth wells (200–500 ft bls), and deep wells (> 500 ft bls). Shallow wells typically have water types related to recent mountain-front recharge, and, near the tidal marshlands north of San Pablo Bay, have high chloride and total dissolved solid concentrations associated with modern saline-water intrusion. Mid-depth and deep wells have water with poor water-quality, likely influenced by connate water from consolidated marine sediments, or a mixture of water from consolidated sediments and thermal water. This cooperative basin characterization of subsurface geology, hydrostratigraphy, and water chemistry will enable SCWA to make strategic water management decisions in Sonoma Valley.

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