Technical Memorandum

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Via Email:	ibannister@westyost.com
To:	Indigo Bannister, Santa Rosa Plain Groundwater Sustainability Agency
From:	Weijie Dong, Reviewed by Rodney Fricke, PG, CHg, and Chris Petersen, PG, CHg
cc:	Andy Rodgers
Date:	July 31, 2026
Re:	Project Completion Summary Aquifer Storage and Recovery Planning Evaluation Sonoma County, CA
Project No.	2403072

Introduction

GEI Consultants, Inc. has completed an evaluation of Aquifer Storage and Recovery (ASR) in the Santa Rosa Plain (SRP) Subbasin as part of the SRP Groundwater Sustainability Agency (GSA) partial implementation of projects for its Groundwater Sustainability Plan (GSP). The evaluation utilized grant funding from the California Department of Water Resources. This technical memorandum provides a project completion summary of the ASR evaluation and describes the initial well identification and selection process of candidate wells for ASR pilot testing. The project completion summary also includes details on the selection of the Martha Way Test Well and the completion of an ASR pilot test at the well.

Purpose

The purpose of this ASR evaluation project is to assist the Santa Rosa Plain GSA in achieving groundwater sustainability for the Santa Rosa Plain Subbasin. ASR is listed as 1 of 3 projects in the Santa Rosa Plain Subbasin GSP that will help balance groundwater pumping and improve groundwater sustainability in the subbasin (Sonoma Water, 2021). This ASR evaluation project explores the feasibility of ASR in the subbasin through a review of existing water supply planning documents completed by local agencies, well completion reports of candidate wells for ASR, an ASR investigation workplan, and ASR pilot testing at a candidate well.

The original scope of work for this ASR evaluation includes the following:

- Prepare a work plan for recommended hydrogeologic investigations at two locations within the Santa Rosa Plain Subbasin
- Conduct recommended hydrogeologic investigations
- Prepare a report documenting the hydrogeologic investigations and a summary of the findings
- An optional task to perform ASR pilot testing of one existing well

Review of Background Documents

To assist with the initial evaluation of ASR feasibility in the Santa Rosa Plain Subbasin, local water supply planning documents were reviewed to identify any previous work completed on ASR within the study area. This review of existing documents provided a foundation for the current ASR evaluation of the subbasin. Additionally, cross-sections from the water supply planning documents and the DWR Airborne Electromagnetic Surveys (AEM) for the Santa Rosa Subbasin were reviewed to identify potential areas suitable for ASR.

Water Supply Planning Documents

Public water supply planning documents for local water agencies and cities were initially reviewed to see if ASR had been previously explored or were included in the planning of local water supply in the subbasin. Additionally, any available well information was compiled from these documents. The documents include groundwater master plans, water master plans, urban water management plans, general plans, and groundwater banking studies. These documents were completed by local water resource agencies, including the City of Santa Rosa, City of Cotati, City of Rohnert Park, Town of Windsor, City of Sebastopol, and Sonoma Water.

City of Santa Rosa

The City of Santa Rosa has explored the feasibility of ASR in Santa Rosa, beginning in 1995 when reclaimed wastewater was considered for ASR (Parsons Engineering Science Inc., 1995). Areas were identified in the report that was most promising for an ASR program. In 2013, the City of Santa Rosa completed a Groundwater Master Plan that included a feasibility-level evaluation of the potential for ASR at city-owned production wells and test well sites (West Yost Associates, 2013). The study used available geologic and hydrogeologic data and identified sites that were most favorable to least favorable in the city for ASR. The study concluded that wells located in the Bennett and Rincon Valleys and completed in the Sonoma Volcanics were most favorable for ASR due to theoretically higher injection and recovery capacities of the volcanic rocks. Several test wells had been installed throughout the City and the Martha Way Test Well was identified as one of the promising wells for ASR (Pueblo, 2012). A more focused ASR feasibility study was recommended for these wells in the study. A discussion of ASR was also included in the 2021 City of Santa Rosa Urban Water Management Plan (UWMP) (City of Santa Rosa and West Yost Associates, 2021). The 2021 UWMP includes a summary of the 2013 Groundwater Master Plan and the ASR feasibility evaluation completed in that plan.

City of Cotati

The City of Cotati completed a 2011 Water Distribution System Master Plan that included well information for their three groundwater wells (Carollo Engineers, Inc., 2011). The report presented information about the performance of the pump installed in one of the wells. In 2013, the City of Cotati and Sonoma Water also submitted a draft ASR technical report for an ASR pilot test at City of Cotati Well No. 2 (Pueblo Water Resources, 2013). This report provided documentation to support the ASR pilot test with permit authorization under the State Water Resources Control Board Water Quality Order 2012-

0010. The report was never finalized, and permit authorization was never sought for the Cotati Well No. 2 ASR Pilot.

City of Rohnert Park

The City of Rohnert Park completed an Urban Water Management Plan in 2020 that discusses water supply enhancements for the city and how ASR projects under development with Sonoma Water and the Santa Rosa Plain GSA could improve water supply reliability (City of Rohnert Park, 2021). Additionally, a water system map was provided in the report and showed the locations of the water supply wells in the city. The City of Rohnert Park's 2040 General Plan was also reviewed and contains policy objectives regarding groundwater protection and water supply (City of Rohnert Park, 2026).

Town of Windsor

The Town of Windsor 2011 Water Master Plan lists groundwater banking as a groundwater supply alternative (RMC Water and Environment, 2011) and mentions a groundwater well siting study from 2007 where groundwater production capacity and ASR were evaluated in the city (Winzler & Kelly Consulting Engineers, 2007). The well siting study identified six viable locations for new groundwater production wells. An update to the Town of Windsor Water Master Plan was completed in 2019 and included the well locations of the active production wells and other water supply sources for Windsor (Woodard & Curran, 2019). Additionally, the appendix of the report includes a summary of the town's production well history and the previous recommendation from the 2011 Water Master Plan to pursue grants for the exploration of well locations for managed aquifer recharge (MAR). However, the 2019 Water Master Plan Update notes that since the 2011 Water Master Plan, the potable water demand has decreased, and the town decided not to move forward with MAR exploration.

City of Sebastopol

The City of Sebastopol completed multiple planning documents that lists groundwater recharge and achieving sustainable yield of the local groundwater aquifer as a goal and policy objective for the city. These documents include a Strategic Plan in 2004 (City of Sebastopol, 2004), a Sebastopol General Plan completed in 2016 (De Novo Planning Group, 2016), and a 2022-2027 Capital Improvement Program document completed in 2022 (City of Sebastopol, 2022). However, it does not appear the city has completed any exploratory work on ASR since the completion of these planning documents.

Sonoma Water

Sonoma Water completed the 2013 Groundwater Banking Feasibility Study (2013 FS) that provided the foundation for this ASR evaluation (GEI Consultants, 2013). ASR was considered in the 2013 FS which summarized the groundwater banking alternatives for the basin, based on the regional hydrogeologic conditions, available well specifications, water quality, recharge area characteristics, and hydrogeologic characteristics in the region. Nine (9) potential groundwater banking alternatives were identified in the report, and ASR was listed as the most practical direct method to implement in the near term. The report recommended beginning the process of identifying locations for a pilot-scale ASR test and obtaining the necessary permits/approvals from the appropriate regulatory agencies.

Local Subsurface Geology

Local subsurface geology was reviewed through cross-sections that were available within many of the local water supply planning documents including the following:

- 1995 ASR Feasibility Report for reclaimed wastewater in the City of Santa Rosa (Parsons Engineering Science Inc., 1995),
- 2013 City of Santa Rosa Groundwater Master Plan (West Yost Associates, 2013),
- 2013 Draft ASR technical report for an ASR pilot test at City of Cotati Well No. 2 (Pueblo Water Resources, 2013), and
- 2019 Town of Windsor Water Master Plan Update (Woodard & Curran, 2019).

These cross-sections were compared with available DWR AEM survey flight lines in the Santa Rosa Plain Subbasin from the DWR AEM Profile Viewer (California Department of Water Resources, 2026). The data comparison assisted with understanding the subsurface geology of the subbasin and identified areas that may be good for recharge and could support ASR.

In addition to the public water supply planning documents, a US Geological Survey geologic map with cross-sections for the Santa Rosa 7.5-minute Quadrangle was reviewed (U.S. Geological Survey, 2008) to help identify geologic formations and layers that may be suitable for ASR. Geologic faults that could affect groundwater flow were also identified during the review of the geologic map. The geologic map and cross-section are attached in **Appendix A**.

Well Identification

Existing water supply wells could be candidate wells for an ASR pilot test. The number of water supply wells identified for each local water agency is summarized below:

- Cotati: 3 water supply wells,
- Rohnert Park: 27 water supply wells,
- Windsor: 2 water supply wells,
- Santa Rosa: 18 water supply wells and test wells, and
- Sonoma Water: 3 water supply wells.

Well Site Selection

Following the identification of these water supply wells, GEI compiled well and aquifer information from publicly available sources, including city utility websites and available technical reports. The compiled information included the following:

- Well condition assessments for all wells considered for ASR
- Borehole geophysical logs

- Well Completion Reports available locally and from the state database to understand age and as-built condition of each well
- Water quality information provided by well owners and available from the state database
- Well rehabilitation records
- Aquifer testing records
- Screen depth and locations of other wells in the vicinity of wells considered for ASR pilot testing
- Proximity to Sonoma Water aqueduct, layout, condition assessments and other available information on source water conveyance to wells under consideration for ASR

The Santa Rosa Plain GSA also reached out to the representatives of the local agencies for additional well information.

A list of well selection criteria was developed that included aquifer considerations, physical well considerations, operational considerations, and site accessibility considerations. The well selection criteria were derived from GEI's experience on other ASR feasibility studies and considerations specific to the Santa Rosa Plain Subbasin, as specified in the 2013 Groundwater Banking Feasibility Study (GEI Consultants, 2013). The well selection criteria include the following:

Aquifer Considerations

- Local hydraulic conductivity and thickness (transmissivity is the product of hydraulic conductivity and thickness)
- Aquifer and well test information (pumping rate, duration, drawdown)
- Proximity and vulnerability to known contamination
- Proximity and vulnerability to potential contaminating activities
- Groundwater quality
- Groundwater levels
- Groundwater flow direction and gradient
- Proximity to other supply wells screened in same aquifer
- Proximity to other wells (production, public, domestic)
- Proximity to monitoring wells (within 200 feet) of potential ASR well
- Consider completing the pilot study in different cities to better characterize feasibility of ASR in different areas of the basin

Physical Well Considerations

- Year constructed
- Total depth
- Length of screen and interval

- Sanitary seal depths
- Annular seal depths
- Casing and screen material
- Screen slot size
- Well diameter
- Current equipment configuration
- Current condition of well screen
- Accessibility of well through ports or open areas of the surface

Operational Considerations

- Historical static and pumping water levels
- Historical specific capacity
- Historical water quality
- Functionality of well (active versus inactive) and overall operational status
- Favorable hydraulic location within the water distribution system
- Records of well maintenance and testing following construction to present day (chemistry, priority pollutants, etc.)

Site Accessibility Considerations

- Well site layout - adequate physical space for an observation well and appurtenances.
- Ability to safely operate a drill rig within the footprint of the established site, including the control of drilling spoils (cuttings, fluids) and logistical obstacles (e.g., underground or overhead utilities)
- Proximity to the potable water transmission piping
- Sensitive noise receptors, such as residences near existing or proposed well sites.
- Ability to discharge produced water generated from well development and testing.
- Landowner/well owner willingness to implement ASR on their wells

A template of the well selection matrix is included in **Appendix B**.

Well Consideration Priorities

During the evaluation of the well selection matrix, the following 13 factors were prioritized from 1 to 3 with 1 being the highest priority. **Table 1** lists the 13 well consideration priorities during the evaluation.

Table 1. Well Consideration Priorities

Priority	Criteria	Notes
1	Annular and sanitary seal depths (feet)	To meet CA wells standards
1	Favorable hydraulic location within the water distribution system	Will provide most benefit to customers
1	Proximity to the potable water transmission piping	Ease of getting recharge water there
1	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	To evaluate total storage
2	Groundwater Levels	To evaluate aquifer capacity
2	Current condition of well casing	
2	Current condition of well screen	
2	Records of well maintenance and testing from construction to present day	
2	Willingness of landowner/well owner to implement ASR on their well	
3	Monitoring wells in proximity (within 200 feet) of potential ASR well	
3	Well diameter (inches)	
3	Functionality of well (active versus inactive) and overall operational status	
3	Well site layout	Adequate physical space for an observation well and appurtenances needed

Due to the limited responses from municipal well owners and the availability of public well data for the municipal wells, a finalized well matrix score with applied weights and a ranking was not completed. Additionally, some considerations (e.g. current well casing conditions, well site layout) required visual inspections. Data were available for many of the wells to calculate the local transmissivity and hydraulic conductivity. GEI used this data and data for the other priority 1 criteria to select wells for visual field inspections.

Transmissivity and hydraulic conductivity for each well were calculated based on the available data from pumping tests and well construction information. The estimated transmissivity and hydraulic conductivity for each well are attached in **Appendix C**.

Based on the local transmissivity and hydraulic conductivity of each well and other priority 1 criteria, the top five (5) wells were selected for a visual field inspection. The purpose of the visual field inspection is to verify the condition of the well and the feasibility of ASR at the well locations. The visual field inspections for the preliminary ASR well locations included the following:

- Accessibility for lowering instruments into the well.
- The overall condition of the well at the surface.
- The distance and ease of conveying potable water to the wells for injection.
- Inspection, measurement, and photographing of topside equipment such as pipeline, valves, chemical feed, electrical controls.

- Input from operations staff on well performance and ease of operations.

Reduced Well List

Based on discussions with the representatives of the local water agencies and the Santa Rosa Plain GSA, the City of Rohnert Park and the City of Santa Rosa were most interested in a potential ASR pilot test. As a result, the following top five wells were selected for visual field inspections from the two cities:

- City of Rohnert Park – Well 15
- City of Rohnert Park – Well 16
- City of Santa Rosa – NW Community Park Test Well
- City of Santa Rosa – Bicentennial Test Well
- City of Santa Rosa – Slater Test Well

During the field visit to the City of Santa Rosa, an additional well was added to the list of wells for visual inspections due to its proximity to the Slater Test Well:

- City of Santa Rosa – Martha Way Test Well

Field Visits

During the field visit at the City of Rohnert Park Well 15 and Well 16, GEI staff and Santa Rosa Plain GSA staff observed that both wells were not operational and downhole well equipment was present. As a result, significant rehabilitation of the well was needed prior to an ASR pilot test. Following the field visit, GEI completed specifications for a potential ASR investigation and rehabilitation at Well 15. The purpose of the well rehabilitation was to clean the screen in the well, perform a step-drawdown pumping test, and complete depth-discrete sampling. A scope of work for well rehabilitation at Rohnert Park Well 15 was completed and is attached in **Appendix D**.

During the field visit in the City of Santa Rosa, GEI and Santa Rosa Plain GSA staff met with City of Santa Rosa operations staff and visited the Northwest Community Park Test Well, the Bicentennial Test Well, and the Slater Test Well. At the Northwest Community Park Test Well, the Santa Rosa Plain GSA staff recommended that an ASR pilot test not be completed at the well since it was a newly constructed well and an ASR pilot testing may disrupt well capacity and local aquifer conditions. The Bicentennial and the Slater Test Wells were visited next and during the field visits, it was observed that extensive temporary piping would be needed to access the potable water from the aqueduct at both locations. Additionally, a water discharge location for ASR pilot testing would be difficult to set up, based on the layout of the well sites at both locations. These issues presented logistical challenges and as a result, neither well was selected for an ASR pilot test.

Due to the proximity of the Martha Way Test Well to the Slater Test Well, GEI staff also completed a visual inspection at the Martha Way Test Well during the visit to the City of Santa Rosa. The Martha Way Test Well was one of the wells recommended for ASR in the 2013 City of Santa Rosa Groundwater Master Plan. At the Martha Way Test Well, it was observed that the well met most of the priority 1 well

considerations from the well matrix (annular/sanitary seal depth that meet CA well standards, favorable hydraulic location within water distribution system, proximity to potable water transmission piping, and high local hydraulic conductivity and transmissivity), but was isolated from water infrastructure so temporary provisions for both injection water and disposal would need to be provided.

Well Selection for ASR Pilot Test

Following the visual field inspections, GEI and Santa Rosa Plain GSA staff engaged the local water agency representatives for the City of Rohnert Park and the City of Santa Rosa on the interest in an ASR pilot test.

Ultimately, the City of Santa Rosa offered the most feasible well site given time and budget constraints associated with the grant and was willing to contribute in-kind support during the ASR pilot test, including the installation of a water service at the well site and laboratory analysis of water samples at their Laguna Environmental Laboratory. As a result, the Santa Rosa Plain GSA and GEI moved forward with selecting a candidate well in the City of Santa Rosa for ASR pilot testing. Based on the reduced well list and visual field inspections completed, the City of Santa Rosa Martha Way Test Well was selected for an ASR pilot test.

Amendment to Original Scope of Work

Following the selection of the Martha Way Test Well for an ASR pilot test, an amendment was made to the original scope of work. The original scope of work included the assessment of 2 wells for rehabilitation work and zone-specific depth discrete water quality sampling with an ASR pilot test being an optional task. The Martha Way Test Well was identified as the best well for an ASR pilot test due to available records on water levels, pumping, water quality, and field observations of the well. The Santa Rosa Plain GSA agreed to use the remaining funds for GEI to develop a Technical Report in support of a permit from the North Coast Regional Water Quality Control Board for ASR pilot testing at the Martha Way Test Well, complete a pilot test, and document of the results in a Technical Addendum to the Technical Report.

ASR Pilot Testing at Martha Way and Technical Addendum

The City of Santa Rosa submitted a Notice of Intent (NOI) with a Technical Report to conduct an ASR pilot test at the Martha Way Test Well under State Water Resources Control Board Water Quality Order 2012-0010 to the North Coast Regional Water Quality Control Board on June 30, 2025. The NOI included the Technical Report (GEI Consultants, 2025) which concluded that the Martha Way Test Well was suitable for an ASR pilot test due to suitable subsurface conditions, its location, and the comparable water quality of the recharge water from the Sonoma Water Aqueduct and the native groundwater.

A Notice of Applicability (NOA) was received by the City of Santa Rosa for ASR pilot testing at the Martha Way Test Well under Water Quality Order 2012-0010 on July 3, 2025 (North Coast Regional Water Quality Control Board, 2025).

After the receipt of the NOA, GEI began scheduling pre-testing activities which included the installation of the potable water service to the Martha Way Test Well (piping, valves, meter) by the City of Santa

Rosa, completing a video survey to document the existing condition of the well, rehabilitating (brushing) the well to prepare for ASR pilot testing, and installation of recharge piping and a pumping system. A 3-cycle ASR pilot test at the Martha Way Test Well began on September 22, 2025, and ended on December 22, 2025. The results of the ASR pilot test were documented in the Technical Addendum completed in May 2026 (GEI Consultants, 2026). The Technical Addendum is attached in **Appendix E**. The Technical Addendum concluded that ASR at the Martha Way Test Well is hydraulically feasible with minimal impacts to water quality (iron and manganese).

Summary

The Santa Rosa Plain GSA has successfully completed an ASR evaluation for the Santa Rosa Plain Subbasin as part of its GSP implementation. This ASR evaluation reviewed the previous work completed on ASR in the subbasin and identified wells that could be suitable for an ASR pilot test utilizing a well selection matrix. The ASR evaluation eventually led to the selection of the Martha Way Test Well for an ASR pilot test. The results of the ASR pilot test demonstrated that ASR at the Martha Way Test Well was feasible, but had the following limitations and constraints:

- Shallow depth to water is seasonably variable, but generally shallow. To avoid draw up in the well and over topping through the open well head, injection rates were reduced. In a dry year or in multiple dry years it is expected that static groundwater levels would drop allowing a higher initial injection flow rate. Conversely, in a wet years or multiple wet years, there will be less draw up potential before overtopping so lower injection flow rates would be required. Based on groundwater level monitoring data from SGMA Data Viewer at the Martha Way Test Well, the average groundwater level elevation between October and March from 2010-2026 ranged from 15.3 feet below top of casing to 31.7 feet below top of casing.
- To obtain higher injection flowrates at this location, the well would need to be equipped with a water tight completion at the wellhead. This would allow for higher injection flow rates while avoiding overtopping of water at the wellhead. If this option is pursued in the future, it is advised that injection pressure be controlled to prevent fracking of the formation during injection.
- The distribution system in the vicinity of the Martha Way test well is also insufficient to sustain higher injection rates at the well head while also maintaining adequacy system pressure to meet water supply needs in the surrounding area. Therefore, a future ASR project at this location would also need an upgraded water supply to sustain higher injection rates.
- The Martha Way Test Well is constructed with low carbon steel which presents a corrosion risk for the well casing and screen over time.
- Due to the construction of the Martha Way Test Well with low carbon steel, scaling (iron oxides) can form and will be transported into the filter pack and formation during injection resulting in plugging. To maintain injection flow rates, this well would require frequent mechanical and chemical redevelopment.
- Iron and manganese water quality issues are present at the well. These constituents were present in native groundwater collected from the well before pilot testing began. The concentration of these constituents in the recharged water was very low or absent. The blended

concentration during aquifer storage was lower than native groundwater concentrations but still hovered just around the secondary MCL for these constituents.

- The current layout of the well site presents a security challenge for full-scale ASR operations, so site improvement designs should address site security should ASR be pursued at this location.

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Standard Limitations and Disclaimer

This report was prepared exclusively for the use of Santa Rosa Plain Groundwater Sustainability Agency. The findings and conclusions, if any provided by GEI in this report, are based solely on the information reported to GEI as of the date of this report. Future investigations or additional information not provided to GEI at the time of this report may result in modification of this report. GEI's scope of work did not include verifying the completeness or accuracy of information provided by others. Accordingly, GEI shall not be liable for any damages, costs, or other consequences resulting from reliance on such information if it is later determined to be inaccurate or incomplete. GEI's professional services for this project have been performed in a manner consistent with that degree of skill and care ordinarily exercised by members of the same profession currently practicing in the same locality, performing similar services under similar conditions. GEI makes no other representations and no warranties, express or implied.

If you have any questions, please feel free to contact me at 530-304-3330.

Sincerely,





Christian Petersen, P.G., CHG.
Vice President, Senior Hydrogeologist

Rodney Fricke, P.G., CHG.
Senior Hydrogeologist

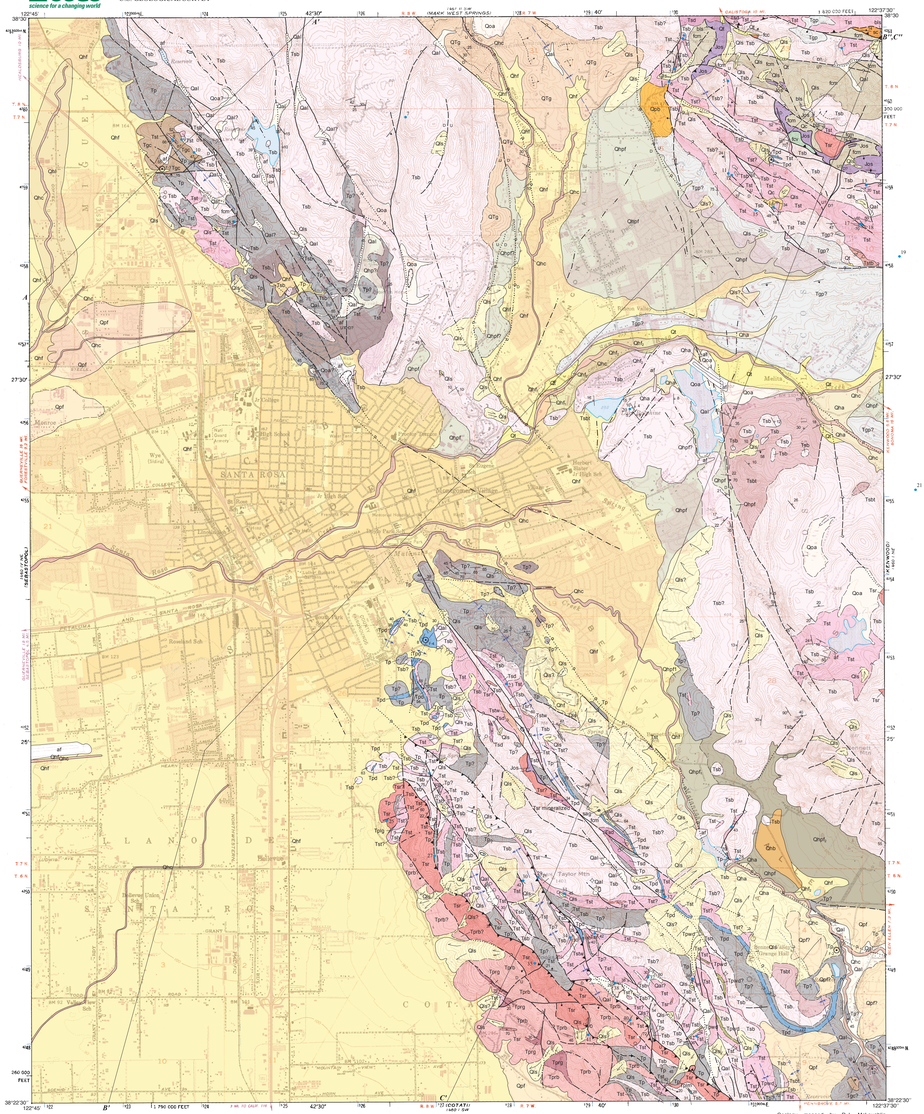
Appendices

Appendix A	Geologic and Geophysical Framework of the Santa Rosa 7.5' Quadrangle, Sonoma County, California
Appendix B	Template Well Selection Matrix
Appendix C	Summary of Transmissivity, Hydraulic Conductivity, and Well Construction Information at Each Well
Appendix D	Well Rehabilitation at Rohnert Park Well #15 Site
Appendix E	Technical Addendum for Martha Way Well ASR Pilot Study

Appendix A Geologic and Geophysical Framework of the Santa Rosa 7.5' Quadrangle, Sonoma County, California

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Open-File Report 2008-1009
Sheet 1 of 3
Pamphlet accompanies map



Map A: Geologic Map

By

R.J. McLaughlin, A.M. Sarna-Wojcicki, R.J. Fleck, V.E. Langenheim, C.A. McCabe, and Elmira Wan

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

af **Artificial Fill**

Qha **Alluvium, undivided (Holocene)**

Qhb **Basin deposits (Holocene)**–Mapped locally, generally includes local silty to muddy alluvial and lacustrine deposits accumulated in low areas where water is ponded

Qhc **Channels (Holocene)**–Incise older deposits

Qhf **Alluvial fan and fluvial terrace deposits, undivided (Holocene)**–Gravel, sand and silt, derived primarily from Pleistocene and older sedimentary and igneous units, including older Tertiary to Pleistocene non-marine gravel, late Tertiary volcanic rocks, and Mesozoic bedrock units of the Franciscan Complex, Coast Range ophiolite and Great Valley sequence. Unit may be further subdivided into the following units.

Qhf_y **Young Holocene alluvial fan and fluvial terrace deposits**–Inset into old Holocene alluvial fans and fluvial terraces and pre-Holocene deposits

Qhf_o **Old Holocene alluvial fan and fluvial terrace deposits (Holocene?)**–Inset into older Holocene and pre-Holocene deposits

Qhl **Natural levee deposits (Holocene)**

Qal **Alluvial deposits, undivided (Holocene and/or Pleistocene)**

Qc **Colluvium (Holocene and/or Pleistocene)**–Unconsolidated soil and rock debris generally transported down-slope by gravitational processes

Qhp **Alluvial deposits, undivided (Holocene and Pleistocene)**

Qhpf **Alluvial fan and terrace deposits (Holocene? and/or Pleistocene)**–Gravel, sand and silt, that commonly includes cobble to boulder gravel reworked from Tertiary to Pleistocene non-marine gravel, from late Tertiary volcanic rocks and from Mesozoic bedrock in Bennett Valley; unit is subdivided into the following.

$Qhpf_y$ **Younger alluvial fan and terrace deposits (Holocene? and/or Pleistocene)**–Deposits on surfaces inset into older undeformed Pleistocene fans and terraces and pre-Pleistocene units

$Qhpf_o$ **Older alluvial fan and terrace deposits (Holocene? and/or Pleistocene)**–Deposits on surfaces inset into and deformed older Pleistocene and pre-Quaternary rocks

Qls **Landslide deposits (Holocene and Pleistocene)**–Deposits varying from intact slabs of rock, to unconsolidated rock, soil, and colluvium, that are displaced down-slope by gravitational processes. Landslides may vary in area from less than 100 m^2 to greater than 1 km^2

Qoa **Older alluvium, undivided (Pleistocene)**–Generally uplifted and dissected, isolated surfaces and alluvial fills of small basins, sag ponds, and marshes

Qpf **Alluvial fans and fluvial terrace deposits, undivided (Pleistocene)**–Gravel, sand and silt in deposits characterized by unsorted character, a relict fan-like morphology, and their presence on elevated surfaces. The unit is distinguished from younger alluvial fan deposits by its dissected irregular surface morphology and incision by younger Pleistocene and Holocene alluvial deposits. Unit unconformably overlies the Petaluma Formation and incises or interfingers with the gravel of Cloverleaf Ranch (Tgc)

Qpls **Volcanic talus breccia (Pleistocene?)**–Coarse volcanic talus composed of debris from silicic ash and andesitic breccia of the Sonoma Volcanics, present along the northeastern side of Rincon Valley. Unit may be derived from normal fault scarps

Qt **Alluvial deposits, undivided (Holocene and Pleistocene)**–Includes undivided Holocene and Pleistocene terrace deposits

EARLY QUATERNARY AND TERTIARY UNITS

QTg **Fluvial and lacustrine deposits (early Pleistocene and Pliocene)**–Gravel, sandstone, siltstone and mudstone, and non-marine diatomite. Minor siliceous ash is present in uppermost part of the unit in northwestern Rincon Valley. Unit includes gravels previously assigned to the Glen Ellen and Huichica Formations; names that are not used here because of new stratigraphic data and inconsistent previous lithologic criteria for separating the Glen Ellen and Huichica Formations. (McLaughlin and others, 2004; Wagner and others, 2005; also discussions in McLaughlin and others, 2005).

Gravel of this unit is pebbly to bouldery, derived predominantly from Tertiary volcanic provenances and pre-Tertiary basement. Locally, gravels have a dominant pre-Tertiary basement provenance from paleodrainage of Dry Creek and the Mayacamas Mountains (McLaughlin and others, 2005).

Stratigraphically high in this unit, fine grained tephra dispersed in a silt bed are correlated with the Bishop Glass Mountain tephra section in the Long Valley area of the southeastern Sierra Nevada Mountains, dated at between 0.8 and 1.2 Ma (Metz and Mahood, 1991; Sarna-Wojcicki and others, 2004). The gravels include rare to common clasts of obsidian with chemical compositions indicating sources in Napa and Franz Valleys (McLaughlin and others, 2005). The gravels are younger than 2.6-3.2 Ma (McLaughlin and others, 2004; McLaughlin and others, 2005), based on the ages of the obsidian clast sources

TERTIARY ROCKS

sc **Silica carbonate rock (Pliocene-Miocene?)**–Hydrothermally altered ultramafic rocks, composed of quartz and magnesium carbonate mineral assemblages, commonly associated with mercury and other epithermal base metal sulfide occurences (Ag, As, Pb, Zn, Cu). Age generally is somewhat younger than age of associated Tertiary volcanic rocks that provided hydrothermal heat sources (McLaughlin and others, 1996; Rytuba, 1992; Peabody and Einaudi, 1992)

Tgc **Gravel of the Cloverleaf Ranch (Pliocene?)**–Fluvial, pebbly to cobbly gravel, pebbly, lithic to quartrose sand, and tuffaceous white clayey mudstone and siltstone. Unit locally contains an undated, waterlain ash layer with a geochemical signature suggesting it is younger than ~ 3.12 Ma (Tables 2.2, 2.3, Loc. 8). Unit also contains common rounded pebbles of obsidian, derived from a source at Annadel State Park, dated at 4.5 Ma (Table 2.1, Loc. 21 Figure 2.2). Unit may be partly coeval with Pleistocene and Pliocene fluvial and lacustrine deposits (QTg), but age of the contained obsidian clast suite and of intercalated ash, suggests that gravels of the Cloverleaf Ranch are largely 2.8 Ma or older

Tgo **Fluvial and lacustrine deposits of Humbug Creek (Pliocene)**–Gravel, sandstone, siltstone, mudstone, nonmarine diatomite, and locally mapped intercalated siliceous tuff (Tbt). In Santa Rosa and western Kenwood quadrangles, unit consists largely of boulder, cobble and pebble gravel, and sand and silt derived from underlying Mesozoic rocks and from Tertiary volcanic rocks and exhibits primarily west-northwest directed paleoflow. On the basis of stratigraphy and the ages of underlying and interbedded volcanic units, we interpret the age of the fluvial and lacustrine deposits of Humbug Creek to be 3.3-4.8 Ma. Unit may be unconformably overlain by Pleistocene and Pliocene fluvial and lacustrine deposits (QTg) in Rincon Valley

Tw **Wilson Grove Formation (Pliocene and Miocene)**–The Wilson Grove Formation is not exposed at the surface in the Santa Rosa or Kenwood 7.5' quadrangles, but it underlies much of the Santa Rosa Plain (cross sections B and C). The Wilson Grove Formation includes marine pebbly sandstone, siltstone and distinctive well-rounded, friable, matrix- and clast-supported pebbly gravel, with quartz, dark chert and porcellanitic shale clasts (Cotati lithofacies of the Wilson Grove and Petaluma formations) in a sandy to silty matrix. Unit is partly coeval with late Miocene part of Petaluma Formation and is locally includes the Rohlar tuff, radiometrically dated at 6.26 ± 0.4 Ma (Ar-Ar)

Tp **Petaluma Formation (Pliocene and Miocene)**–Dominantly sandy to silty gravel, silty sandstone, siltstone, and mudstone (Tp). Contains diatomite (Tpd) and clayey diatomaceous shale with local lenses of lignite and lignitic mudstone (Tplg), silicified wood (Tpwd), and fresh water limestone (Tpln). Petaluma Formation strata were deposited in fluvial, lacustrine, and brackish to estuarine settings and the formation locally contains the 6.26 ± 0.4 Ma (Ar-Ar) Rohlar tuff. Depositional settings are locally constrained by invertebrate fossils, diatoms, ostracodes, rare foraminifers and rare land mammals. The formation locally includes interbedded gravel with well rounded and polished pebbles of banded porcellanite, milky quartz and black chert and argillite correlative with the gravels of Cotati (Fox, 1983), a lithofacies of the Petaluma and Wilson Grove Formations
The Petaluma Formation is older than ~4.8-5.0 Ma and younger than ~8.0 Ma where exposed along the E side of Santa Rosa Plain. Beneath the Santa Rosa Plain and southwest of Cotati and Robnert Park, the lower Petaluma Formation is intercalated with the older, ~8.5-10 Ma Tolay Volcanics, and overlies Mesozoic basement of the Franciscan Complex, Coast Range ophiolite and Great Valley sequence. The Petaluma Formation locally includes the following units.

Tpd **Diatomite and diatomaceous mudstone**–The diatom flora in these strata (fossil locality 4) suggest a shallow, eutrophic, neutral to slightly alkalic, stagnant lacustrine setting (S. Starart, written commun. 2006)

Tplg **Lignite and lignitic mudstone**

Tpwd **Silicified (petrified) wood**

Tpln **Limestone**–Brackish or fresh water depositional setting, locally fossiliferous, present as lenses in the upper parts of basaltic andesite flows and breccias

Tpfb **Breccia**–Composed dominantly of angular, tectonically slickened clasts of rhyodacitic rocks with variable textures, interpreted to represent a fault scarp-derived breccia. Breccia includes clasts up to 3m in a comminuted matrix derived from rhyodacitic intrusives, flows and tuffs. Breccia locally includes:

Tpgg **Gravel lenses**–Intercalated in breccia, up to ~5m thick, unsorted to poorly sorted, un-organized to weakly segregated and cross-bedded. Gravel is composed of rounded to subangular pebbles to cobbles derived from Franciscan and related Mesozoic sources and from older Tertiary volcanics deposited in alluvial fans, debris flows and talus settings

LATE TERTIARY VOLCANIC ROCKS

Sonoma Volcanics (Pliocene and Miocene)–Rhyolitic to dacitic ash-flow and air fall tuff, andesitic water-lain tuff, and rhyolitic to basalic flows and flow breccia. Regionally, the volcanic section becomes increasingly silicic up-section, and younga from southwest to northeast, across the Rodgers Creek-Healdsburg and Maacama faults (McLaughlin and others, 2005; Fox and others, 1985). The Sonoma Volcanics consist of the following units.

Tsd **Dacitic flows**–Mapped near the northeast corner of the Santa Rosa quadrangle and in the southeast half of the quadrangle along the Rodgers Creek Fault Zone. The dacite lacks macroscopic quartz or K-feldspar, commonly contains plagioclase phenocrysts, and rare hornblende

Tsr **Rhyolitic and rhyodacitic flows and intrusive rocks**–Porphyritic to aphanitic, with phenocrysts of quartz and plagioclase. Includes the rhyodacitic rocks of Zamarano Quarry (7.26±0.04 Ma), the rhyodacitic rocks of Cook Peak (7.94±0.02 Ma), and perlitic to banded rhyolitic to rhyodacitic flow rocks and obsidian in Annadel State Park (4.5±0.01 Ma)

Tst **Rhyolitic to dacitic and minor andesitic pumiceous tuff**–Mostly ash-flows and minor air fall. This unit includes named and unnamed tephra layers of different ages in the Sonoma Volcanics (see Tephra data Tables 2.2 and 2.3, figure 2.2, and discussion in pamphlet)

Tstw **Crystal-rich rhyolitic to rhyodacitic welded tuff**–Welded zones locally at tops of tuff layers that are overlain by flows of andesite or basalt

Tstb **Andesitic to rhyodacitic breccia (Pliocene)**–Mapped locally in the northeast part of Santa Rosa 7.5' quadrangle, between the 4.83 Ma Lawlor Tuff and overlying basaltic andesite. Breccia consists of angular boulders and blocks of basalt, andesite, and vitric, porphyritic rhyodacite, in a lithic rhyo-dacitic pumiceous tuff matrix. The breccia may be associated with syn-volcanic faulting and (or) proximal pyroclastic venting

Tsb **Andesite, basaltic andesite and basalt**–Subaerial andesitic to basaltic flows, flow breccia and tuff-breccia, local waterlain andesitic tuff and minor dacitic ash-flow tuff, aerially between the Healdsburg and southern Rodgers Creek segments of the Rodgers Creek Fault Zone and the Mark West Fault Zone. Unit may compose a relatively thin cover to pre-Miocene basement (cross sections A-C). Andesitic rocks are intercalated with and underlain by the Petaluma Formation and the numerous named and unnamed rhyodacitic to andesitic tuffs (Tbt), and local rhyodacitic flows and intrusive rocks (Tbr) of the Sonoma Volcanics.
Dated andesitic rocks in the Santa Rosa 7.5' quadrangle (table 2.2, and figure 2.2) span a significantly narrower age range than the tephra units (Tbt) . Andesite along Fountain Grove Parkway northeast of the Healdsburg Fault Zone is dated at 5.0 ± 0.4 Ma. Basaltic andesite from the Cloverleaf Ranch area yielded a plateau age of 4.53 ± 0.04 Ma. Andesitic flows in an area of abandoned cobblestone quarries east of Lake Ralphine are dated at 4.4 ± 0.03 Ma. East of the Bennett Valley Fault in Annadel State Park, a lithologically and texturally similar plagioclase-rich, olivine-bearing andesite is dated at 4.7 ± 0.03 Ma.
Near the northeast corner of Santa Rosa 7.5' quadrangle, porphyritic basaltic andesite that overlies the 4.83 Ma Lawlor Tuff, is dated at 4.63 ± 0.02 Ma. Collectively, andesitic rocks northeast of the Rodgers Creek-Healdsburg Fault Zone and southwest of the Maacama Fault appear to range in age from ~5.4 to 4.4 Ma

Tsbd **Andesitic to dacitic tuff, breccia and minor flows**–Includes air fall and ash flow tuffs and some possibly reworked waterlain tuff (Higgins, 1983). Unit underlies basaltic andesite flows dated at 4.7 ± 0.03 Ma. Andesitic tuff breccia also overlies andesitic flows and breccias (Tsb) and rhyolitic rocks (Tsr) northeast of Bennett Mountain, that are probably correlative with the obsidian of Annadel State Park (4.5 ± 0.01 Ma)

Tvt **Tolay Volcanics (Miocene)**–Rhyolite, andesite and basalt, interbedded with the sedimentary rocks of the Petaluma Formation. Unit is not present at the surface in Santa 7.5' Rosa quadrangle, but is mapped in the adjacent Cotati 7.5' quadrangle (Cahan and others, 2003) and beneath Santa Rosa plain, based on exploratory oil and gas well data (cross section C, figure 2.3A)

PRE-TERTIARY ROCKS

KJso **Great Valley Sequence and Coast Range Ophiolite, undivided (Cretaceous and Jurassic)**–Marine sedimentary rocks of the Cretaceous and Jurassic Great Valley Sequence and (or) igneous and pelagic rocks of the Jurassic Coast Range ophiolite, inferred to be locally present beneath Santa Rosa plain and beneath Miocene and younger units between the Rodgers Creek-Healdsburg and Maacama Fault Zones. Great Valley Sequence strata includes thin- to medium-bedded, shaly to arkosic, sandy turbidites and thick bedded to massive, conglomeratic submarine channel deposits. No exposures of Great Valley Sequence strata are recognized at the surface in the map area but are inferred in the subsurface based on along-strike and down-plunge projection from exposures in adjacent quadrangles

Coast Range Ophiolite (Jurassic)–Rocks presumed to be derived from the Coast Range Ophiolite in the map area include:

Jos **Serpentinized ultramafic rocks**–Predominantly serpentinized non-cumulate tectonic harzburgite and dunite. Serpentine mineral assemblage is typically a mixture of lizardite and chrysotile. In places, unit includes minor cumulate ultramafic to gabbroic rocks. Locally, pods and lenses of unit are imbricated with melange of Franciscan Complex Central Belt

Central Belt of the Franciscan Complex (Upper Cretaceous to Lower Jurassic)

fcm **Undifferentiated melange**–Largely penetratively sheared sandstone and argillite, containing blocks of varying lithology. Where blocks are large enough to map, includes:

bls **Blueschist blocks**–Mafic to felsic igneous and pelagic rocks, metamorphosed to high blueschist grade. Includes eclogite and amphibolite-grade blocks partially retrograded to blueschist and locally, tuffaceous pelitic rocks that contain chromic mica (fuchsite), white mica, lawsonite and sodic amphibole

frc **Radiolarian chert of Marin Headlands-Geysers terrane**–Red to green, locally tuffaceous, and in places depositional on, or interlayered with, basaltic volcanic rocks. Where section is complete, radiolarian chert overlies pillow basalt, is of early Late Cretaceous (Cenomanian) to Early Jurassic (Pliensbachian) age (McLaughlin and Pessagno, 1978; Hagstrum and Murchey, 1993) and is depositionally overlain by terrigenous metasandstone and shale

fcv **Basaltic volcanic rocks**–Massive to pillowed basaltic flows, breccia and tuff, generally metamorphosed to low-greenschist grade, containing epidote and pumpellyite. Includes basaltic rocks of Marin Headlands-Geysers terrane

Contact–Dashed where approximately located; dotted where concealed; queried where uncertain

Fault–Dashed where approximately located or inferred; dotted where concealed; queried where uncertain

Normal fault–Showing geometry of fault plane and sense of slip. Bar and ball on down-dropped block; ↓ on upthrown block; ↕ on down-dropped block where fault dip unknown. Arrows show direction of relative horizontal movement. Dip of fault plane shown by arrow normal to fault with dip amount indicated where known; arrow and number at angle to fault indicates rake of lineation; diamond astride fault indicates vertical dip

Thrust fault–Sawteeth on upper plate

Fault lineament–Inferred from linear features on aerial photography; dotted where projected beneath surficial deposits; queried where uncertain. Arrows show relative horizontal motion

Fault scarp–Showing fault line at base of scarp. Hachures point downscarp

Fold–Dashed where approximately located; dotted where concealed; queried where uncertain

Anticline

Syncline

Overturned syncline–Showing dip

Minor syncline–Showing bearing and plunge

Closed depression or sag pond

Strike and dip of beds

Inclined

Inclined–Top of beds known from local features

Vertical

Approximate–Determined by sighting from distant location; dip indicated where measured

Strike and dip of foliation in sheared or foliated rock

Inclined

Vertical or near vertical

Strike and dip of volcanic flow unit

Fossil locality

Radiometric dating and tephrochronology localities–Numbers refer to figures 3.4,B and tables 1-3

Spring

Water well

Area of hydrothermal alteration

Landslide–Arrows indicate direction of movement

CORRELATION OF MAP UNITS

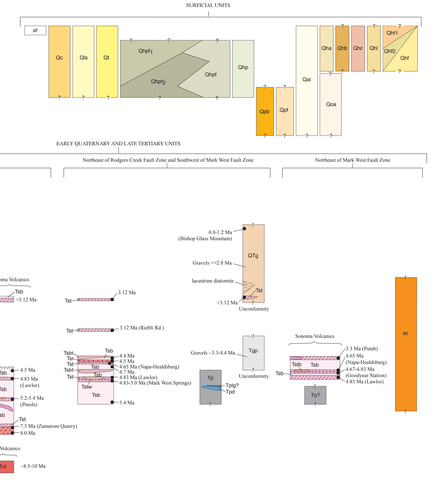




Figure 1. Index map, showing location of Santa Rosa 7.5' quadrangle (red box) within the grids of Napa and Healdsburg 30' x 60' quadrangles, northern California. Green box on inset map shows location of index map.

Geologic and Geophysical Framework of the Santa Rosa 7.5' Quadrangle, Sonoma County, California

By

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2008

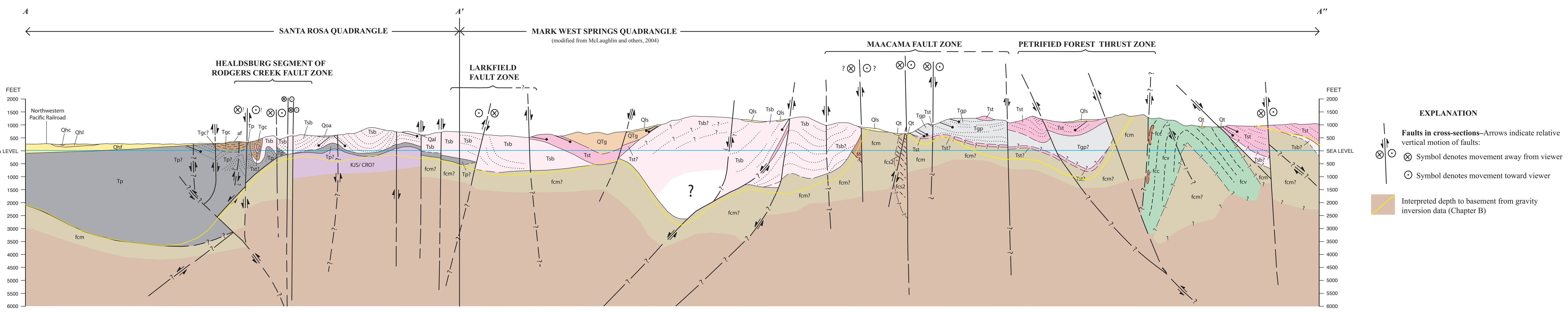
[1]U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025

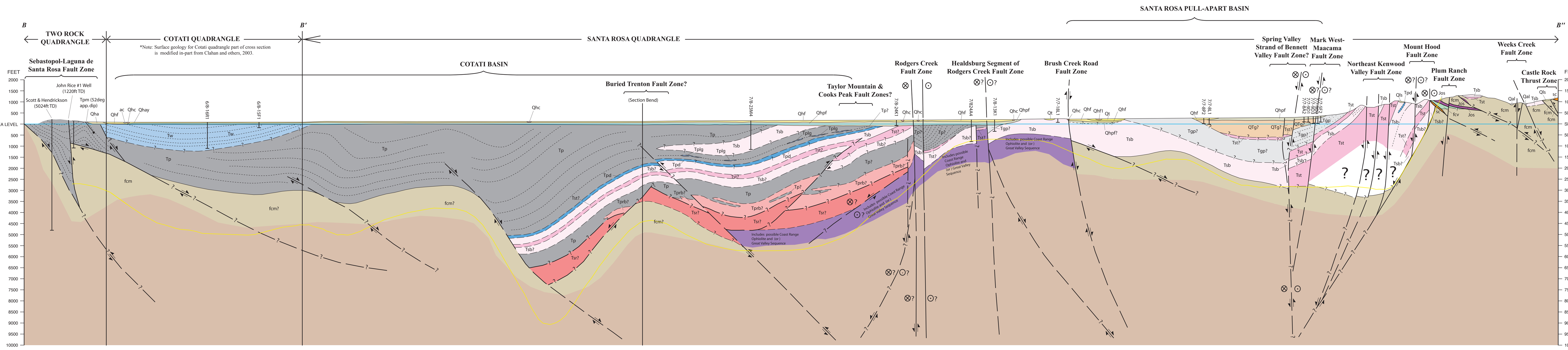
Any use of trade, firm, or product names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

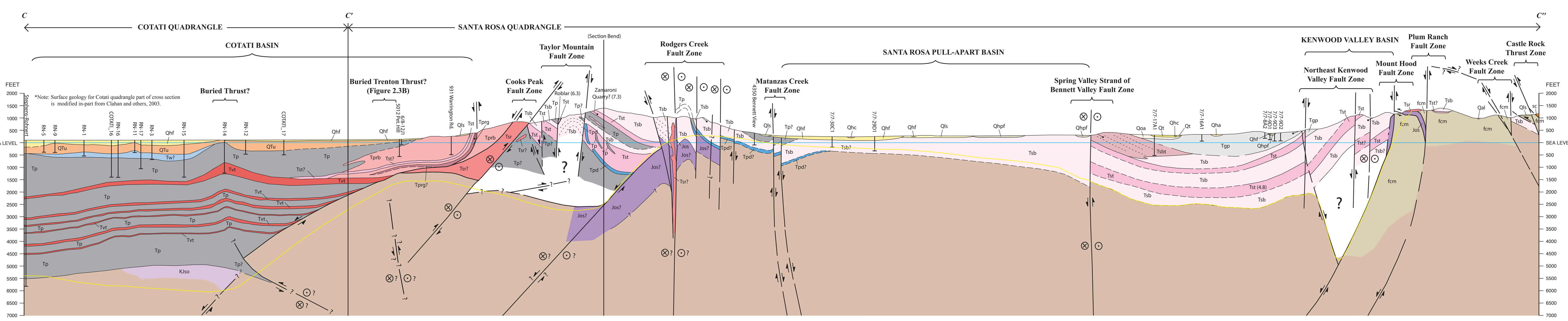
This map was printed on an electronic plotter directly from digital files. Dimensional calibration may vary between electronic plotters and between A and Y dimensions on a single plot. Because paper may change dimensions with atmospheric conditions, therefore, scale and proportions may not be true on plots of this map.

Digital files available on World Wide Web at http://pubs.usgs.gov/of/2008/1009/

Open-File Report 2008-1009
Sheet 2 of 3
Pamphlet accompanies map







COMPARATIVE STRATIGRAPHY

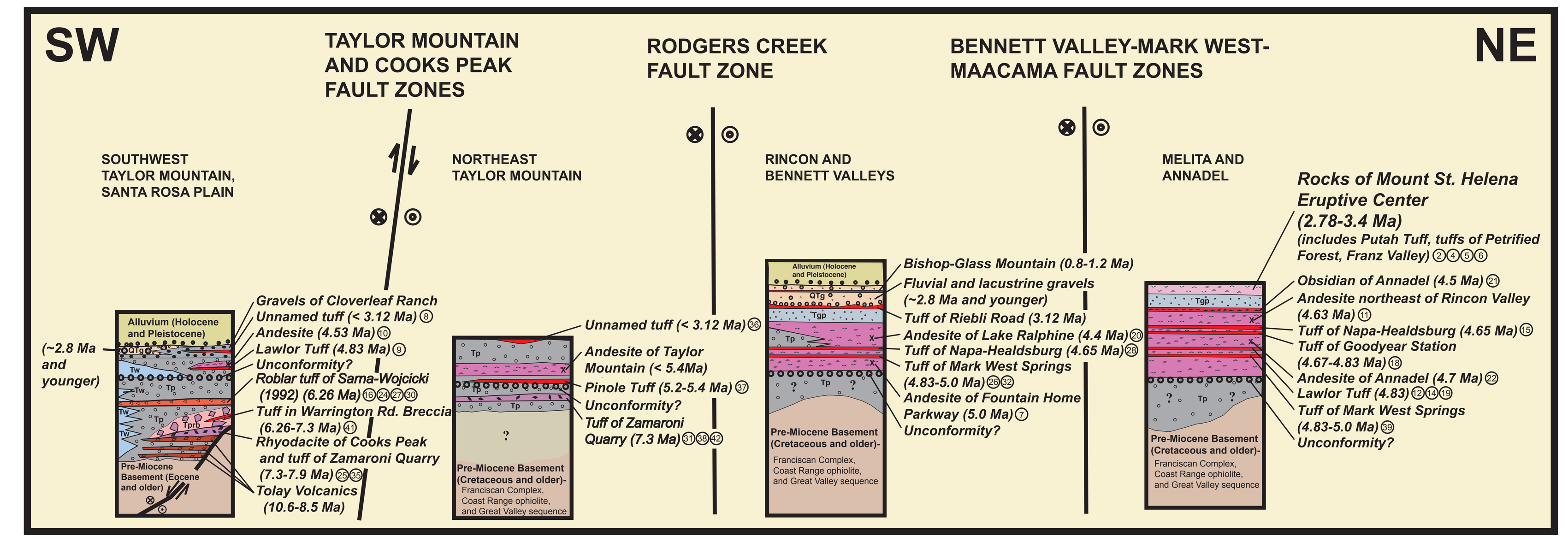


Figure 3. Schematic stratigraphic sections for major structural blocks of Santa Rosa 7.5' quadrangle, showing stratigraphic positions of dated and correlated tephra and other volcanic units of Sonoma and Tolay Volcanics. Circled numbers refer to map locality numbers in tables 1, 2 and figure 4. See these tables and figure 4 for map locations and analytical data.

Table 2. *Tephrochronologic data for the Santa Rosa and Kenwood 7.5' quadrangles.*

[All tephra unit names listed are informal names, with the exception of the Putah, the Roblar, and the Lawlor Tuff (Sarna-Wojcicki, 1976). Localities are arranged according to their latitudinal distribution from north to south (fig. 4).]

Map Locality No.	Field No.	West Longitude (°)	North Latitude (°)	Tephra Unit	Interpolated age from correlation with dated locations (Ma±1σ)	Source of Age Data	Comments	Tephra locality (fig. 4)
1	MRM10-03 MRM10-03	122.654	38.4978	Tuff below Napa-Healdsburg	4.64-4.65±0.03	This report		●
2	MRM11-03	122.65415	38.49745	Calistoga Road tuff 1	3.22±0.02 (?)	McLaughlin et al., 2004 McLaughlin et al., 2005	Matches MRM24-03 (Map Loc. #5); similar to Putah Tuff	●
3	MRM21-03	122.63087	38.49628	Northeast Santa Rosa tuff 1	undetermined			●
4	MRM15-03	122.65547	38.49395	Calistoga Road tuff 2	2.78-3.22 (?)	This report; McLaughlin et al., 2005	Smiliarities to Putah Tuff, tuff of Pepperwood Ranch and Franz Valley suite	●
5	MRM24-03	122.64757	38.49252	Calistoga Road tuff 1	3.22±0.02 (?)	McLaughlin et al., 2004; McLaughlin et al., 2005	CaO is low for good Putah Tuff match	●
6	MRM16-03	122.6562	38.49247	Putah Tuff	3.22±0.02	McLaughlin et al., 2004	Good match to Putah Tuff	●
8	MRM12-02	122.729	38.486	Tuff of Cloverleaf Ranch	□3.12	McLaughlin et al., 2004; this report	Similar to unnamed tuff (MRM10-97) which overlies tuff of Riebli Road in Mark West Springs quadrangle	●
9	MRM9-02	122.72766	38.486	Lawlor Tuff	4.83	Sarna-Wojcicki, 1976; McLaughlin et al., 2004; McLaughlin et al., 2005	Overlain (?) by basaltic andesite (Map Loc. #10)	●
12	MRM43-03	122.64707	38.48168	Lawlor Tuff	4.83	Sarna-Wojcicki, 1976; McLaughlin et al., 2004; McLaughlin et al., 2005	Good match to Lawlor Tuff	●
13	MRM29-03	122.62735	38.48045	Calistoga Road tuff 1	3.22±0.02 (?)	McLaughlin et al., 2004; McLaughlin et al., 2005	CaO is low for Putah Tuff; matches to Map Locs. #2, #5	●
14	MRM45-03	122.64095	38.47795	Lawlor Tuff	4.83	Sarna-Wojcicki, 1976; McLaughlin et al., 2004; McLaughlin et al., 2005	Good match to Lawlor Tuff	●
15	MRM40-03	122.64358	38.47763	Tuff of Napa-Healdsburg	4.65	this report; Sarna-Wojcicki, 1976; McLaughlin et al., 2005		●
16	ASW-020102-C	122.71996	38.4765	Roblar Tuff	6.26±0.03	Sarna-Wojcicki, 1976; McLaughlin et al., 2005	Collected with J. Allen	●
17	MRM33-03	122.62827	38.476	Northeast Santa Rosa tuff 2	undetermined			●
18	MRM32-03	122.6281	38.47593	Tuff of Goodyear Station	>4.67 <4.83	This report; McLaughlin et al., 2005		●
19	MRM35-03	122.62253	38.47223	Lawlor Tuff	4.83	This report; McLaughlin et al., 2005	Collected in quarry northwest of Los Alamos Road	●
23	MRM68-04	122.68035	38.42315	Taylor Mountain tuff 1	undetermined		Present along northeast side of Rodgers Creek Fault	●
24	MRM25-04	122.69162	38.41288	Roblar Tuff	6.26±0.03	Sarna-Wojcicki, 1976; McLaughlin et al., 2005	Southwest of Rodgers Creek Fault near Kawana Springs	●
25	MRM6-97	122.69791	38.40746	Tuff of Zamaroni Quarry	7.26±0.04	This report; McLaughlin et al., 2005	Collected in Zamaroni Quarry; associated with flow or neck	●
26	MRM29-05	122.64746	38.40658	Tuff of Mark West Springs	<~5.02 >4.8	McLaughlin et al., 2004	Collected northeast of Matanzas Creek Reservoir	●
27	MRM12-04	122.69095	38.40338	Roblar Tuff	6.26±0.03	Sarna-Wojcicki, 1976; McLaughlin et al., 2005	Good match to Roblar Tuff. Located southwest side, Rodgers Creek Fault near Kawana Springs	●
28	MRM31-05	122.64661	38.40288	Tuff of Napa-Healdsburg	4.65	McLaughlin et al., 2005	Collected northeast of Matanzas Creek Reservoir, Bennett Valley	●
29	MRM16-04	122.67583	38.40083	Taylor Mountain tuff 2	~6.26-7.26	This report	Similar to Roblar Tuff. Collected on Taylor Mountain, southwest of Rodgers Creek Fault	●
30	MRM15A-04 MRM15B-04	122.67798	38.40046	Roblar Tuff	6.26±0.03 6.26±0.03	Sarna-Wojcicki, 1976; McLaughlin et al., 2005	Collected on Taylor Mountain, southwest of Rodgers Creek Fault	●
31	MRM18-04A	122.67205	38.39896	Tuff of Zamaroni Quarry?	~7.26 (?)	This report; McLaughlin et al., 2005	Similar to tuff of Zamaroni Quarry; collected southwest of Rodgers Creek Fault	●
32	MRM33-04	122.65718	38.39858	Tuff of Mark West Springs	<~5.02 >4.83	McLaughlin et al., 2004	Collected northeast of Rodgers Creek Fault, Taylor Mountain	●
33	MRM36-04	122.66755	38.39436	Taylor Mountain tuff 3	undetermined	This report; McLaughlin et al., 2004	No good matches; similarities to tuff of Pepperwood Ranch and Pinole Tuff	●
34	MRM20-04A MRM20-04B	122.67116	38.39392	Unnamed, younger than Pinole Tuff?	undetermined □5.2-5.4 (?)	This report; McLaughlin et al., 2005; Sarna-Wojcicki, unpublished data	Collected southwest of Rodgers Creek Fault, Taylor Mountain; mixed populations, but with composition like a tuff that overlies Pinole Tuff	●
36	MRM32-05	122.65322	38.38910	Unnamed tuff north of Guenza Road	□3.12	This report; McLaughlin et al., 2004	Mixed population tuff; similar to MRM10-97 which overlies tuff of Riebli Road in Mark West Springs quadrangle	●
37	MRM40-04	122.65977	38.38928	Pinole Tuff	5.2-5.4	McLaughlin et al., 2005	Collected southwest of Rodgers Creek Fault, Taylor Mountain area	●
38	MRM42-04	122.66456	38.38863	Tuff of Zamaroni Quarry	7.26±0.04	This report; McLaughlin et al., 2005	Collected southwest of Rodgers Creek Fault, Taylor Mountain area	●
39	ASW-020102-D	122.59320	38.38671	Tuff of Mark West Springs	<~5.02 >4.83	McLaughlin et al., 2004	Along northeast side of Bennett Valley Fault Zone	●
40	MRM49-04 MRM49-04	122.66243	38.38438	Taylor Mountain tuff 4	~6.26-7.26 (?)	This report	Composition similar to Roblar tuff; high and low Fe populations; collected southwest of Rodgers Creek Fault, Taylor Mountain area	●
41	MRM50-04	122.66855	38.38268	Tuff in Warrington Road Breccia	<7.26>6.26	This report	Mapped as part of breccia overlying rhyolite and dacite of Cooks Peak	●
42	MRM38-04	122.65270	38.38250	Tuff of Zamaroni Quarry	7.26±0.04	This report	Collected southwest of Rodgers Creek Fault on Taylor Mountain	●

Table 1. *$^{40}Ar/^{39}Ar$ ages of volcanic rocks in the Santa Rosa and Kenwood 7.5' quadrangles.*

[Localities arranged in numerical order, from north to south (Fig. 2). All ages were determined in the U.S. Geological Survey radiometric dating laboratory, Menlo Park, California by Robert J. Fleck. Samples were irradiated in the U.S. Geological Survey TRIGA Reactor Facility in Denver, Colo.]

Map Locality No.	Field No.	Map Unit	Locality Description	Rock Type	Material Analyzed	West Longitude (°)	North Latitude (°)	Best Estimate Age $^{40}Ar/^{39}Ar$ (Ma±1σ)	Total-Fusion Age (Ma±1σ)	Plateau Age (Ma±1σ)	Isochron Age (Ma±1σ)
7	MRM1-97	Tsb	Andesite along Fountain Grove Parkway	Andesite	Plagioclase	122.69483	38.48850	5.0±0.4	3.618±0.876	no plateau	4.996±0.390
10	MRM8-02	Tsb	Andesite of Cloverleaf Ranch	Andesite	groundmass	122.72583	38.48450	4.53±0.04	4.753±0.037	4.531±0.041	4.456±0.116
11	047-14B	Tsb	Porphyritic andesite, NE Santa Rosa quadrangle	Andesite	groundmass	122.64756	38.48188	4.77±0.03 (run 1) 4.63±0.02 (run 2)	4.77±0.03 4.625±0.016	no plateau no plateau	4.93±0.34 5.01±0.39
20	047-13C	Tsb	Hard, fine-grained flaggy Andesite, SE of Lake Ralphine	Andesite	groundmass	122.66211	38.45478	4.37±0.03	4.195±0.035	4.368±0.025	4.39±0.26
21	MRM82-99	Tsr	Obsidian of Annadel State Park	Obsidian	whole rock	122.62030	38.44534	4.51±0.01 (run 1) 4.54±0.01 (run 2)	4.51±0.30 4.54±0.20	4.51±0.01 4.54±0.01	4.51±0.05 4.55±0.06
22	047-14C	Tsb	Andesite, Annadel State Park, plagioclase-rich, olivine-bearing	Andesite	groundmass	122.61490	38.43635	4.7±0.03	4.687±0.027	no plateau	4.7±0.6
25	MRM6-97 (HRC-5C)	Tst	Silicic flow or neck in Zamaroni Quarry	Rhyodacite	Plagioclase	122.69791	38.40746	7.26±0.04	7.311±0.038	7.261±0.039	7.269±0.064
35	047-13B	Tsr	Cooks Peak, hard, gray, coarse porphyritic Rhyodacite	Rhyodacite	Plagioclase	122.67632	38.39097	7.94±0.02 (run 1) 7.98±0.03 (run 2)	8.057±0.020 8.077±0.014	7.94±0.02 7.98±0.03	7.93±0.08 8.00±0.14

Table 3. *Chemical compositions of volcanic glass in pyroclastic units in the Santa Rosa and Kenwood 7.5' quadrangles.*

[Values given are weight percent oxide normalized to 100 percent to correct for variations in water content of the glasses. Values reported here as Fe_2O_3 are converted from analyses originally reported as FeO and recalculated to 100 percent. The values for a homogenous obsidian used as an internal standard, RLS-132, are given below to provide an approximate analytical error in the electron-microprobe analyses. All tephra unit names listed are informal names, with the exception of the Putah, the Roblar, and the Lawlor Tuff. Localities are arranged according to their latitudinal distribution from north to south.]

Map No.	Tephra Unit	Sample Field No., Lab No.	Interpolated age from correlation to dated locations (Ma±1σ)	Weight Percent Oxide								
				SiO_2	Al_2O_3	Fe_2O_3	MgO	MnO	CaO	TiO_2	Na_2O	K_2O
1	Tuff below Napa-Healdsburg	MRM10-03, T513-3 MRM10-03, T512-2	4.64-4.65±0.03	75.96 73.6	12.97 13.81	1.79 2.58	0.01 0.03	0.03 0.07	0.34 0.64	0.12 0.18	3.74 4.86	5.04 4.22
2	Calistoga Road tuff 1	MRM11-03, T513-6	3.22±0.02 (?)	74.27	13.89	1.93	0.1	0.04	0.57	0.17	3.46	5.57
3	Northeast Santa Rosa tuff 1	MRM21-03, T513-4	undetermined	75.41	13.35	1.73	0.03	0.03	0.63	0.13	3.72	4.97
4	Calistoga Road tuff 2	MRM15-03, T512-8	2.78-3.22 (?)	74.79	13.28	1.94	0.02	0.03	0.44	0.14	4.02	5.35
5	Calistoga Road tuff 1	MRM24-03, T513-5	3.22±0.02 (?)	74.25	13.83	1.96	0.09	0.03	0.56	0.17	3.91	5.2
6	Putah Tuff	MRM16-03, T512-4	3.22±0.02	74.85	13.53	1.95	0.05	0.04	0.78	0.14	3.83	4.82
8	Tuff of Cloverleaf Ranch	MRM12-02, T499-9	□3.12	78.2	12.48	0.91	0.04	0.03	0.44	0.08	2.57	5.24
9	Lawlor Tuff	MRM9-02, T497-2	4.83	73.73	14.15	2.18	0.1	0.05	0.86	0.16	4.59	4.18
12	Lawlor Tuff	MRM43-03, T513-1	4.83	73.68	14.27	2.21	0.1	0.05	0.92	0.16	4.35	4.26
13	Calistoga Road tuff 1	MRM29-03, T512-1	3.22±0.02 (?)	74.8	13.89	1.78	0.09	0.03	0.5	0.16	3.53	5.23
14	Lawlor Tuff	MRM45-03, T513-2	4.83	73.87	14.22	2.16	0.09	0.04	0.89	0.17	4.52	4.03
15	Tuff of Napa-Healdsburg	MRM40-03, T512-10	4.65	72.44	14.53	2.98	0.09	0.08	0.94	0.21	5.53	3.19
16	Roblar Tuff	ASW-020102-C, T488-9	6.26±0.03	75.26	13.82	1.52	0.07	0.03	0.61	0.1	3.2	5.38
17	Northeast Santa Rosa tuff 2	MRM33-03 (Low Ca Pop), T512-6	undetermined	74.86	13.35	1.75	0.03	0.03	0.11	0.14	3.2	6.53
18	Tuff of Goodyear Station	MRM32-03, T512-5	>4.67 <4.83	75.23	13.46	1.84	0.04	0.04	0.69	0.15	4.11	4.45
19	Lawlor Tuff	MRM35-03, T512-7	4.83	73.84	14.26	2.04	0.1	0.05	0.92	0.17	4.27	4.33
23	Taylor Mountain tuff 1	MRM68-04, T527-3	undetermined	74.9	13.63	1.64	0.07	0.04	0.48	0.15	3.35	5.75
24	Roblar Tuff	MRM25-04, T523-4	6.26±0.03	75	13.6	1.45	0.06	0.01	0.58	0.11	4.65	4.53
25	Tuff of Zamaroni Quarry	MRM6-97, T395-7	7.26±0.04	76.01	12.98	1.39	0.04	0.02	0.47	0.09	3.86	5.13
26	Tuff of Mark West Springs	MRM29-05, T533-2	<~5.02 >4.8	74.81	13.83	1.68	0.05	0.04	0.79	0.1	3.87	4.83
27	Roblar Tuff	MRM12-04, T520-10	6.26±0.03	75.57	13.51	1.46	0.06	0.03	0.57	0.11	3.97	4.73
28	Tuff of Napa-Healdsburg	MRM31-05, T533-3	4.65	72.35	14.4	3.16	0.09	0.08	0.97	0.2	5.52	3.22
29	Taylor Mountain tuff 2	MRM16-04, T520-3	~6.26-7.26	76.61	13.59	1.53	0.07	0.03	0.53	0.14	2.23	5.28
30	Roblar Tuff	MRM15A-04, T517-3 MRM15B-04, T517-2	6.26±0.03 6.26±0.03	75.1 75.24	13.66 13.59	1.43 1.43	0.07 0.07	0.03 0.02	0.58 0.58	0.12 0.12	4.15 4.31	4.86 4.63
31	Tuff of Zamaroni Quarry?	MRM18-04A, T520-4	~7.26 (?)	76.58	13.02	1.3	0.09	0.02	0.56	0.12	3.69	4.61
32	Tuff of Mark West Springs	MRM33-04, T523-5	<~5.02 >4.83	75.05	13.86	1.68	0.04	0.02	0.78	0.12	3.41	5.02
33	Taylor Mountain tuff 3	MRM36-04, T517-4	undetermined	72.53	14.57	3.01	0.22	0.06	1.17	0.27	3.2	4.96
34	Unnamed, younger than Pinole Tuff?	MRM20-04A, T520-2 MRM20-04B, T523-3	undetermined undetermined	75.15 72.02	12.37 13.86	3.21 3.3	0.01 0.06	0.05 0.04	0.28 0.47	0.19 0.21	2.71 3.52	6.04 6.52
36	Unnamed, tuff north of Guenza Road	MRM32-05 (pop. 3), T533-4	□3.12	73.14	14.27	2.74	0.13	0.05	1.09	0.23	4.81	3.54
37	Pinole Tuff	MRM40-04, T517-6	5.2-5.4	71.45	14.43	3.47	0.05	0.1	1.1	0.25	5.82	3.34
38	Tuff of Zamaroni Quarry	MRM42-04, T517-7	7.26±0.04	75.9	13.13	1.36	0.04	0.04	0.45	0.09	4.01	4.99
39	Tuff of Mark West Springs	ASW-020102-D, T488-10	<~5.02 >4.83	74.78	14.02	1.7	0.05	0.04	0.78	0.11	3.21	5.31
40	Taylor Mountain tuff 4	MRM49-04 (Low Fe pop.), T527-1 MRM49-04 (High Fe pop.), T527-1	~6.26-7.26 (?)	77.67 76.39	13.08 13.59	0.63 1.51	0.02 0.09	0.03 0.03	0.35 0.6	0.06 0.1	3.12 3.06	5.04 4.63
41	Tuff in Warrington Road Breccia	MRM50-04 OBS, T528	<7.26>6.26	76.84	13.33	0.71	0.02	0.03	0.39	0.06	4.2	4.43
42	Tuff of Zamaroni Quarry	MRM38-04, T517-5	7.26±0.04	75.77	13.12	1.33	0.05	0.02	0.51	0.1	3.82	5.28
			RLS-132, obsidian standard	74.05	11.36	4.66	0.05	0.15	0.10	0.19	5.09	4.37
			Standard Deviation	0.65	0.10	9.04	0.01	0.01	0.01	0.01	0.16	0.05
			No. of runs (~20 shards/run)	83	83	83	83	83	83	83	83	83

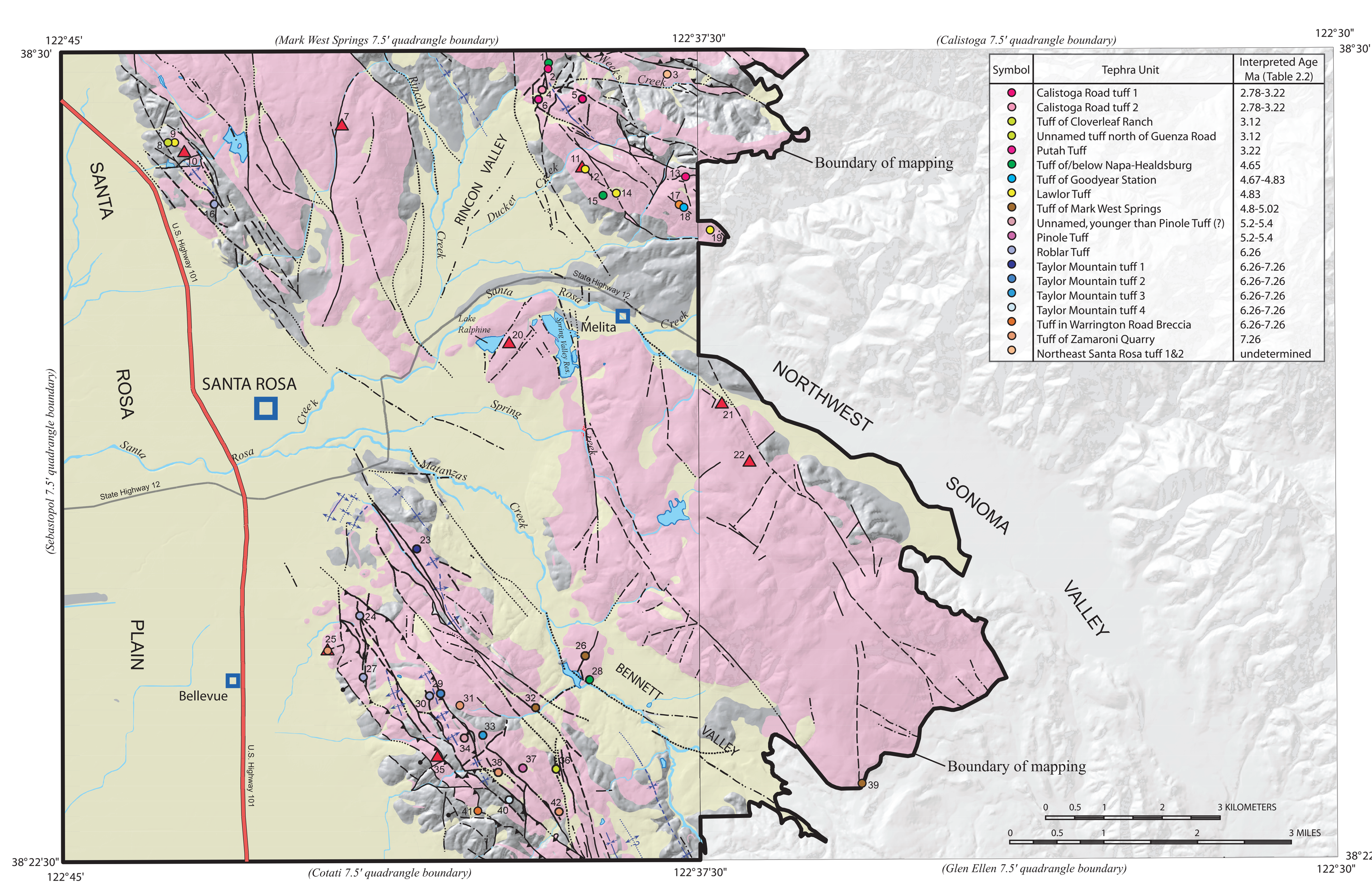


Figure 4. Index map showing locations of analyzed tephra and radiometrically dated samples from the Sonoma Volcanics in Santa Rosa and western Kenwood 7.5' quadrangles. Sonoma Volcanics are shown in pink, Quaternary sediments in beige. Tephra sample localities are shown as colored circles and correlate to data in tables 2 and 3. $^{40}Ar/^{39}Ar$ sample locations are shown as red triangles, and correlate to data in table 1.

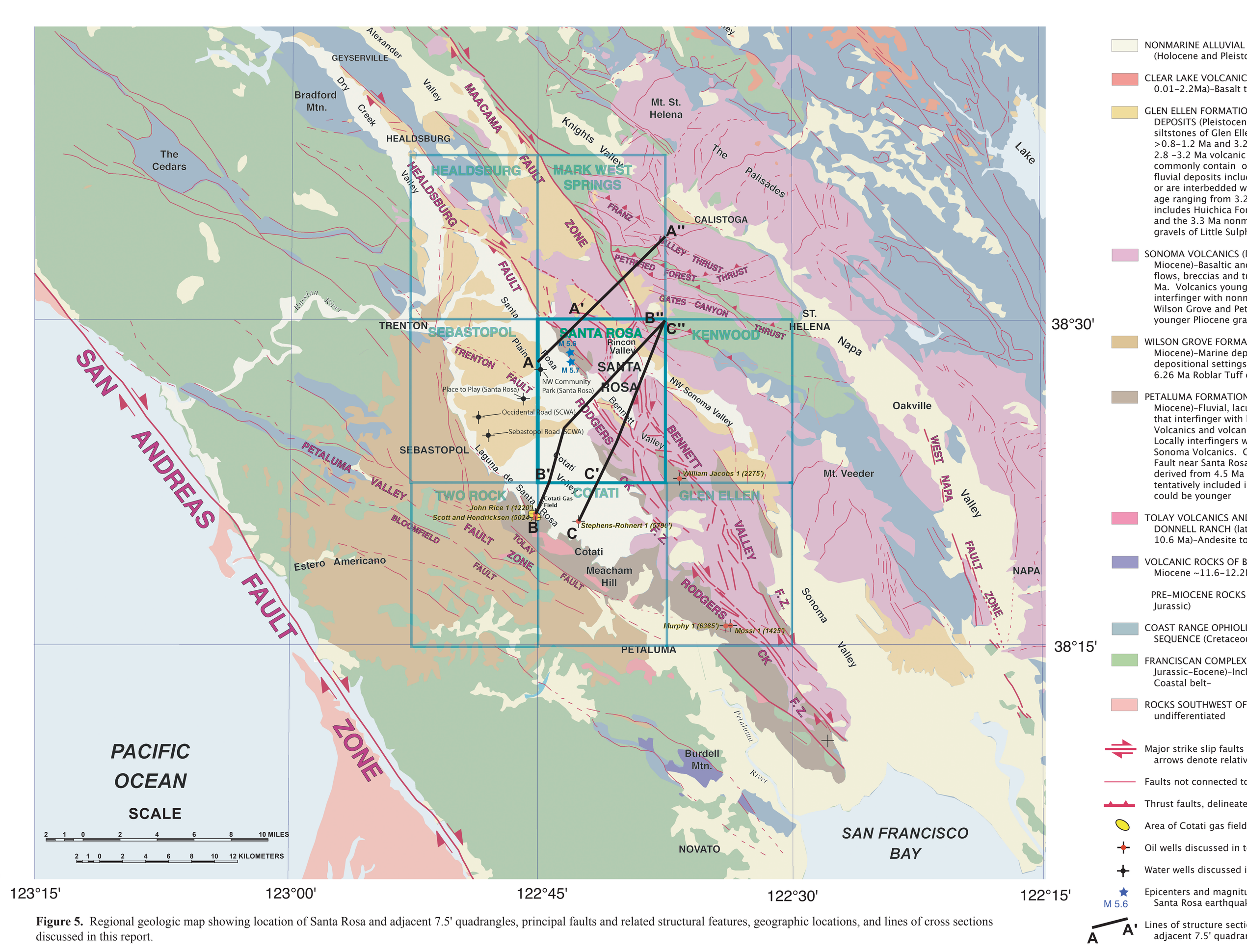


Figure 5. Regional geologic map showing location of Santa Rosa and adjacent 7.5' quadrangles, principal faults and related structural features, geographic locations, and lines of cross sections discussed in this report.

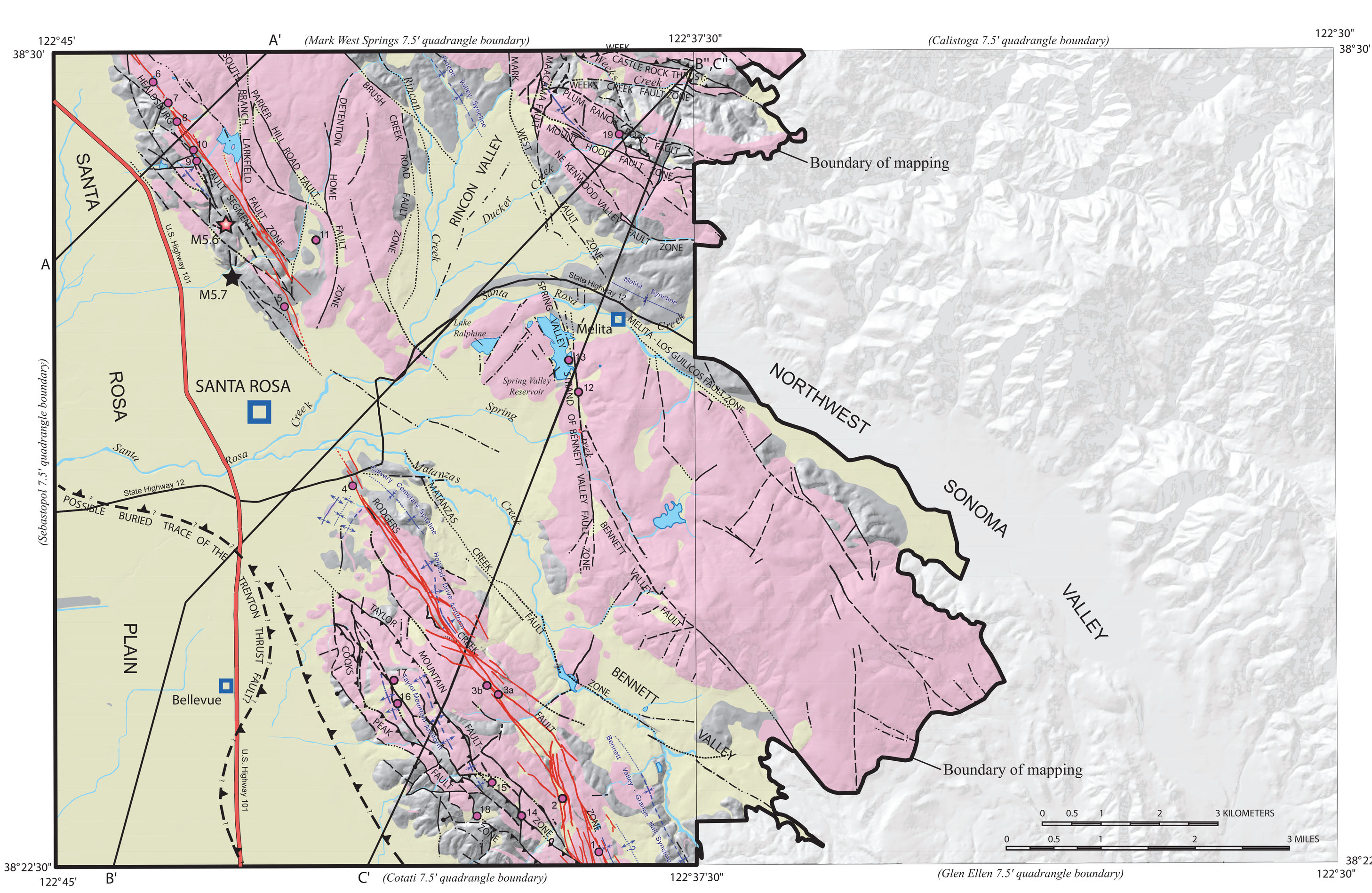


Figure 6. Map showing principal faults and folds and locations of structure sections in the Santa Rosa and western Kenwood quadrangles. Sonoma Volcanics are shown in pink, Quaternary deposits are shown in beige. Locations of the mainshocks of the 1969 Santa Rosa earthquake sequence (Wong and Bott, 1995) shown as red stars. Open squares show the locations of the cities of Santa Rosa, Bellevue, and Melita. Numbered magenta circles correspond to localities mentioned in the pamphlet text. Holocene traces of the Rodgers Creek and Healdsburg fault zones are shown in red, adopted from Graymer and others, 2006a. Heavy black lines with barbs delineate possible locations of traces of buried thrust faults on basement surface inferred from gravity data (Chapter B), along the southwest side of Trenton Ridge and east side of Bellevue basin.

Geologic and Geophysical Framework of the Santa Rosa 7.5' Quadrangle, Sonoma County, California

By
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2008

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This map was printed on an electronic plotter directly from digital files. Dimensional calibration may vary between electronic plotters and between X and Y directions on the same plotter, and paper may change size due to atmospheric conditions; therefore, scale and proportions may not be true on plots of this map.

Digital files available on World Wide Web at http://pubs.usgs.gov/of/2008/1009/

Appendix B Template Well Selection Matrix

ASR Well Site Scoring and Ranking Matrix

Two copies of this matrix will be used to: (1) compile actual measured values, and (2) rank wells with the ranking scale

			Wells									
			Cotati			Rohnert Park						
			1A	2	3	1	2	5	6	7	8A	9
Item	***Scoring and Ranking Criteria***	***Source***	**Values**									
	Well Information											
1	Well Log											
2	Report											
3	Documentation from Well Owner											
4	Other Documents											
	Aquifer Considerations											
1	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	Based on Well Information - gpd/ft2										
2	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	Based on Well Information - gpd/ft										
3	Pumping test information (pumping rate, duration, drawdown)	Existing/available well data										
4	Proximity and vulnerability to known contamination	Distance to nearest contaminant site										
5	Proximity and vulnerability to potential contaminating activities	Distance to nearest land use area										
6	Groundwater quality	Available water quality records										
7	Groundwater flow direction and gradient - upgradient, mid-gradient, or downgradient	Location map.										
8	Proximity to other supply wells screened in same aquifer	Distance to nearest municipal well on location map										
9	Proximity to other wells, based on DWR square-mile summary of production, public, & domestic wells	DWR download - total number of nearby wells w/n ~1 mile										
10	Monitoring wells in proximity (within 200') of potential ASR well	DWR download - total number of nearby wells w/n ~1 mile										
11	Complete pilot in another city for diversity of hydrogeology	City representatives										
	Physical Well Considerations											
12	Year constructed	From Well Information										
13	Total depth	From Well Information										
14	Length of screen and interval	From drillers' well logs										
15	Annular/sanitary seal depths	From drillers' well logs										
16	Casing/screen material	From drillers' well logs										
17	Screen Slot Size	From drillers' well logs										
18	Well diameter	From drillers' well logs										
19	Current equipping of the well (pump and motor rating, depth of equipment, etc.)	From Well Information										
20	Current condition of well casing	City representatives / Well information										
21	Current condition of well screen	City representatives / Well information										
22	Acessibility of well through ports or open areas of the surface	From Well Information										
	Operational Considerations											
23	Historical static and pumping water levels	SGMA Data Viewer or Available City Data										
24	Historical specific capacity	From Well Information										
25	Historical water quality	Available water quality records										
26	Functionality of well (active versus inactive) and overall operational status	Confirm with city representatives										
27	Records of well maintenance and testing following construction to present day (chemistry, priority pollutants)	From well owner										
	Site Accessibility Considerations											
28	Well site layout - Adequate physical space for an observation well and appurtenances	Available well info and/or future site visits										
29	Ability to safely operate a drill rig within the foot print of the established site or public right-of-way	Available well info and/or future site visits										
30	Proximity to the surface water transmission piping	Available well info and/or future site visits										
31	Sensitive noise receptors	Available well info and/or future site visits										
32	Ability to contain/discharge drilling spoils (drilling cuttings and fluids)	Temporary storage of cuttings in bins										
33	Logistical obstacles to drilling and well construction (e.g., underground or overhead utilities)	Available well info and/or future site visits										
34	Ability to discharge produced water generated from well development and testing	Available well info and/or future site visits										
35	Landowner/well owner willing to complete ASR on their wells	Discussion with well owner										

ASR Well Site Scoring and Ranking Matrix

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			Wells							
			Rohnert Park							
			10	11	12	13	14	16	18	20
Item	***Scoring and Ranking Criteria***	***Source***	**Values**							
	Well Information									
1	Well Log									
2	Report									
3	Documentation from Well Owner									
4	Other Documents									
	Aquifer Considerations									
1	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	Based on Well Information - gpd/ft2								
2	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	Based on Well Information - gpd/ft								
3	Pumping test information (pumping rate, duration, drawdown)	Existing/available well data								
4	Proximity and vulnerability to known contamination	Distance to nearest contaminant site								
5	Proximity and vulnerability to potential contaminating activities	Distance to nearest land use area								
6	Groundwater quality	Available water quality records								
7	Groundwater flow direction and gradient - upgradient, mid-gradient, or downgradient	Location map.								
8	Proximity to other supply wells screened in same aquifer	Distance to nearest municipal well on location map								
9	Proximity to other wells, based on DWR square-mile summary of production, public, & domestic wells	DWR download - total number of nearby wells w/n ~1 mile								
10	Monitoring wells in proximity (within 200') of potential ASR well	DWR download - total number of nearby wells w/n ~1 mile								
11	Complete pilot in another city for diversity of hydrogeology	City representatives								
	Physical Well Considerations									
12	Year constructed	From Well Information								
13	Total depth	From Well Information								
14	Length of screen and interval	From drillers' well logs								
15	Annular/sanitary seal depths	From drillers' well logs								
16	Casing/screen material	From drillers' well logs								
17	Screen Slot Size	From drillers' well logs								
18	Well diameter	From drillers' well logs								
19	Current equipping of the well (pump and motor rating, depth of equipment, etc.)	From Well Information								
20	Current condition of well casing	City representatives / Well information								
21	Current condition of well screen	City representatives / Well information								
22	Acessibility of well through ports or open areas of the surface	From Well Information								
	Operational Considerations									
23	Historical static and pumping water levels	SGMA Data Viewer or Available City Data								
24	Historical specific capacity	From Well Information								
25	Historical water quality	Available water quality records								
26	Functionality of well (active versus inactive) and overall operational status	Confirm with city representatives								
27	Records of well maintenance and testing following construction to present day (chemistry, priority pollutants)	From well owner								
	Site Accessibility Considerations									
28	Well site layout - Adequate physical space for an observation well and appurtenances	Available well info and/or future site visits								
29	Ability to safely operate a drill rig within the foot print of the established site or public right-of-way	Available well info and/or future site visits								
30	Proximity to the surface water transmission piping	Available well info and/or future site visits								
31	Sensitive noise receptors	Available well info and/or future site visits								
32	Ability to contain/discharge drilling spoils (drilling cuttings and fluids)	Temporary storage of cuttings in bins								
33	Logistical obstacles to drilling and well construction (e.g., underground or overhead utilities)	Available well info and/or future site visits								
34	Ability to discharge produced water generated from well development and testing	Available well info and/or future site visits								
35	Landowner/well owner willing to complete ASR on their wells	Discussion with well owner								

ASR Well Site Scoring and Ranking Matrix

Two copies of this matrix will be used to: (1) compile actual measured values, and (2) rank wells with the ranking scale

			Wells							
			Rohnert Park							
			22	27	29	30	31	33	34	35
Item	***Scoring and Ranking Criteria***	***Source***	**Values**							
	Well Information									
1	Well Log									
2	Report									
3	Documentation from Well Owner									
4	Other Documents									
	Aquifer Considerations									
1	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	Based on Well Information - gpd/ft2								
2	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	Based on Well Information - gpd/ft								
3	Pumping test information (pumping rate, duration, drawdown)	Existing/available well data								
4	Proximity and vulnerability to known contamination	Distance to nearest contaminant site								
5	Proximity and vulnerability to potential contaminating activities	Distance to nearest land use area								
6	Groundwater quality	Available water quality records								
7	Groundwater flow direction and gradient - upgradient, mid-gradient, or downgradient	Location map.								
8	Proximity to other supply wells screened in same aquifer	Distance to nearest municipal well on location map								
9	Proximity to other wells, based on DWR square-mile summary of production, public, & domestic wells	DWR download - total number of nearby wells w/n ~1 mile								
10	Monitoring wells in proximity (within 200') of potential ASR well	DWR download - total number of nearby wells w/n ~1 mile								
11	Complete pilot in another city for diversity of hydrogeology	City representatives								
	Physical Well Considerations									
12	Year constructed	From Well Information								
13	Total depth	From Well Information								
14	Length of screen and interval	From drillers' well logs								
15	Annular/sanitary seal depths	From drillers' well logs								
16	Casing/screen material	From drillers' well logs								
17	Screen Slot Size	From drillers' well logs								
18	Well diameter	From drillers' well logs								
19	Current equipping of the well (pump and motor rating, depth of equipment, etc.)	From Well Information								
20	Current condition of well casing	City representatives / Well information								
21	Current condition of well screen	City representatives / Well information								
22	Acessibility of well through ports or open areas of the surface	From Well Information								
	Operational Considerations									
23	Historical static and pumping water levels	SGMA Data Viewer or Available City Data								
24	Historical specific capacity	From Well Information								
25	Historical water quality	Available water quality records								
26	Functionality of well (active versus inactive) and overall operational status	Confirm with city representatives								
27	Records of well maintenance and testing following construction to present day (chemistry, priority pollutants)	From well owner								
	Site Accessibility Considerations									
28	Well site layout - Adequate physical space for an observation well and appurtenances	Available well info and/or future site visits								
29	Ability to safely operate a drill rig within the foot print of the established site or public right-of-way	Available well info and/or future site visits								
30	Proximity to the surface water transmission piping	Available well info and/or future site visits								
31	Sensitive noise receptors	Available well info and/or future site visits								
32	Ability to contain/discharge drilling spoils (drilling cuttings and fluids)	Temporary storage of cuttings in bins								
33	Logistical obstacles to drilling and well construction (e.g., underground or overhead utilities)	Available well info and/or future site visits								
34	Ability to discharge produced water generated from well development and testing	Available well info and/or future site visits								
35	Landowner/well owner willing to complete ASR on their wells	Discussion with well owner								

ASR Well Site Scoring and Ranking Matrix

Two copies of this matrix will be used to: (1) compile actual measured values, and (2) rank wells with the ranking scale

			Wells				
			Rohnert Park			Windsor	
			39	40	41	Bluebird	Esposti
Item	***Scoring and Ranking Criteria***	***Source***	**Values**				
	Well Information						
1	Well Log						
2	Report						
3	Documentation from Well Owner						
4	Other Documents						
	Aquifer Considerations						
1	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	Based on Well Information - gpd/ft2					
2	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	Based on Well Information - gpd/ft					
3	Pumping test information (pumping rate, duration, drawdown)	Existing/available well data					
4	Proximity and vulnerability to known contamination	Distance to nearest contaminant site					
5	Proximity and vulnerability to potential contaminating activities	Distance to nearest land use area					
6	Groundwater quality	Available water quality records					
7	Groundwater flow direction and gradient - upgradient, mid-gradient, or downgradient	Location map.					
8	Proximity to other supply wells screened in same aquifer	Distance to nearest municipal well on location map					
9	Proximity to other wells, based on DWR square-mile summary of production, public, & domestic wells	DWR download - total number of nearby wells w/n ~1 mile					
10	Monitoring wells in proximity (within 200') of potential ASR well	DWR download - total number of nearby wells w/n ~1 mile					
11	Complete pilot in another city for diversity of hydrogeology	City representatives					
	Physical Well Considerations						
12	Year constructed	From Well Information					
13	Total depth	From Well Information					
14	Length of screen and interval	From drillers' well logs					
15	Annular/sanitary seal depths	From drillers' well logs					
16	Casing/screen material	From drillers' well logs					
17	Screen Slot Size	From drillers' well logs					
18	Well diameter	From drillers' well logs					
19	Current equipping of the well (pump and motor rating, depth of equipment, etc.)	From Well Information					
20	Current condition of well casing	City representatives / Well information					
21	Current condition of well screen	City representatives / Well information					
22	Acessibility of well through ports or open areas of the surface	From Well Information					
	Operational Considerations						
23	Historical static and pumping water levels	SGMA Data Viewer or Available City Data					
24	Historical specific capacity	From Well Information					
25	Historical water quality	Available water quality records					
26	Functionality of well (active versus inactive) and overall operational status	Confirm with city representatives					
27	Records of well maintenance and testing following construction to present day (chemistry, priority pollutants)	From well owner					
	Site Accessibility Considerations						
28	Well site layout - Adequate physical space for an observation well and appurtenances	Available well info and/or future site visits					
29	Ability to safely operate a drill rig within the foot print of the established site or public right-of-way	Available well info and/or future site visits					
30	Proximity to the surface water transmission piping	Available well info and/or future site visits					
31	Sensitive noise receptors	Available well info and/or future site visits					
32	Ability to contain/discharge drilling spoils (drilling cuttings and fluids)	Temporary storage of cuttings in bins					
33	Logistical obstacles to drilling and well construction (e.g., underground or overhead utilities)	Available well info and/or future site visits					
34	Ability to discharge produced water generated from well development and testing	Available well info and/or future site visits					
35	Landowner/well owner willing to complete ASR on their wells	Discussion with well owner					

ASR Well Site Scoring and Ranking Matrix

Two copies of this matrix will be used to: (1) compile actual measured values, and (2) rank wells with the ranking scale

			Wells		
			Santa Rosa		
			Leete	Carley	Peters Springs
Item	*Scoring and Ranking Criteria*	*Source*	Values		
	Well Information				
1	Well Log				
2	Report				
3	Documentation from Well Owner				
4	Other Documents				
	Aquifer Considerations				
1	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	Based on Well Information - gpd/ft2			
2	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	Based on Well Information - gpd/ft			
3	Pumping test information (pumping rate, duration, drawdown)	Existing/available well data			
4	Proximity and vulnerability to known contamination	Distance to nearest contaminant site			
5	Proximity and vulnerability to potential contaminating activities	Distance to nearest land use area			
6	Groundwater quality	Available water quality records			
7	Groundwater flow direction and gradient - upgradient, mid-gradient, or downgradient	Location map.			
8	Proximity to other supply wells screened in same aquifer	Distance to nearest municipal well on location map			
9	Proximity to other wells, based on DWR square-mile summary of production, public, & domestic wells	DWR download - total number of nearby wells w/n ~1 mile			
10	Monitoring wells in proximity (within 200') of potential ASR well	DWR download - total number of nearby wells w/n ~1 mile			
11	Complete pilot in another city for diversity of hydrogeology	City representatives			
	Physical Well Considerations				
12	Year constructed	From Well Information			
13	Total depth	From Well Information			
14	Length of screen and interval	From drillers' well logs			
15	Annular/sanitary seal depths	From drillers' well logs			
16	Casing/screen material	From drillers' well logs			
17	Screen Slot Size	From drillers' well logs			
18	Well diameter	From drillers' well logs			
19	Current equipping of the well (pump and motor rating, depth of equipment, etc.)	From Well Information			
20	Current condition of well casing	City representatives / Well information			
21	Current condition of well screen	City representatives / Well information			
22	Acessibility of well through ports or open areas of the surface	From Well Information			
	Operational Considerations				
23	Historical static and pumping water levels	SGMA Data Viewer or Available City Data			
24	Historical specific capacity	From Well Information			
25	Historical water quality	Available water quality records			
26	Functionality of well (active versus inactive) and overall operational status	Confirm with city representatives			
27	Records of well maintenance and testing following construction to present day (chemistry, priority pollutants)	From well owner			
	Site Accessibility Considerations				
28	Well site layout - Adequate physical space for an observation well and appurtenances	Available well info and/or future site visits			
29	Ability to safely operate a drill rig within the foot print of the established site or public right-of-way	Available well info and/or future site visits			
30	Proximity to the surface water transmission piping	Available well info and/or future site visits			
31	Sensitive noise receptors	Available well info and/or future site visits			
32	Ability to contain/discharge drilling spoils (drilling cuttings and fluids)	Temporary storage of cuttings in bins			
33	Logistical obstacles to drilling and well construction (e.g., underground or overhead utilities)	Available well info and/or future site visits			
34	Ability to discharge produced water generated from well development and testing	Available well info and/or future site visits			
35	Landowner/well owner willing to complete ASR on their wells	Discussion with well owner			

ASR Well Site Scoring and Ranking Matrix

Two copies of this matrix will be used to: (1) compile actual measured values, and (2) rank wells with the ranking scale

			Wells		
			Santa Rosa		
			Freeway	Farmers Lane 1	Farmers Lane 2
Item	***Scoring and Ranking Criteria***	***Source***	**Values**		
	Well Information				
1	Well Log				
2	Report				
3	Documentation from Well Owner				
4	Other Documents				
	Aquifer Considerations				
1	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	Based on Well Information - gpd/ft2			
2	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	Based on Well Information - gpd/ft			
3	Pumping test information (pumping rate, duration, drawdown)	Existing/available well data			
4	Proximity and vulnerability to known contamination	Distance to nearest contaminant site			
5	Proximity and vulnerability to potential contaminating activities	Distance to nearest land use area			
6	Groundwater quality	Available water quality records			
7	Groundwater flow direction and gradient - upgradient, mid-gradient, or downgradient	Location map.			
8	Proximity to other supply wells screened in same aquifer	Distance to nearest municipal well on location map			
9	Proximity to other wells, based on DWR square-mile summary of production, public, & domestic wells	DWR download - total number of nearby wells w/n ~1 mile			
10	Monitoring wells in proximity (within 200') of potential ASR well	DWR download - total number of nearby wells w/n ~1 mile			
11	Complete pilot in another city for diversity of hydrogeology	City representatives			
	Physical Well Considerations				
12	Year constructed	From Well Information			
13	Total depth	From Well Information			
14	Length of screen and interval	From drillers' well logs			
15	Annular/sanitary seal depths	From drillers' well logs			
16	Casing/screen material	From drillers' well logs			
17	Screen Slot Size	From drillers' well logs			
18	Well diameter	From drillers' well logs			
19	Current equipping of the well (pump and motor rating, depth of equipment, etc.)	From Well Information			
20	Current condition of well casing	City representatives / Well information			
21	Current condition of well screen	City representatives / Well information			
22	Acessibility of well through ports or open areas of the surface	From Well Information			
	Operational Considerations				
23	Historical static and pumping water levels	SGMA Data Viewer or Available City Data			
24	Historical specific capacity	From Well Information			
25	Historical water quality	Available water quality records			
26	Functionality of well (active versus inactive) and overall operational status	Confirm with city representatives			
27	Records of well maintenance and testing following construction to present day (chemistry, priority pollutants)	From well owner			
	Site Accessibility Considerations				
28	Well site layout - Adequate physical space for an observation well and appurtenances	Available well info and/or future site visits			
29	Ability to safely operate a drill rig within the foot print of the established site or public right-of-way	Available well info and/or future site visits			
30	Proximity to the surface water transmission piping	Available well info and/or future site visits			
31	Sensitive noise receptors	Available well info and/or future site visits			
32	Ability to contain/discharge drilling spoils (drilling cuttings and fluids)	Temporary storage of cuttings in bins			
33	Logistical obstacles to drilling and well construction (e.g., underground or overhead utilities)	Available well info and/or future site visits			
34	Ability to discharge produced water generated from well development and testing	Available well info and/or future site visits			
35	Landowner/well owner willing to complete ASR on their wells	Discussion with well owner			

ASR Well Site Scoring and Ranking Matrix

Two copies of this matrix will be used to: (1) compile actual measured values, and (2) rank wells with the ranking scale

			Wells		
			Santa Rosa		
			Farmers Lane 3	Grace	Sharon Park
Item	***Scoring and Ranking Criteria***	***Source***	**Values**		
	Well Information				
1	Well Log				
2	Report				
3	Documentation from Well Owner				
4	Other Documents				
	Aquifer Considerations				
1	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	Based on Well Information - gpd/ft2			
2	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	Based on Well Information - gpd/ft			
3	Pumping test information (pumping rate, duration, drawdown)	Existing/available well data			
4	Proximity and vulnerability to known contamination	Distance to nearest contaminant site			
5	Proximity and vulnerability to potential contaminating activities	Distance to nearest land use area			
6	Groundwater quality	Available water quality records			
7	Groundwater flow direction and gradient - upgradient, mid-gradient, or downgradient	Location map.			
8	Proximity to other supply wells screened in same aquifer	Distance to nearest municipal well on location map			
9	Proximity to other wells, based on DWR square-mile summary of production, public, & domestic wells	DWR download - total number of nearby wells w/n ~1 mile			
10	Monitoring wells in proximity (within 200') of potential ASR well	DWR download - total number of nearby wells w/n ~1 mile			
11	Complete pilot in another city for diversity of hydrogeology	City representatives			
	Physical Well Considerations				
12	Year constructed	From Well Information			
13	Total depth	From Well Information			
14	Length of screen and interval	From drillers' well logs			
15	Annular/sanitary seal depths	From drillers' well logs			
16	Casing/screen material	From drillers' well logs			
17	Screen Slot Size	From drillers' well logs			
18	Well diameter	From drillers' well logs			
19	Current equipping of the well (pump and motor rating, depth of equipment, etc.)	From Well Information			
20	Current condition of well casing	City representatives / Well information			
21	Current condition of well screen	City representatives / Well information			
22	Acessibility of well through ports or open areas of the surface	From Well Information			
	Operational Considerations				
23	Historical static and pumping water levels	SGMA Data Viewer or Available City Data			
24	Historical specific capacity	From Well Information			
25	Historical water quality	Available water quality records			
26	Functionality of well (active versus inactive) and overall operational status	Confirm with city representatives			
27	Records of well maintenance and testing following construction to present day (chemistry, priority pollutants)	From well owner			
	Site Accessibility Considerations				
28	Well site layout - Adequate physical space for an observation well and appurtenances	Available well info and/or future site visits			
29	Ability to safely operate a drill rig within the foot print of the established site or public right-of-way	Available well info and/or future site visits			
30	Proximity to the surface water transmission piping	Available well info and/or future site visits			
31	Sensitive noise receptors	Available well info and/or future site visits			
32	Ability to contain/discharge drilling spoils (drilling cuttings and fluids)	Temporary storage of cuttings in bins			
33	Logistical obstacles to drilling and well construction (e.g., underground or overhead utilities)	Available well info and/or future site visits			
34	Ability to discharge produced water generated from well development and testing	Available well info and/or future site visits			
35	Landowner/well owner willing to complete ASR on their wells	Discussion with well owner			

ASR Well Site Scoring and Ranking Matrix

Two copies of this matrix will be used to: (1) compile actual measured values, and (2) rank wells with the ranking scale

			Wells		
			Llano		
			Occidental	Sebastopol	Todd
Item	***Scoring and Ranking Criteria***	***Source***	**Values**		
	Well Information				
1	Well Log				
2	Report				
3	Documentation from Well Owner				
4	Other Documents				
	Aquifer Considerations				
1	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	Based on Well Information - gpd/ft2			
2	Local hydraulic conductivity (permeability) and transmissivity (accounts for thickness)	Based on Well Information - gpd/ft			
3	Pumping test information (pumping rate, duration, drawdown)	Existing/available well data			
4	Proximity and vulnerability to known contamination	Distance to nearest contaminant site			
5	Proximity and vulnerability to potential contaminating activities	Distance to nearest land use area			
6	Groundwater quality	Available water quality records			
7	Groundwater flow direction and gradient - upgradient, mid-gradient, or downgradient	Location map.			
8	Proximity to other supply wells screened in same aquifer	Distance to nearest municipal well on location map			
9	Proximity to other wells, based on DWR square-mile summary of production, public, & domestic wells	DWR download - total number of nearby wells w/n ~1 mile			
10	Monitoring wells in proximity (within 200') of potential ASR well	DWR download - total number of nearby wells w/n ~1 mile			
11	Complete pilot in another city for diversity of hydrogeology	City representatives			
	Physical Well Considerations				
12	Year constructed	From Well Information			
13	Total depth	From Well Information			
14	Length of screen and interval	From drillers' well logs			
15	Annular/sanitary seal depths	From drillers' well logs			
16	Casing/screen material	From drillers' well logs			
17	Screen Slot Size	From drillers' well logs			
18	Well diameter	From drillers' well logs			
19	Current equipping of the well (pump and motor rating, depth of equipment, etc.)	From Well Information			
20	Current condition of well casing	City representatives / Well information			
21	Current condition of well screen	City representatives / Well information			
22	Acessibility of well through ports or open areas of the surface	From Well Information			
	Operational Considerations				
23	Historical static and pumping water levels	SGMA Data Viewer or Available City Data			
24	Historical specific capacity	From Well Information			
25	Historical water quality	Available water quality records			
26	Functionality of well (active versus inactive) and overall operational status	Confirm with city representatives			
27	Records of well maintenance and testing following construction to present day (chemistry, priority pollutants)	From well owner			
	Site Accessibility Considerations				
28	Well site layout - Adequate physical space for an observation well and appurtenances	Available well info and/or future site visits			
29	Ability to safely operate a drill rig within the foot print of the established site or public right-of-way	Available well info and/or future site visits			
30	Proximity to the surface water transmission piping	Available well info and/or future site visits			
31	Sensitive noise receptors	Available well info and/or future site visits			
32	Ability to contain/discharge drilling spoils (drilling cuttings and fluids)	Temporary storage of cuttings in bins			
33	Logistical obstacles to drilling and well construction (e.g., underground or overhead utilities)	Available well info and/or future site visits			
34	Ability to discharge produced water generated from well development and testing	Available well info and/or future site visits			
35	Landowner/well owner willing to complete ASR on their wells	Discussion with well owner			

Appendix C Summary of Transmissivity, Hydraulic Conductivity, and Well Construction Information at Each Well

Summary of Transmissivity, Hydraulic Conductivity, and Well Construction Information at Each Well

City			
Cotati	Well 3	T: 9494-12658, K: 237.3-316.5	40', 16-10" diam
Rohnert Park	Well 1	T: 5918-7890, K:30.7-40.9	
Rohnert Park	Well 5	T: 11250-15000, K: 80.4-107.1	140', 16" diam
Rohnert Park	Well 7	T: 12054-16071, K: 123-164	98', 16" diam
Rohnert Park	Well 14	T: 39216-52288, K: 98-130.7	356', 16" diam
Rohnert Park	Well 15	T: 5505-7339, K: 19.3-25.8	16", 10.75" diam
Rohnert Park	Well 16	T: 3695-4926, K: 6.9-9.2	
Rohnert Park	Well 20	T: 5455-7273, K: 45.5-60.6	
Rohnert Park	Well 22	T: 2472-3296, K: 38-50.7	
Rohnert Park	Well 27	T: 2636-3515, K: 18.8-25.1	
Rohnert Park	Well 29	T: 775-1033, K: 2.4-3.2	
Rohnert Park	Well 30	T: 3868-5158, K: 14.9-19.8	
Rohnert Park	Well 33	T: 3325-4433, K: 11.9-15.8	
Rohnert Park	Well 34	T: 4317-5755, K: 17.6-23.5	
Rohnert Park	Well 39	T: 5000-6667, K: 31.3-41.7	
Rohnert Park	Well 40	T: 3916-5221, K: 24.5-32.6	
Rohnert Park	Well 41	T: 3279-4372, K: 19.9-26.5	
Windsor	Bluebird	T: 181-241, K: 3.6-4.8	
Windsor	Esposti	T: 7595-10127, K: 47.5-63.3	160', 10" diam
Santa Rosa	Doyle Park Test Well	T: 66-88, K: 1.3-1.8	
Santa Rosa	Martha Way Test Well	T: 21875-29167, K: 95.1-126.8	230', 8" diam
Santa Rosa	North Village Test Well	T: 1400-1866, K: 9.3-12.4	8" diam
Santa Rosa	NW Community Park Test Well	T: 7895-10526, K: 35.2-47	224', 8.625" diam
Santa Rosa	A Place to Play Test Well	T: 6501-8668, K: 28-37.4	232', 8.625" diam
Santa Rosa	Bicentennial Test Well	T: 9350-12467, K: 103.9-138.5	90', 8" diam
Santa Rosa	Madrone Test Well	T: 4512-6016, K: 64.5-85.9	
Santa Rosa	Slater Test Well	T: 6466-8621, K: 129.3-172.4	50', 8.625" diam

Highlighted = Not considered as a candidate well for ASR pilot test

Appendix D Well Rehabilitation at Rohnert Park Well #15 Site

Well Rehabilitation at Rohnert Park Well #15 Site

Completed in 1977, the Rohnert Park Well #15 was constructed at 200 Golf Course Drive in Rohnert Park, California as an emergency backup well that is currently on standby and has not been operated since approximately 2015. The well is in a locked enclosure between the light rail tracks and the Double Decker Lanes to the east. The well was constructed with Johnson Irrigator screen (0.080-in; 80-slot) with a 16-inch diameter casing to a depth of 596-feet below ground surface, reduced to a 10.75-inch diameter casing to a total depth of 1,501-feet below ground surface. Per a video log conducted in 1999, the well looked to be backfilled to a depth of 1,200-feet below ground surface. Available well information is attached to this document.

The well has stood unused since approximately 2015 and requires cleaning and video assessment to confirm it is fit for ASR pilot testing this fall and potentially long-term aquifer storage and recovery (ASR) operations. The well is on standby from public water supply due to water quality concerns. The initial work will address static conditions.

The City of Rohnert Park staff would prefer the use of a sewer turnout approximately 450-feet away for water disposal. A second mobilization may be requested from you, for the installation of submersible pump for ASR backflush pumping, in addition to the items listed below.

Work at Rohnert Park Well #15

1. Remove existing pump and motor
2. Rehabilitate the well by brushing the casing and screen, and air-lift surging the screen intervals to an agreed upon discharge point.
3. Video survey to assess pre- and post-rehabilitation condition.
4. Confirm that there are no obstructions in the piezometer.
5. Install a temporary test pump with a sampling port plumbed in at the surface to further develop the well for water quality sampling.
6. Perform 8-hour step test with 2 hours steps beginning at 100 gpm and ramping up to 400+gpm
7. Perform vertical flow profiling to quantify contribution of total well flow by each screened interval – contract with Pacific Surveys (https://pacificsurveys.com/)
8. Perform depth discrete water quality sampling of each screened interval – contract with Pacific Surveys.
9. Inspect pump and motor and report findings and recommendations.
10. Reinstall pump and motor
11. Disinfect the well.

Appendix E Technical Addendum for Martha Way Well ASR Pilot Study



GEI Consultants

Technical Addendum

Martha Way Well ASR Pilot Study

Santa Rosa, California

Submitted to:
Santa Rosa Plain Groundwater Sustainability Agency
2235 Mercury Way, Suite 105
Santa Rosa, CA 95407

Submitted by:
GEI Consultants
11010 White Rock Road, Suite 200
Rancho Cordova, CA 95670
916-912-4790

May 2026
Project No. 2403072



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Project Manager, Vice President,
Principal Hydrogeologist

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Senior Hydrogeologist

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Acronyms and Abbreviations

ASR	Aquifer Storage and Recovery
bgs	below ground surface
bTOC	below top of casing
DO	dissolved oxygen
DtW	depth to water, typically below top of casing
DBPs	disinfection byproducts
City	City of Santa Rosa
ft/day	feet per day
gpd/ft	gallons per day per foot
gpm	gallons per minute
GEI	GEI Consultants Inc.
K-gallons	thousand gallons
HAAs	haloacetic acids (DBPs)
µS/cm	microsiemens per centimeter
M-gallons	million gallons
MGD	millions of gallons per day
µg/L	micrograms per liter
mg/L	milligrams per liter
aMSL	above mean sea level
NOA	Notice of Availability
OW	observation well
NTU	nephelometric turbidity unit
NPDES	National Pollution Discharge Elimination System
PVC	polyvinyl chloride
RWQCB	North Coast Regional Water Quality Control Board
SpC	Specific Capacity of a well in gallons per minute per foot of drawdown (gpm/ft-dd)
SpR	Specific Recharge of a well in gallons per minute per foot of drawup (gpm/ft-du)
SWRCB	State Water Resources Control Board
THMs	trihalomethanes (DBPs)
WL	water level
WQ	water quality
WYA	West Yost Associates

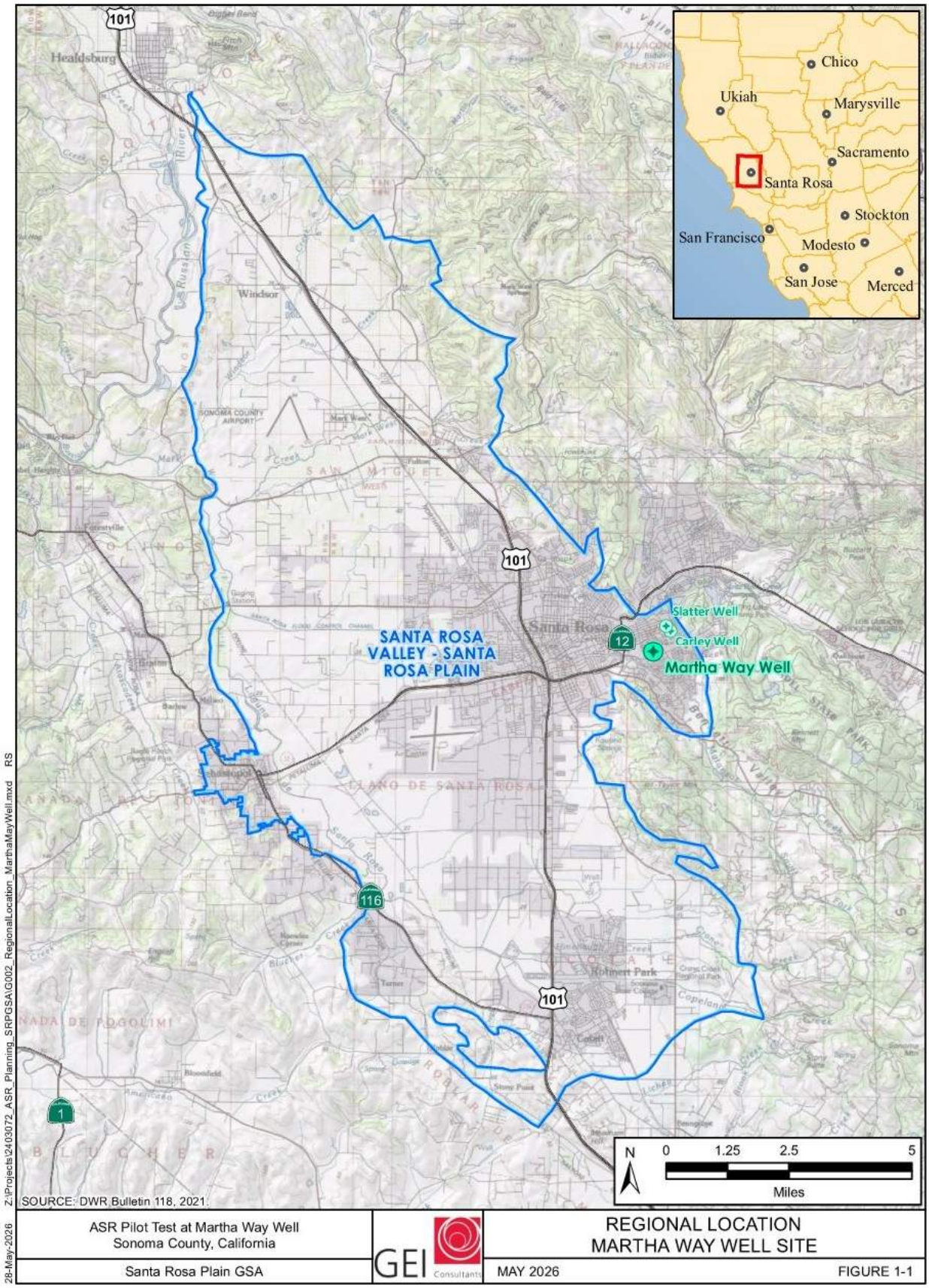
1. Introduction

In compliance with the ASR General Order, this Technical Addendum was prepared by GEI Consultants, Inc., (GEI), on behalf of the Santa Rosa Plain Groundwater Sustainability Agency (GSA) in coordination with the City of Santa Rosa (City), to describe the results of an Aquifer Storage and Recovery (ASR) pilot test at the City's Martha Way Well. **Figure 1-1** shows the location of the Martha Way well site on the eastern side of Santa Rosa and on the eastern side of the Santa Rosa Plain groundwater subbasin. This geographic area is located within Bennet Valley, which is part of the Valley groundwater storage unit (USGS, 2013).

The City submitted a Notice of Intent (NOI) to the North Coast Regional Water Quality Control Board (RWQCB) to perform the ASR pilot test under the State Water Resources Control Board's (SWRCB) Water Quality Order 2012-0010, *General Waste Discharge Requirements for Aquifer Storage and Recovery Projects that Inject Drinking Water into Groundwater* (ASR General Order) on June 30, 2025, including a Technical Report about the well and local hydrologic conditions. The RWQCB provided a Notice of Applicability (NOA) on July 3, 2025, which allowed the test to proceed according to the plan in the Technical Report. The ASR pilot test began on September 17 and was concluded on December 22, 2025.

This project was funded by a grant from the California Department Water Resources under the Sustainable Groundwater Management Program for implementation of projects within the Santa Rosa Plain. ASR was identified in the 2021 Groundwater Sustainability Plan (Sonoma Water) as a Group 3 Project to achieve sustainability.

Figure 1-1. Regional Location – Martha Way Well Site



2. Field Activities

2.1. Background

The Martha Way well site is located on the northern side of a greenway at the end of Martha Way, as shown by **Figure 2-1**. The greenway is about 200 feet wide and 2,100 feet long, between Franquette Avenue and Yulupa Avenue, and the well site is located near the middle of this length. A drainage channel is located on the south side of the greenway for most (80%) of its length and then shifts diagonally to the north side to a storm sewer.

Figure 2-1. Site Vicinity – Martha Way Well



Figure 2-2 provides a closer view of the well site. A potable water line and a sanitary sewer line traverse the greenway to the east of the well, subparallel to the pedestrian path across the greenway to the west.

Figure 2-2. Martha Way Well Site



2.1.1. Well Construction

The Martha Way Well was installed and tested between December 2009 and March 2010 as part of a City-wide study of groundwater resources to establish a backup water supply to supplement the City's supply of potable water from their wholesale water supply agency (Sonoma Water). The well was installed to a depth of 870 feet below ground surface (bgs) using nominal 8-inch diameter low-carbon steel casing and wire-wrap screen in a nominal 17.5-inch-diameter borehole. The screen has 0.080-inch apertures. Two sections of screen, totaling 230 feet, were installed between 500 and 680 feet bgs and 750 to 860 feet bgs. The well logs are included in Appendix A.

The annular space of the well was backfilled with a Silia Resources Inc., #6 sand from 490 to 638 feet bgs and from 738 to 874 feet bgs. A mixture of bentonite clay and sand (50:50) was placed above, below, and between the screen intervals; and at various depths toward the surface along with sand layers to 170 feet bgs. A cement sanitary seal was placed from ground surface to a depth of 170 feet bgs. Static depths to water (DtW) varied between 18 and 20 feet during well development and pumping tests during late March and early April 2010.

The borehole was drilled by reverse rotary rig to a total depth of 1070 feet bgs and encountered sediments to a depth of about 190 feet bgs and then mostly volcanic rocks thereafter. According to the driller's log, six types of rock were present opposite the two filter packs and screens (284 feet total), including 19 intervals of mostly volcanic rock and blue clay (128 feet), gravel and rock (86 feet) along with volcanic rock (30 feet), rocks (20 feet), clay (10 feet), gravel rock and sand (10 feet), and rock and sand (10 feet). The thickness of these layers varied from 4 to 50 feet (median: 10 feet).

The ECON (2011) geologist log identified three types of rock and five intervals opposite the filter packs and screens. The rock was comprised mostly of basalt (271 feet) along with siltstone (8 feet) and sandy silt (6 feet). The basalt was described as black to bluish black, hard, moderately to very strong, slightly weathered, and vesicular. Basalt within the upper screen also included cuttings of siltstone; and the two layers of sediments were also present within the upper screen.

The resistivity logs show that four thick higher-resistivity zones are present opposite the two screen/filter pack intervals with three thin intervening low-resistivity zones. The high resistivity zones comprised roughly 70 to 80 percent of the screen/filter interval. Moreover, two of the low resistivity zones corresponded to the interbedded sedimentary rocks (sandy silt and siltstone).

The caliper log shows numerous zones of irregular larger-diameter intervals in the borehole, including 12 intervals in throughout the upper screen/filter pack and 8 intervals in upper 60 percent of the lower screen/filter pack. These irregularities vary up to 10 feet thick (mean: 4 to 5 feet) and diameters are up to 3 inches larger (mean: 0.7 to 1.1 inches). One zone corresponds to the siltstone layer. These caliper data may represent other sedimentary interbeds within the volcanic rock and/or fractures or openings in the rock, which would allow the relatively rapid flow of groundwater.

The Martha Way Well was part of a test drilling program during 2010 to evaluate the groundwater resources beneath the City and is not currently used for municipal supply. Groundwater quality at the well was compliant with all primary drinking water standards during the 2010 sampling events but

exceeded the secondary standard for iron (300 µg/L[1]) in three (340 to 650 µg/L) of four samples and exceeded the secondary standard for manganese (50 µg/L) in all four samples (58 to 82 µg/L).

2.2. Pre-Test Activities

Pre-test activities were completed by both City staff and GEI staff, including

- City installed a temporary water service to the north side of the Martha Way Well, including valves and a digital flow meter plus a 10-foot length of 2-inch polyvinyl chloride (PVC) piping beneath the pedestrian path to facilitate the discharge of water onto the eastern area of the greenway without blocking the path. The water service was removed upon the completion of the pilot test.
- GEI hired PumpMan – NorCal (Santa Rosa, CA) to complete a video survey (Appendix B) to document the existing condition of the Martha Way Well, rehabilitate the well via approximately 14 hours of downhole brushing, and provide/install various equipment and materials for the pilot test. Equipment included a test pump with flow meter, valves, and sampling ports; two 5,000-gallon tanks to hold turbid water; an electric generator; and perimeter fencing with sound curtain panels. Materials included PVC piping and connections for the recharge tubing and water level (WL) tubing in the well, top-side piping connections for the water service to the recharge tube, piping and connections between the pump and tanks and to the corrugated plastic discharge piping (blank and perforated). The discharge piping was initially laid out along the central east-west axis of the greenway, approximately 500 to 600 feet long on both sides of the pedestrian path. The western discharge piping was damaged after a truck drove over various sections and broke several connections during the evening of October 27, 2025. In addition, both sections of discharge piping were shifted south after water began accumulating along Martha Way and in several backyards. **Figures 2-3 through 2-6** are photographs of the Martha Way wellsite before and during the pilot test.
- GEI collected a sample from the Martha Way Well on September 17, 2025, to establish the native water quality characteristics, as described later in this Addendum. Prior to sample collection, field water quality parameters were measured periodically , including turbidity, temperature (T), pH, electrical conductivity (EC) , dissolved oxygen (DO), and oxidation-reduction potential (ORP). The samples were submitted to Santa Rosa Water, Laguna Environmental Laboratory (ELAP Certification #1126). The City utilized Alpha Analytical Laboratory, Inc. (ELAP #1551) in Ukiah for analyses that they were not qualified to complete.

[1] µg/l = micrograms per liter

Figure 2-3. Martha Way Well before the ASR Pilot Test – March 2025



Figure 2-4. Martha Way Well surrounded by Sound Barrier



Figure 2-5. Martha Way Well inside Sound Barrier



Figure 2-6. Discharge of Recovered Water from Flexible Tubing within Greenway



Figure 2-7. Tire Tracks across Discharge Tubing



- GEI staff conducted a 3-hour 'step-recharge' test on September 18th to evaluate the recharge potential of the Martha Way Well. WLs were measured during three nominal 60-minute recharge periods. Depth to water was 38.3 feet below the top of the WL sounding port at the start of the test. Drawup was less than 5 feet for recharge rates of approximately 100 gpm, as shown by **Table 2-1**. The valve controlling the water service was completely open during the 3rd step (and apparently during the 2nd step) and was the limiting factor for the rate of recharge. A total of 14,900 gallons were recharged during the step-recharge test.

Table 2-1. Summary of Step-Recharge Test

Step	Recharge Rate, mean gpm	Duration, minutes	Drawup at end of step
1	50	60	2.0'
2	99	65	4.6'
3	98	56	4.7'

2.3. Pilot Test

Field monitoring and pilot test operations were conducted by GEI staff, including flow adjustments, routine measurements of water quality (WQ) parameters, WL measurements, and the collection of water samples for laboratory analysis by the Santa Rosa Water, Laguna Environmental Laboratory and Alpha Analytical Laboratory. West Yost Associates (WYA) staff operated the City-owned transducer in the Martha Way Well and provided consulting services to the Santa Rosa Plain GSA. WYA staff checked on the pilot test periodically and recorded flow data and manual WL measurements. PumpMan staff operated the generator, repaired the discharge line, and maintained the overall integrity of the site.

The pilot test was divided into three cycles with three periods per cycle: recharge, storage, and recovery pumping. **Table 2-2** summarizes the dates of each ASR cycle/periods and **Table 2-3** provides details for each ASR cycle and period.

Table 2-2. Dates of ASR Pilot Test Operations during 2025

Period	ASR Cycle 1	ASR Cycle 2	ASR Cycle 3
Recharge	September 22nd to 25th	October 2nd to 8th	November 3rd to November 14th
Storage	↙	↙	↙
Recovery	September 29th to 30th	October 27th to 31st	December 17th to 22nd
↙ Arrow for storage period, connecting end of recharge with start of recovery pumping			

During the 3.6-month ASR pilot test, a total of nearly 2.26 million (M-) gallons of potable water were recharged to the aquifer system via the Martha Way Well and nearly 2.52 M-gallons were pumped from the Martha Way Well, including nearly 20.4 thousand (K-) gallons of backflush water at the end of the 1st and 2nd recharge periods plus 25.2 K-gallons of purge water associated with sampling during the 2nd and 3rd storage periods. Overall, the total recovered volume is nearly 300.7 K-gallons greater than the recharge volume, and this excess volume was removed in order to mitigate any potential impact of the pilot test on the aquifer system. These volumes equate to 6.94 acre-feet (100%) of recharge water and 7.86 acre-feet of recovered water (113%).

Backflush pumping was conducted at the end of the 1st and 2nd recharge periods to condition the well for normal pumping and to remove any fine particles that might inhibit flow into or from the aquifer. After each recharge period, backflush pumping included four nominal 12- to 14-minute pumping intervals that were separated by 10- to 21-minutes of WL recovery. Pumping rates were variable, but the overall, average rates were 197 and 192 gpm, respectively. Turbidity was measured while backflush pumping and is shown in **Figure 2-8**. The range of turbidity values was substantial during both sets of backflush pumping intervals (BF 1 and BF 2), exceeding the upper limit (1000 NTUs) of the field meter during the 1st set and the 1st and 2nd set. By the 4th backflush interval of each set, turbidity was considerably lower and ranged between 27 and 46 NTUs. The figure shows that the 2nd set (BF 2) of backflush intervals were more variable than the 1st set.

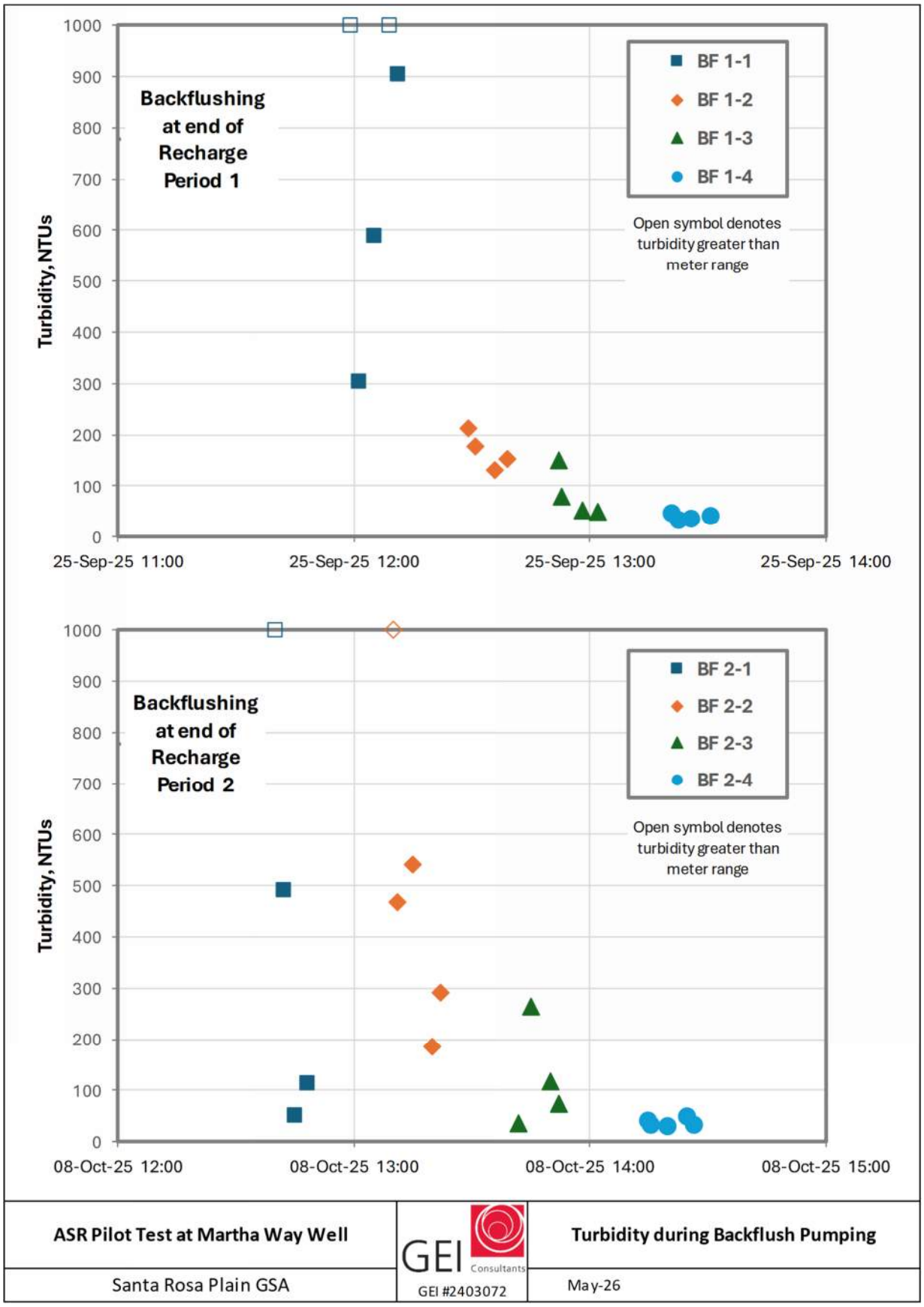
Table 2-3. Summary of Flow, Volume and Duration of ASR Periods

Period	Step-Recharge	Cycle 1	Cycle 2	Cycle 3	Total
Recharge # of Samples	3.0 hours 14,900 gallons 82 gpm* 0	3.0 days 330,600 gallons 76 gpm* 2	6.0 days 665,000 gallons 77 gpm* 2	11.1 days 1,249,400 gallons 78 gpm* 1	20.2 days 2,259,900 gallons 78 gpm* 5
Backflush Pumping 4 intervals		9,830 gallons 13 minutes* each 197 gpm*	10,550 gallons 14 minutes* each 192 gpm*	0 gallons	20,380 gallons 105 minutes total 194 gpm*
Storage # of Samples Purge Pumping		4.0 days 0 0 gallons	19.0 days 1 9,620 gallons 196 gpm*	56.1 days 2 15,580 gallons 179 gpm*	79.0 days 3 25,200 gallons 185 gpm*
Recovery Pumping Excluding no-pumping periods: # of Samples		1.2 days 357,400 gallons 199 gpm* 6.1 hours 3	2.6 days 727,400 gallons 192 gpm* 22.4 hours 3	5.1 days 1,430,200 gallons 196 gpm* 0 hours 4	9.0 days 2,515,000 gallons 195 gpm* 28.5 hours 10
Total Duration Total # of Samples	3.0 hours 0	8.2 days 5	27.6 days 6	72.3 days 7	108.2 days 18
Recovery[+] minus Recharge	-14,900 gallons	36,630 gallons	82,570 gallons	196,380 gallons	300,680 gallons
Recovery[+] / Recharge		111%	112%	116%	113%

* Mean

[+] includes Backflush and Sample Purge

Figure 2-8. Turbidity during Backflush Pumping



Field WQ parameters were measured throughout the pilot test with a YSI-brand Pro DDS multiple parameter meter and probe within a flow-through cell. The measurements were recorded while sampling the recharge water and water from the Martha Way Well, and are shown in **Table 2-4** and **Table 2-5**, respectively.

A review of the WQ field measurements shows several distinctions in the two primary sources of water (potable water supply, Martha Way Well).

- The pH of the recharge water (8.08 to 8.16) was more alkaline in comparison to the pH of the native groundwater (7.48) from the Martha Way Well.
- The electrical conductivity[2] (EC) of the recharge water was relatively low (278 to 292 µS/cm in comparison to the EC of the native groundwater 508 µS/cm.
- Dissolved oxygen (DO) was considerably higher in the recharge water (2.2 to 4.6 milligrams per liter [mg/L]) than in the native groundwater (0.1 mg/L). Note that DO in the recharge water decreased slightly during the first 11 days of the test (2.6 to 2.2 mg/L) and then increased thereafter (3.3 to 4.6 mg/L), possibly due to the transition from the dry season to the wet season.
- The oxidation-reduction potential[3] (ORP) of the recharge was high (555 to 685 millivolts [mV]) while the ORP of the native groundwater was -248 mV.
- The turbidity was low in the first four samples of recharge water (0.2 to 0.3 Nephelometric Turbidity Units [NTU]) but increased to 0.8 NTU in the last sample which was likely related to the onset of the rainy / wet season. The turbidity of the native groundwater was 21 NTUs, which exceeded the California secondary drinking water standard of 5 NTU, and could be related to well design or possibly to the rehabilitation work that preceded the pilot test.

[2] Electrical conductivity is an indirect measurement for the concentration of total dissolved solids in microsiemens per centimeter (µS/cm).

[3] Positive ORP values represent oxidizing conditions while negative ORP values represent reducing conditions, and these conditions affect the chemistry of the mixed waters. For example, sulfur can exist in water as the sulfate ion (SO_4^{2+}) in oxidizing water while the sulfide ion (S^{-2}) is stable in reducing water.

Table 2-4. Summary of Field WQ Parameters for Recharge Water

ASR Period:		Recharge 1	Recharge 1	Recharge 2	Recharge 2	Recharge 3
Well:		to Martha Way	to Martha Way	to Martha Way	to Martha Way	to Martha Way
Date:		22-Sep-25	25-Sep-25	02-Oct-25	08-Oct-25	03-Nov-25
Parameter	**Time:**	13:10	11:22	12:55	11:58	12:06
Temperature	° Celsius	24.6	24.0	24.4	22.8	21.3
pH	units	8.09	8.08	8.16	8.15	8.09
Electrical Conductivity	µS/cm	299	307	305	298	288
Dissolved Oxygen	mg/L	2.6	2.4	2.2	3.3	4.6
Oxidation-Reduction Potential	mV	648	591	685	664	555
Turbidity	NTUs	0.3	0.2	0.3	0.3	0.8

Table 2-5. Summary of Field WQ Parameters for Water from the Martha Way Well

ASR Period:		Native Groundwater	Storage / Recovery 1	Recovery 1	Recovery 1
Well:		Martha Way	Martha Way	Martha Way	Martha Way
Date:		17-Sep-25	29-Sep-25	29-Sep-25	30-Sep-25
Parameter	**Time:**	10:44	11:25	22:00	22:35
Temperature	° Celsius	26.9	25.0	24.2	26.2
pH	units	7.48	7.78	7.43	7.74
Electrical Conductivity	µS/cm	508	313	397	454
Dissolved Oxygen	mg/L	0.1	0.1	4.4	0.4
Oxidation-Reduction Potential	mV	-248	-96	306	140
Turbidity	NTUs	21	9.2	3.5	22

Parameter		ASR Period: / Well: / Date: / Time:			
		Storage 2 Martha Way 15-Oct-25 10:45	**Storage / Recovery 2 Martha Way** 27-Oct-25 12:30	**Recovery 2 Martha Way** 28-Oct-25 15:36	**Recovery 2 Martha Way** 30-Oct-25 23:56
Temperature	° Celsius	23.9	24.5	25.1	26.0
pH	units	7.80	7.63	7.57	7.54
Electrical Conductivity	µS/cm	329	369	407	462
Dissolved Oxygen	mg/L	0.1	0.1	0.1	0.1
Oxidation-Reduction Potential	mV	-123	-78	-17	32
Turbidity	NTUs		3.8	0.7	2.5

Table 2-5 – continued. Summary of Field WQ Parameters for Water from the Martha Way Well

Parameter		ASR Period: / Well: / Date: / Time:					
		Storage 3 Martha Way 01-Dec-25 9:59	**Storage 3 Martha Way** 08-Dec-25 10:28	**Storage / Recovery 3 Martha Way** 17-Dec-25 12:10	**Recovery 3 Martha Way** 17-Dec-25 23:45	**Recovery 3 Martha Way** 18-Dec-25 11:30	**Recovery 3 Martha Way** 22-Dec-25 12:56
Temperature	° Celsius	21.8	22.3	22.9	23.6	24.0	25.3
pH	units	7.69	7.65	7.61	7.62	7.64	7.55
Electrical Conductivity	µS/cm	357	369	379	379	390	454
Dissolved Oxygen	mg/L	0.1	0.1	0.1	0.1	0.1	0.1
Oxidation-Reduction Potential	mV	-99	-156	-125	-40	-57	295
Turbidity	NTUs	9.0	5.4	5.6	0.8	0.5	13

3. Pilot Test Results

Pilot test operations occurred at the Martha Way Well from September 22, 2025, to December 22, 2025, and included three cycles of recharge, storage, and recovery (three periods per cycle), as presented in the previous section. Groundwater levels were monitored throughout much of the pilot test via a pressure transducer in the Martha Way Well to better define the hydraulic response of the aquifer system to ASR operations. The transducer data were not available between September 25th at 13:59 and October 1st at 6:55; and between November 3rd at 12:36 and December 1st at 11:48, and manual measurements were used to define the hydraulic response during these time periods. In addition, transducers were present in two inactive supply wells (Carley and Slater), located upgradient to the northeast over 3000 feet from the Martha Way Well. The WL data in these two inactive wells did not respond to the recharge or pumping activities of the pilot test.

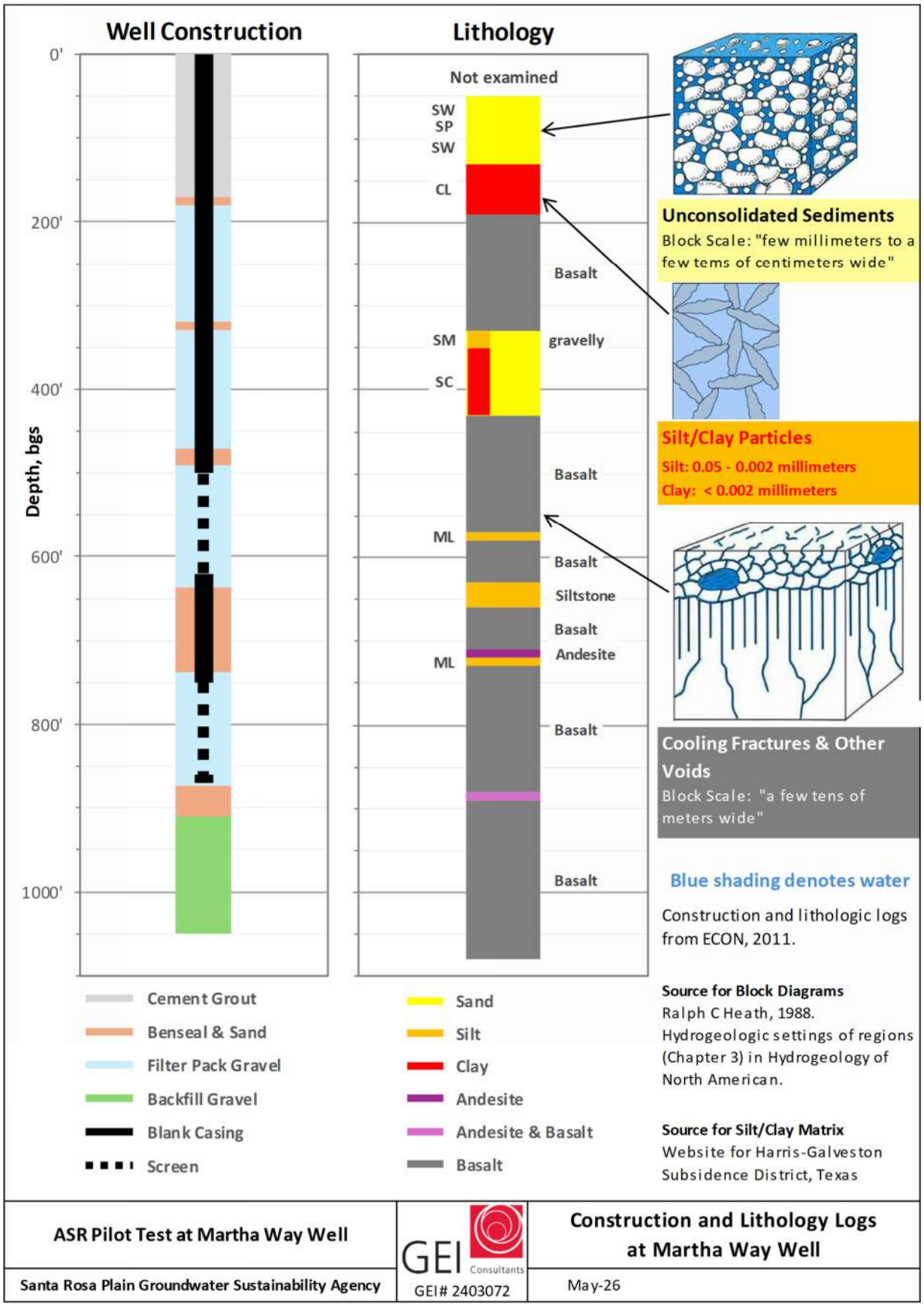
Water samples were collected from the Martha Way Well on September 17, 2025, for laboratory analysis to define native water quality conditions; and periodically from the well during the test (14) and from the City potable water distribution system (5).

3.1. Conceptual Site Model

The Martha Way Well was perforated in Tertiary-age Sonoma Volcanics beneath the eastern margin of the Santa Rosa Plain groundwater basin. **Figure 3-1** compares the construction of the well with the lithologic log and provides some conceptual illustrations of groundwater flow in the sedimentary aquifer systems and in the basalt aquifer systems. The well penetrated an upper sedimentary sequences that included 130 feet of mostly sand which was underlain by 60 feet of clay on top of 140-foot thick layer of basalt. A second sedimentary sequence was found beneath the first basalt layer and was comprised of silty-gravelly sand (20 feet thick) and clayey sand (80 feet thick). Thereafter, the rock was mostly basalt with three minor layers of silt that varied from 10 to 30 feet in thickness and with two minor layers of andesite (10 feet or less in thickness).

Groundwater flow in basalt can be quite variable and, according to Heath (1983), hydraulic conductivities can vary by 12 orders of magnitude (10^{-9} feet per day for unfractured basalt to 10^{4} feet per day for basalt lava flows). The Martha Way Well received a notable amount of recharge water with minimal drawup and produced water with modest drawdown, as further discussed below. Water likely flowed between the well and the aquifer during recharge and pumping periods via 1) fractures caused by cooling of the lava and later by tectonic forces and 2) small sediment-filled gaps between individual lava flows, as shown on Figure 3-1. Lava tubes have not been identified in the Sonoma Volcanics. Groundwater flow in such fractures and other voids can be rapid and relatively challenging to quantify or predict. Flow through or within the basalt matrix would likely be negligible. The two screen intervals are separated by 130 feet of blank casing with a 101-foot-thick sand-clay (bentonite) seal in the annular space. Packers were used in 2010 to isolate the upper and lower screen during pumping tests. Water levels and water quality data for each screen indicate that the two screens are hydraulically connected in the vicinity of the well (ECON, 2011).

Figure 3-1. Construction and Lithologic Logs at Martha Way Well



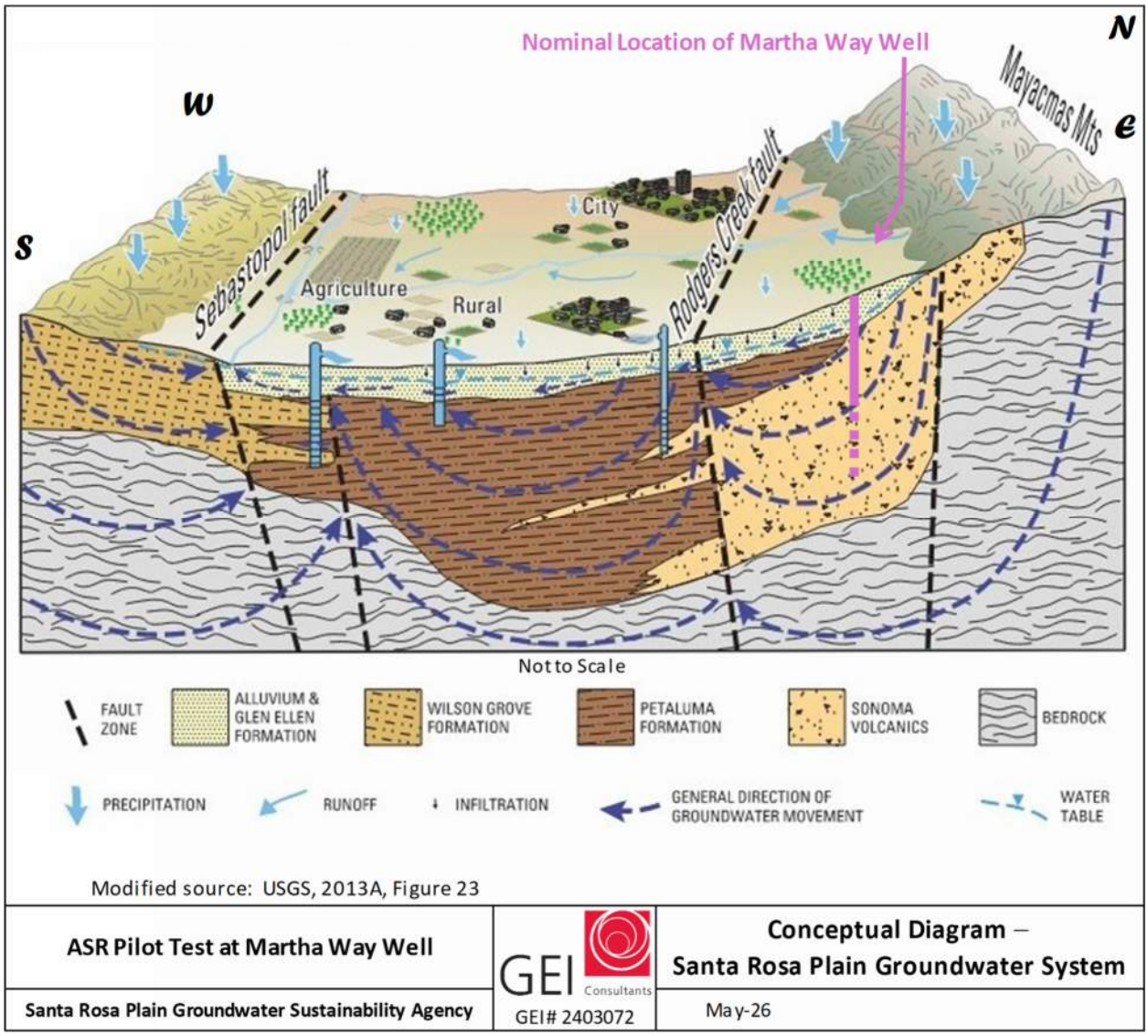
While the Martha Way Well is not perforated within the upper sedimentary sequences, these sediments are part of a local shallower groundwater system and may interact with the deeper volcanic aquifer units. Groundwater occurs within the smaller pores of the unconsolidated sedimentary material, as shown by Figure 3-1, and groundwater flow in such aquifers is generally well understood, quantifiable, and predictable. According to Heath (1983), hydraulic conductivities for sands can vary over four orders of magnitude (10^{-2} to 10^{2} feet per day), so groundwater flow can be slower in comparison to flow in basalt. The 60-foot clay layer beneath the upper sand could isolate the upper sand groundwater system and, in conjunction with the uppermost basalt layer, serves as a confining layer over the deeper volcanic aquifer system that is tapped by the Martha Way Well.

As shown in Figure 3-1, both screen intervals in the Martha Way well are installed within the basalt aquifer. Unlike the sedimentary block diagram shown in the upper right area of Figure 1 in which the recharge water would displace native groundwater in the pore space creating a predictable stored volume near the well, the nature and extent of fractures and other voids within the basalt rock are highly uncertain; and water recharged into this aquifer system could travel faster over greater distances away from the well.

Figure 3-2 is a northwesterly-facing block diagram (USGS, 2013) that shows the conceptual groundwater flow within the watershed of the Santa Rosa Plain. The Marta Way Well is shown on the right side of the diagram, along the eastern margin of the groundwater basin and produces groundwater from the Sonoma Volcanics. Groundwater in the volcanics flows westerly towards the Rodgers Creek Fault, which is shown as barrier to this flow. According to the USGS (2008), the Martha Way Well is located approximately 1,000 feet southwest of a mapped portion of the northwest-trending Healdsburg Segment of the Rodgers Creek Fault Zone. The southeastern end of a second, similar segment is located about 1,500 feet northwest of the Martha Way Well. These fault segments could disrupt groundwater flow in the sedimentary and the volcanic aquifer systems and likely contributed to the fracturing of the volcanic rocks.

The City of Santa Rosa operates two deep production wells that are located along Farmers Lane, approximately 3,550 feet northwest and downgradient of the Martha Way Well. These wells are reported to be 1,000 and 1,200 feet deep, although well logs are not available to document construction details or the aquifer system. These wells may produce groundwater from both the sedimentary and volcanic aquifer systems and could eventually produce water recharged at the Martha Way Well should future ASR operation be performed at the Martha Way Well.

Figure 3-2. Conceptual Diagram – Santa Rosa Plain Groundwater System



3.2. Groundwater Levels – Martha Way Well

Groundwater levels were recorded at the Martha Way Well via a transducer set for 15-minute readings. These electronic data were downloaded by GEI or obtained from WYA and used to produce hydrographs in combination with manual WL data, as presented below.

Figure 3-3 is a hydrograph for the Martha Way Well for 1st ASR cycle, starting in early September 2025 and ending with the conclusion of the 3rd ASR cycle in late December 2025. Transducer data (normalized) are shown via a black line while manual measurements are shown by a red line. A brown dashed line denotes an estimate of WLs for the end of the 3rd recharge period and during the early portion of the storage period when transducer data were not available. Sampling is shown as purple-rimmed open circles, and backflush pumping is shown orange triangles. The wide, blue vertical line denote the recharge (R#) periods, and the wide, green vertical lines denote the recovery pumping (RP#) periods. Storage (S#) periods occurred between the two active ASR periods. During early September, the

static depth to water (DtW) was approximately 34 feet below ground surface (bgs) and overall rate of WL change was -0.21 feet per day (deeper). By middle September, the DtW was approximately 35 feet bgs and the rate of WL change slowed to -0.07 feet per day. Thereafter, DtW increased to nearly 36 feet during static periods (e.g. time between ASR Cycles, Storage 2) while the rates of WL change remain fairly low and varied from 0.05 to -0.01 feet per day. During the 3rd recharge period, or possibly the beginning of the 3rd storage period, WLs began to rise due to natural recharge from precipitation. The rate of WL change increased between 0.20 and 0.24 feet per day during the 3rd storage period and the DtW was approximately 26 feet bgs prior to the start of the 3rd recovery pumping period.

3.2.1. Recharge Periods

Three recharge periods were included in the 3.6-month ASR pilot test, as shown by Figure 3-3. Flow and WL data are summarized in **Table 3-1**. The duration of each recharge period increased during the test and varied from 3 to 6 to 11 days for a total of 20 days. Average recharge rates were fairly steady and varied between 76 to 78 gpm. Drawup was found vary between 3.1 and 3.5 feet.

To integrate recharge flow and drawup for a more uniform comparison, 'specific recharge' was determined for average values of the two parameters in units of gallons per minute per feet of drawup (gpm/ft-du), similar to the specific capacity (SpC) of a pumping well. The table shows comparable values of specific recharge for the three recharge periods which can be used to assess the potential recharge capacity of the Martha Way Well.

Figure 3-3. Hydrograph for ASR Pilot Test at Martha Way Well

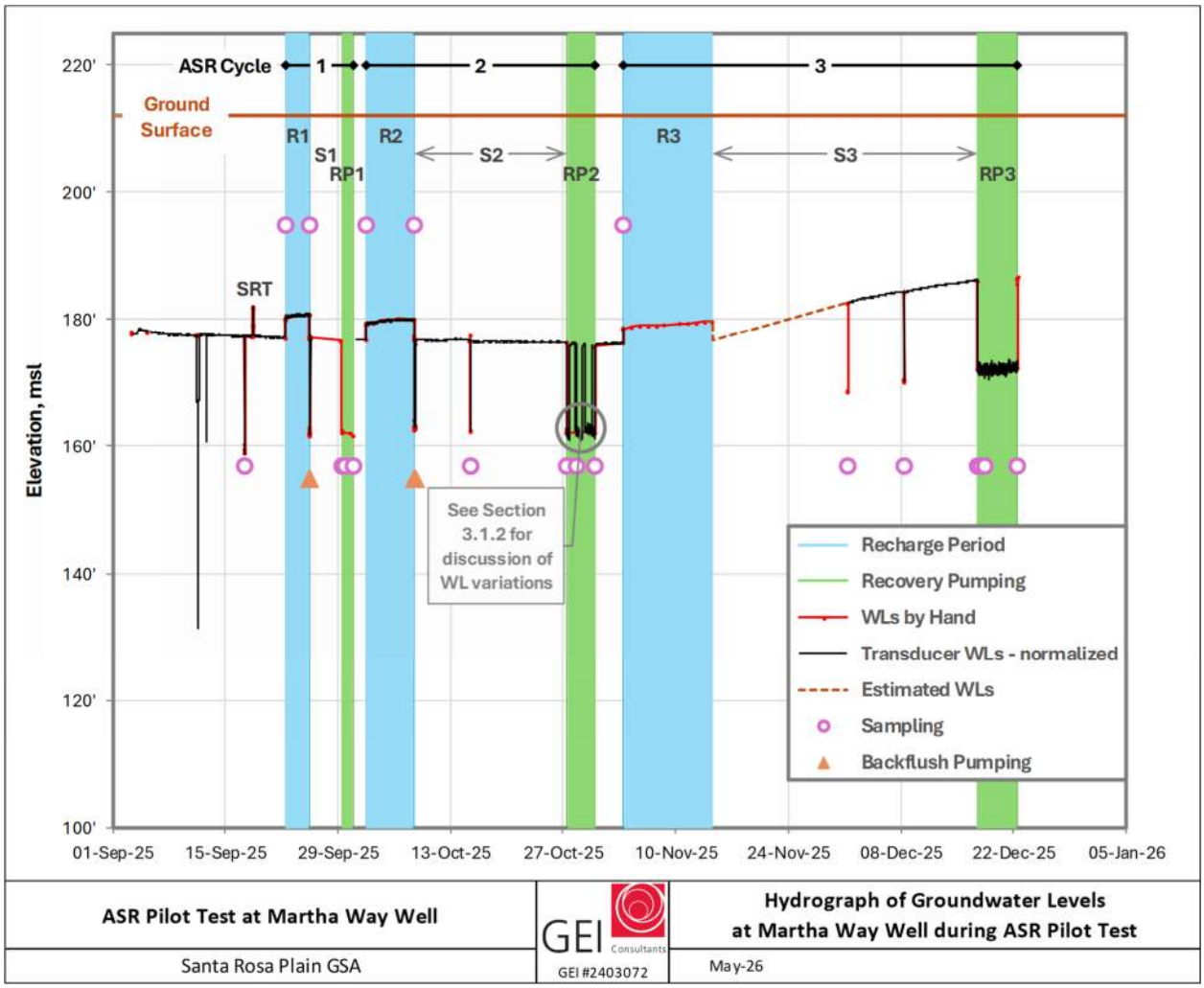


Table 3-1. Depths to Water and Drawup during ASR Recharge Periods

Recharge Period	Mean[4] DtW prior to Start	Average Recharge Rate, gpm	Mean[4] DtW at end of Period	Shallowest DtW	WL Drawup		Specific Recharge, gpm/ft-du
					Mean[4]	Projected for 121 days	
1	34.8’ bgs	76	31.2’	31.0’	3.6’	4.1’	21 to 19
2	35.2’ bgs	77	32.0’	31.9’	3.2’	3.7’	24 to 21
3	35.8’ bgs	78	32.3’	32.3’	3.4’	3.6’	23 to 22

The recharge capacity of the Martha Way Well could be 300 gpm if the specific recharge value is 20 gpm/ft-du and available drawup is at least 15 feet for WLs between 10 and 25 feet bgs (upper WL limit: 10 feet bgs and 25 feet bgs is highest natural WL in well during wet season, respectively). This rate equates to 432,000 gallons per day (gpd) or nearly 52.3 million (M-) gallons or 160 acre-feet for a 4-month

[4] Mean WL value over 4-hour period of transducer data.

recharge period (December through March). A higher recharge flow would likely be possible during the early portion of the wet season when DtW is deeper and might be lower at the end of the wet season.

The estimated recharge capacity is comparable to a previous estimate of 390 gpm, which was part of a preliminary feasibility evaluation of ASR on 12 existing wells in the Santa Rosa vicinity (Pueblo Water Resources, 2012). This feasibility evaluation also indicated that the Martha Way Well might be capable of 1,155 gpm of recharge under a pressurized delivery system of 30 pounds per square inch. This pressurized flow of recharge is less than a constraint for hydrofracturing of the confining material above the screen (1,620 gpm) and a constraint for offsite impacts (1,200 gpm). The offsite impact was defined as increasing the water level above the top of a nearby well after six months of recharge. For the Martha Way Well, the distance to a nearby well was 550 feet.

3.2.2. Recovery Pumping Periods

Three recovery pumping periods were included in the 3.6-month ASR pilot test, as shown by the above figure. **Table 3-2** summarizes pumping and WL data and provides values for SpC for the end of the pumping periods. Static WL measurements varied from 35 to 36 feet bgs prior to the 1st and 2nd pumping periods but was 10 feet higher in the well at nearly 26 feet prior to the 3rd pumping period.

Manual WLs were used to define the 1st recovery pumping period because transducer data were not available. These WL data were taken at the beginning and end of the pumping period and show 15 feet of drawdown while pumping at an average rate of 199 gpm for 1.2 days for a SpC of 13 gpm/ ft-dd.

Table 3-2. Depths to Water and Drawdown at Martha Way Well during Recovery Pumping

Recovery Pumping Period	DtW prior to Start, bgs	Mean Pumping Rate, gpm	Mean Pumping DtW, bgs	Deepest DtW, bgs	Drawdown (Average DtW – DtW at start)	Specific Capacity, gpm/ft-dd
1	35.4’	199	50.4’	50.4’	15.0’	13
2	35.7’	192	49.7’	51.0’	14.0’	14
3	25.7’	196	39.8’	41.4’	14.1’	14

Transducer WL data (15-minute intervals) were available for the 2nd and 3rd pumping periods and showed fluctuating WLs. For the 2nd pumping period, WLs are irregular due to numerous relatively short pumping intervals, producing drawdown, and intervening intervals of no pumping when WLs rose to nearly static conditions due to interruptions of generator operation, repairs of the discharge piping (vandalized), and management of the discharge runoff. These operational intervals totaled 63.2 hours, and non-operational intervals totaled 22.4 hours, as listed below.

RP2 Pump on: 9.4 ↘ 2.5 ↗ ↘ 19.0 ↗ ↘ 0.2 ↗ ↘ 1.2 ↗ ↘ 17.1 ↗ ↘ 13.9 ↗ hours

RP2 Pump off: 16.4 0.3 5.1 0.1 0.4 0.2 hours

The pumping hydrograph also shows WL fluctuations during the seven operational intervals, and these WL fluctuations were as much as 1.4 feet (+/-) for the 15-minute measurement intervals. Recovery pumping for the 3rd period (5.1 days) was continuous, and the WLs fluctuated up to 1.9 feet (+/-). These fluctuations were also present in the 2010 transducer data when the new well was tested for its capacity.

Specific capacity values were calculated for the numerous pumping periods, including purge pumping for the native groundwater sample and the two water samples during the 3rd storage period, and the three recovery pumping periods. The SpC values range from 12 to 16 gpm/ft-dd (average: 12.5 gpm/ ft-dd) and were based on the estimated drawdown at 24 hours. The well completion report (ECON, 2011) stated that the Martha Way Well has a SpC of 13.5 gpm/ft-dd for pumping activities during 2010.

Specific capacity values for a well typically decrease with higher pumping rates and with longer periods of time but is commonly used to estimate the transmissivity of an aquifer. For unconfined aquifers (relatively shallow), the SpC is multiplied by a factor of 1500 to calculate transmissivity and by 2000 for a confined aquifer. This empirical relationship is described by Driscoll (1986) and is most applicable to sedimentary aquifers. The Martha Way Well was constructed in volcanic rocks (basalt: 220 feet with < 10 feet of sandy silt) at depths between 500 and 860 feet. As such, this calculation may not be representative but does provide a relative comparison between 2010 and 2025 data. Nevertheless, the confined transmissivity at the Martha Way Well is calculated to be 21,000 to 27,000 gallons per day per foot (gpd/ft). This range of transmissivity values is considerably less than estimates from the Cooper-Jacob method, which is applicable to sedimentary aquifers that are homogeneous and isotropic. Volcanic rocks are not homogeneous and isotropic.

The well completion report (ECON, 2011) calculated a transmissivity value of 43,000 gpd/ft using transducer recordings of depths to pumping WLs during 2010 and the Cooper-Jacob method. An evaluation of 2010 drawdown data from manual WLs found transmissivity values of 59,000 gpd/ft for a 47-hour pumping period and 91,300 gpd/ft for a 23-hour period. The former and latter values were used in the Technical Report to estimate well capacity and groundwater flow.

Manual WL data from various pumping periods during the pilot test (well purging for sampling, recovery pumping) produced a wide range of transmissivity using the Cooper-Jacob method, including 81,200 gpd/ft for the sampling of native groundwater and between 151,000 and 191,600 gpd/ft (mean: 160,000 gpd/ft) during the ASR pilot test. The lowest value was obtained from pumping prior to the sampling of native groundwater and is comparable to the highest 2010 value while the subsequent higher values were obtained after implementing the ASR pilot test. Backflushing, and possibly recharge, appear to have improved the hydraulic conditions of the well.

Hydraulic conductivity (K) values can be estimated from the quotient of the transmissivity and aquifer thickness or well screen length (230 feet for Martha Way Well). For the SpC-derived transmissivity values, K varies from 12 to 16 feet per day (mean: 15 feet/day). For the Copper-Jacob transmissivity values, K varies from 47 to 111 feet per day (mean: 85 feet/day). According to Heath (1983), these K values occur at the lower end of the range for fractured basalt and lava flows (0.7 to 7,500 gpd/ft or 0.1 to 1,000 feet/day).

3.3. Geochemical Evaluation

Water quality is an important consideration for an ASR program because the mixing of two waters can result in the precipitation of minerals that reduce the hydraulic conductivity of the aquifer and the performance of the well. The chemistry of the recharge water can also mobilize trace metals from the surface of aquifer particles and can dissolve minerals with trace minerals. Moreover, residual chlorine in the recharge water can produce disinfection by-products (DBPs) in the aquifer.

Numerous samples (19) were collected for this ASR pilot test, including five samples of recharge water and 14 samples from the Martha Way Well.

Laboratory analyses were provided by the Santa Rosa Water, Laguna Environmental Laboratory and by Alpha Analytical Laboratory, Ukiah, CA. These analyses included a variety of constituent groups: general parameters, major anions and cations, nutrients, metals, miscellaneous, and DBPs. Some samples were analyzed for the complete list of constituents while other samples were analyzed for a partial list, depending on the results of previous analyses (minimize non-detect analyses).

Tables 3-3 and **3-4** provide the laboratory results for the recharge water and for the Martha Way Well, respectively.

3.3.1. Overall Water Quality

Overall, the quality of the recharge water and the native groundwater is excellent and appears to be compatible for an ASR program. The recharge water is derived from the Russian River and conveyed to the City of Santa Rosa via the Sonoma Water aqueduct. The recharge water exhibited a relatively dilute mixed-cation-bicarbonate character with magnesium and calcium as the dominant cations in comparison to sodium plus potassium. The total dissolved solids (TDS) concentrations ranged between 160 and 190 mg/L in four samples with a questionable value of 320 mg/l in one sample as the electrical conductivity (EC) of that sample was 298 microsiemens per centimeter (µs/cm) and the EC of the other samples ranged from 288 to 307 µs/cm.

The Martha Way Well produces mixed-cation-bicarbonate groundwater, except that sodium plus potassium are dominant over calcium and magnesium. Moreover, potassium in the native groundwater occurs at a notably higher concentration than in the recharge water (7 mg/L versus mean of 1.1 mg/L). The TDS of the native groundwater was 350 mg/L and the EC was 508 µs/cm, both higher than the recharge water.

The pH of the native groundwater was less alkaline than the recharge water (7.6 versus 8.0 to 8.2).

Table 3-3. Summary of WQ Results for Recharge Water during ASR Pilot Test

			Recharge 1		Recharge 1		Recharge 2		Recharge 2		Recharge 3		
		Date:	22-Sep-25 12:15		25-Sep-25 11:15		02-Oct-25 12:15		08-Oct-25 11:20		03-Nov-25 12:15		Drinking Water Limts Primary /
No Analysis / none / erroneous		Laboratories:	Alpha & City of Santa Rosa		Alpha & City of Santa Rosa		Alpha & City of Santa Rosa		Alpha & City of Santa Rosa		Alpha & City of Santa Rosa		Secondary
Constituent			NDs	Detects	NDs	Detects	NDs	Detects	NDs	Detects	NDs	Detects	
General													
pH	units			8.1		8.0		8.1		8.0		8.2	6.5 to 8.5
Conductivity @ 25C - field	µS/cm			299		307		305		298		288	900
Total Dissolved Solids	mg/L	TDS		160		190		180		320		170	500
Odor as Threshold Odor Number:	TON			**7.1**		2.9		**7.1**		2.9	<1.0		3
Total Organic Carbon	mg/L	TOC		0.69		0.71		0.65 J		0.61 J		0.63	
Major Cations													
Calcium	mg/L	Ca		22		22		22		23		21	
Magnesium	mg/L	Mg		13		14		14		14		12	
Sodium	mg/L	Na		20		21		21		20		18	
Potassium	mg/L	K		1.2		1.1		1.1		1.1		1.1	
Major Anions													
Alkalinity (HCO_3, CO_3, OH)	mg/L	as $CaCO_3$		130		140		140		140		130	
Bicarbonate	mg/L	HCO_3		160		170		170		170		160	
Carbonate	mg/L	as $CaCO_3$	<10		<10		<10		<10		<10		
Hydroxide	mg/L	as $CaCO_3$	<10		<10		<10		<10		<10		
Sulfate	mg/L	SO_4		13		13		13		13		12	250
Chloride	mg/L	Cl		6.2		6.2		6.2		6.1		6.0	250
Fluoride	mg/L	F		0.08		0.09		0.09 J		0.09 J		0.09 J	**2**
Nutrients													
Nitrate	mg/L	as N		0.23		0.27		0.26		0.25		0.24	**10**
Nitrite	mg/L	as N	<0.010		<0.010		<0.010		<0.010		<0.010		**1**
Orthophoshate	mg/L	as P	<0.30		<0.30								
Miscellaneous													
Boron	µg/L	B		0.22		0.21		0.21		0.21		0.21	
Silica	mg/L	SiO_2		18		18		18		18		17	
Metals													
Aluminum	µg/L	Al	<50		<50		<50		<50		<50		1000
Arsenic	µg/L	As	<2.0		<2.0		<2.0		<2.0		<2.0		**10**
Chromium - total	µg/L	Cr		0.46 J		0.49 J		0.35 J		0.57		0.64	**50**
Chromium-VI	µg/L	Cr-VI		0.38		0.53		0.48		0.47			**10**
Iron - total	µg/L	Fe	<50		<50		<50		<50		<50		300
Lead	µg/L	Pb		0.42 J		0.20 J		0.16 J		0.26 J		0.22 J	**15**
Manganese - total	µg/L	Mn	<0.50		<0.50		<0.50		<0.50		<0.50		50
Selenium	µg/L	Se	<2.0		<2.0		<2.0		<2.0		<2.0		**50**
Uranium	pCi/L	U	<1.0		<1.0		<1.0		<1.0		<1.0		**25**
Total Trihalomethanes	µg/L	T-THMs		18		22		16		15		16	**80**
Bromodichloromethane	µg/L	BDCM		5.1		7.5		4.8		4.9		5.0	
Bromoform	µg/L	BF		1.1		1.4		1.1	<1.0		<1.0		
Chloroform	µg/L	CF		7.5		7.5		5.9		6.1		7.0	
Dibromochloromethane	µg/L	DBCM		4.0		5.7		4.10		4.2		4.0	
Total Haloacetic Acids	µg/L	T-HAAs		6.2		8.2		6.2		5.8		5.8	**60**
Dibromoacetic acid	µg/L	DBAA		1.4		1.8		1.6		1.8		1.4	
Dichloroacetic acid	µg/L	DCAA		2.8		3.7		3.0		2.5		2.8	
Monobromoacetic acid	µg/L	MBAA	<1		<1.0		<1.0		<1.0		<1.0		
Monochloroacetic acid	µg/L	MCAA	<2		<2.0		<2.0		<2.0		<2.0		
Trichloroacetic acid	µg/L			2.0		2.7		1.6		1.5		1.6	

Table 3-4. Summary of WQ Results for Martha Way Well during ASR Pilot Test

No Analysis: none			Native Groundwater	Storage / Recovery 1	Recovery 1	Recovery 1	Storage 2	Storage / Recovery 2	Recovery 2	Recovery 2	Storage 3	Storage 3	Storage / Recovery 3	Recovery 3	Recovery 3	Recovery 3	
Well:			**Martha Way**	**Martha Way**	**Martha Way**	**Martha Way**	**Martha Way**	**Martha Way**	**Martha Way**	**Martha Way**	**Martha Way**	**Martha Way**	**Martha Way**	**Martha Way**	**Martha Way**	**Martha Way**	
Date:			17-Sep-25 10:50	29-Sep-25 11:15	29-Sep-25 22:15	30-Sep-25 22:20	15-Oct-25 10:45	27-Oct-25 12:00	28-Oct-25 15:15	30-Oct-25 23:30	01-Dec-25 10:00	08-Dec-25 10:30	17-Dec-25 11:45	17-Dec-25 23:20	18-Dec-25 11:05	22-Dec-25 12:30	**Drinking Water Limts Primary /**
Laboratory:			Alpha & City of Santa Rosa	Alpha & City of Santa Rosa	Alpha & City of Santa Rosa	Alpha & City of Santa Rosa	Alpha & City of Santa Rosa	Alpha & City of Santa Rosa	Alpha & City of Santa Rosa	Alpha & City of Santa Rosa	Alpha & City of Santa Rosa	Alpha & City of Santa Rosa	Alpha & City of Santa Rosa	Alpha & City of Santa Rosa	Alpha & City of Santa Rosa	Alpha & City of Santa Rosa	Secondary
Constituent			NDs Detects	NDs Detects	NDs Detects	NDs Detects	NDs Detects	NDs Detects	NDs Detects	NDs Detects	NDs Detects	NDs Detects	NDs Detects	NDs Detects	NDs Detects	NDs Detects	
General																	
pH	units		7.6	7.9	7.8	7.8	7.9	7.7	7.7	7.6	7.9	7.8	8.0	7.9	7.8	7.8	6.5 to 8.5
Conductivity @ 25C - field	µS/cm		508	313	397	449		369	406	461	357	369	381	379	390	454	900
Total Dissolved Solids	mg/L	TDS	350	220	270	300	210	250	260	270	150	190	250	250	250	280	500
Odor as Threshold Odor Number:	TON		<1.0	7.1	1.7	7.1	2.5	5.0	<1.0	7.1	6.3	4.0	7.1	<1.0	14	40	3
Total Organic Carbon	mg/L	TOC	0.81	0.83	0.74	0.64	0.88	0.85	0.81	0.66	0.85	0.95	0.76	0.76	0.74	0.68	
Major Cations																	
Calcium	mg/L	Ca	29	20	24	27	21	22	25	27	22	22	23	22	23	27	
Magnesium	mg/L	Mg	19	13	16	18	13	14	16	18	14	14	15	15	15	18	
Sodium	mg/L	Na	44	28	37	41	26	30	36	41	28	28	31	32	34	39	
Potassium	mg/L	K	7.0	3.6	5.5	6.2	3.1	4.0	5.1	6.2	3.4	3.6	3.9	4.6	4.8	5.9	
Major Anions																	
Alkalinity (HCO_3, CO_3, OH)	mg/L	as $CaCO_3$	240	160	190	200	150	170	160	220	160	170	180	170	180	210	
Bicarbonate	mg/L	HCO_3	290	200	230	240	180	210	200	270	200	210	220	210	220	260	
Carbonate	mg/L	as $CaCO_3$	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	
Hydroxide	mg/L	as $CaCO_3$	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	
Sulfate	mg/L	SO_4	0.44 J	13	7.8	3.9	11	8.7	6.7	3.0	9.6	9.0	7.6	8.5	7.9	3.4	250
Chloride	mg/L	Cl	17.6	7.7	11.3	14.2	7.7	9.2	11	14	9.3	10.1	10.0	12.4	10.1	14.2	250
Fluoride	mg/L	F	0.16	0.12	0.14	0.15	0.12	0.14	0.15	0.15	0.18	0.11	0.12	0.14	0.14	0.15	**2**
Nutrients																	
Nitrate	mg/L	as N	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	**10**
Nitrite	mg/L	as N	0.003 J	0.036	0.024	0.019	0.012	0.003 J	<0.010	<0.010	0.004 J	0.003 J	<0.010	<0.010	<0.010	<0.010	**1**
Orthophoshate	mg/L	as P	<0.30			<0.30				<0.30						<0.30	
Miscellaneous																	
Boron	µg/L	B	0.43	0.26	0.34	0.39	0.26	0.31	0.33	0.39	0.28	0.29	0.31	0.31	0.33	0.38	
Silica	mg/L	SiO_2	101	50	73	79	45	55	67	80	49	51	56	66	69	80	
Metals																	
Aluminum	µg/L	Al	1,700	238	<50	<50	239	122	<50	<50	168	47 J	67	<50	<50	<50	1000
Arsenic	µg/L	As	1.0	1.5 J	1.6 J	1.8 J	1.8 J	1.9 J	2.0 J	1.5 J	1.5 J	1.5 J	1.5 J	<2.0	<2.0	<2.0	**10**
Chromium - total	µg/L	Cr	1.8	0.74	<0.50	<0.50	0.81	0.41 J	<0.50	<0.50	0.72	0.38 J	<0.50	<0.50	<0.50	<0.50	**50**
Chromium-VI	µg/L	Cr-VI	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**10**
Iron - total	µg/L	Fe	**12,000**	**822**	92	85	**1,050**	**429**	92	59	**924**	280	**337**	68	51	42 J	300
Lead	µg/L	Pb	0.49	0.2 J	<0.50	0.05 J	0.18 J	0.10 J	<0.50	<0.50	0.16 J	0.11 J	0.08 J	<0.50	<0.50	<0.50	**15**
Manganese - total	µg/L	Mn	**134**	39	45	**55**	34	41	44	**55**	38	38	46	37	39	48	50
Selenium	µg/L	Se	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	**50**
Uranium	pCi/L	U	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**25**
Total Trihalomethanes	µg/L	T-THMs		11	4.1	2.1	6.8	3.5	2.8	1.1	2.5	1.5	0	0	0	0	**80**
Bromodichloromethane	µg/L	BDCM		1.7	<1.0	<1.0	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
Bromoform	µg/L	BF		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
Chloroform	µg/L	CF		7.9	4.1	2.1	5.7	3.5	2.8	1.1	2.5	1.5	<1.0	<1.0	<1.0	<1.0	
Dibromochloromethane	µg/L	DBCM		1.2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
Total Haloacetic Acids	µg/L	T-HAAs		3.1	2.0	0	1.9	1.3	1.5	1.1	3.2	1.4	0	0	0	0	**60**
Dibromoacetic acid	µg/L	DBAA		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
Dichloroacetic acid	µg/L	DCAA		1.7	2.0	<1.0	1.9	1.3	1.5	1.1	2.0	1.4	<1.0	<1.0	<1.0	<1.0	
Monobromoacetic acid	µg/L	MBAA		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
Monochloroacetic acid	µg/L	MCAA		<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	
Trichloroacetic acid	µg/L	TCAA		1.4	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.2	<1.0	<1.0	<1.0	<1.0	<1.0	

Figure 3-4 is the first of four figures that show a Piper diagram (Piper, 1944) and Stiff patterns (Stiff, 1951) for the anion and cation composition of the 19 water samples. Figure 3-4 addresses recharge water and the native groundwater from the Martha Way Well. For the Piper diagram, anion and cation concentrations in milliequivalents per liter (mass per volume plus ionic charge [meq/l]) are plotted as percentages with anion compositions plotted in the right triangle and cation compositions plotted in the left triangle. These locations are then projected upward, and the intersections of the anion-cation projections establishes the resultant locations within the diamond area, which further distinguishes the similarity and differences of the waters. Recharge water is shown as open blue diamonds while the native pre-test groundwater from the Martha Way Well is shown as the solid orange triangle. Mixtures of the recharge and native groundwater would be expected to plot within the space between these end members.

The small cluster of symbols in the lower left apex of the large anion triangle (right side) illustrates the dominance of the bicarbonate anion. In the large cation triangle (left side), the symbols for the recharge water cluster along the left interior perimeter of the small central triangle; and illustrate the dominance of calcium and magnesium (lower left apex and top apex of cation triangle, respectively). The recharge water shows a consistent mixed-cation-bicarbonate WQ character over the 42-day sampling period where calcium and magnesium dominate over sodium plus potassium.

The Martha Way Well produce a mixed-cation-bicarbonate groundwater where sodium plus potassium dominate over calcium and magnesium, as previously discussed above.

The Stiff patterns (upper right corner) utilize the same data to illustrate the similarities/differences in the overall quality of the waters using distinctive patterns or shapes that are based on the concentrations (meq/l) of the major anions and cations on four horizontal axes, where anions extend to the right and cations extend to the left. A distinctive shape is produced by a perimeter line connecting the ends of each scale. The size of the shape is proportional to the concentrations of the constituents. The Stiff pattern for the native groundwater is larger because the TDS is nearly twice the TDS of the recharge water.

Figure 3-5 is the second of four figures and focuses on the WQ characteristics for the 1st ASR cycle and shows the positions of the recovery pumping samples (orange dots with blue perimeter) shifting from the cluster of recharge water samples toward the well samples. The anion shift is nearly complete whereas the cation shift is approaching 50 percent. Within the diamond, the uppermost dot represents the 1st sample during recovery pumping.

Figure 3-6 is the third of four figures and focuses on the WQ characteristics for the 2nd ASR cycle and shows similar results as the 1st ASR cycle. The uppermost dot within the diamond represents the storage sample of the 2nd ASR cycle.

Figure 3-7 is the fourth of four figures and focuses on the WQ characteristics for the 3rd ASR cycle and shows similar results as the previous cycles. The two uppermost dots within the diamond represents the two storage sample of the 3rd ASR cycle.

Figure 3-4. Graphical Illustrations of Water Quality – Recharge Water versus Native Groundwater

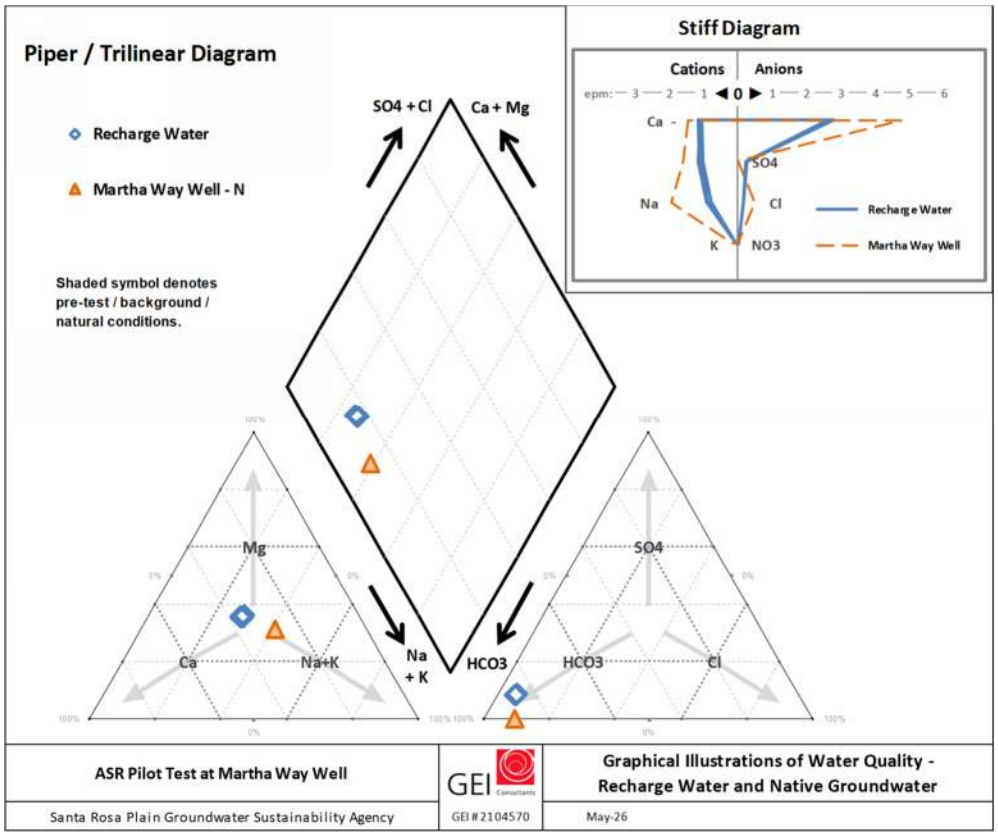


Figure 3-5. Graphical Illustrations of Water Quality – ASR Cycle 1 Water

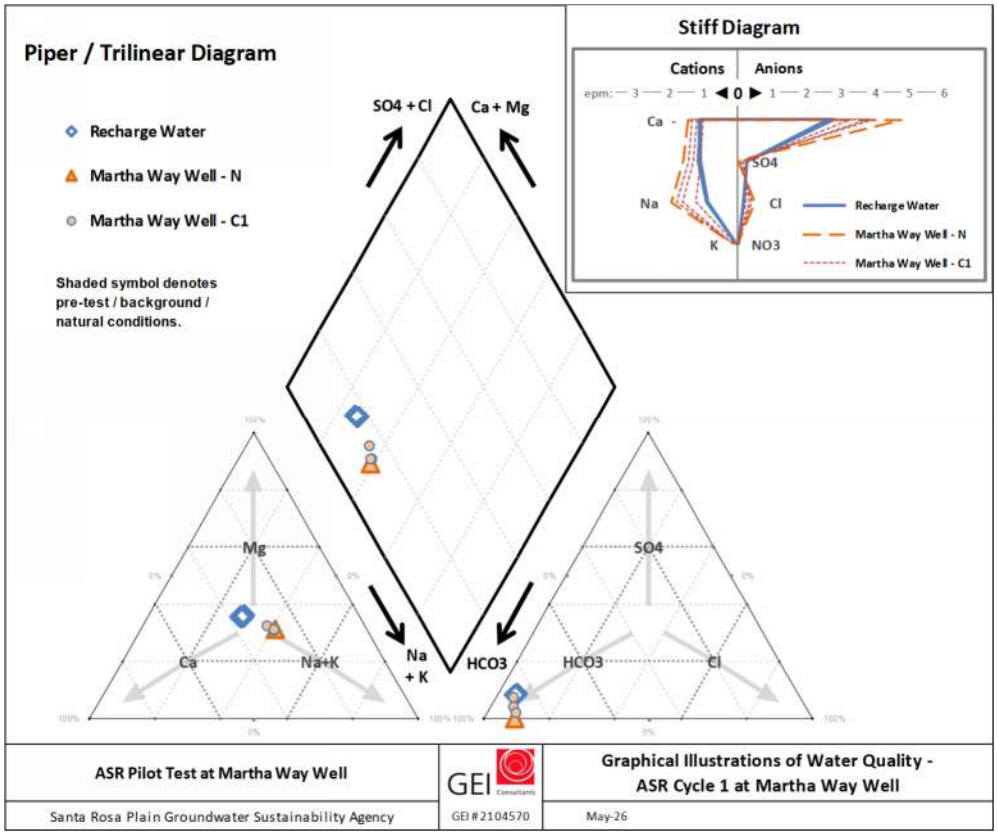


Figure 3-6. Graphical Illustrations of Water Quality – ASR Cycle 2 Water

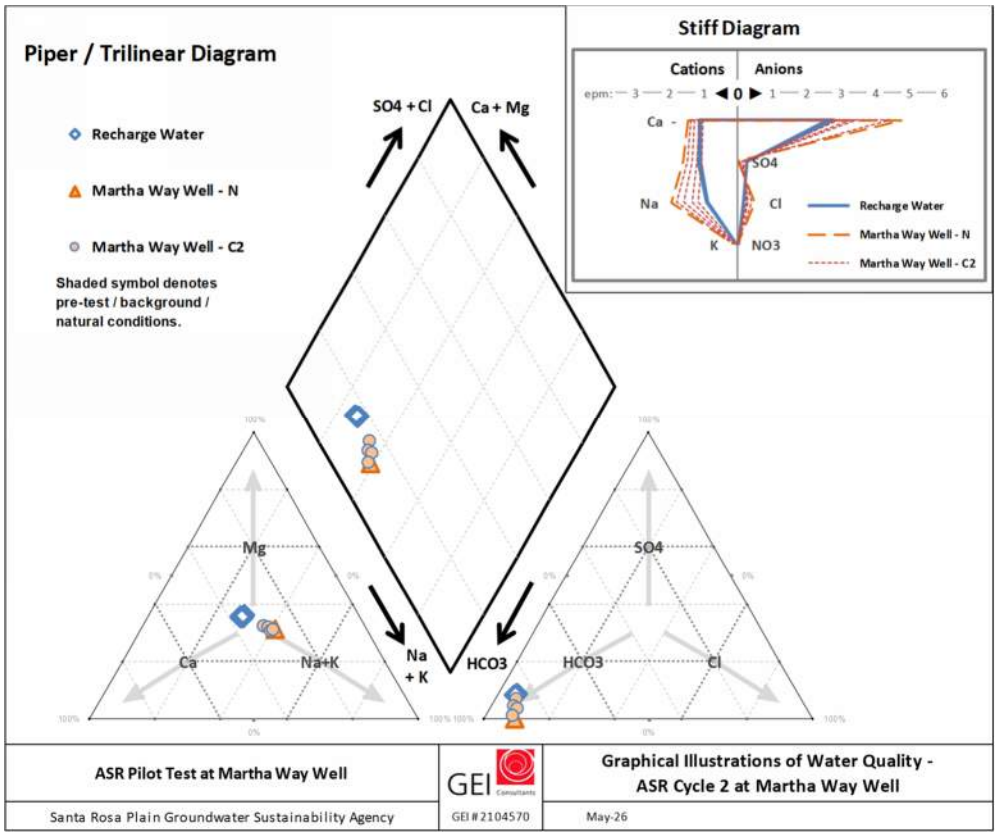
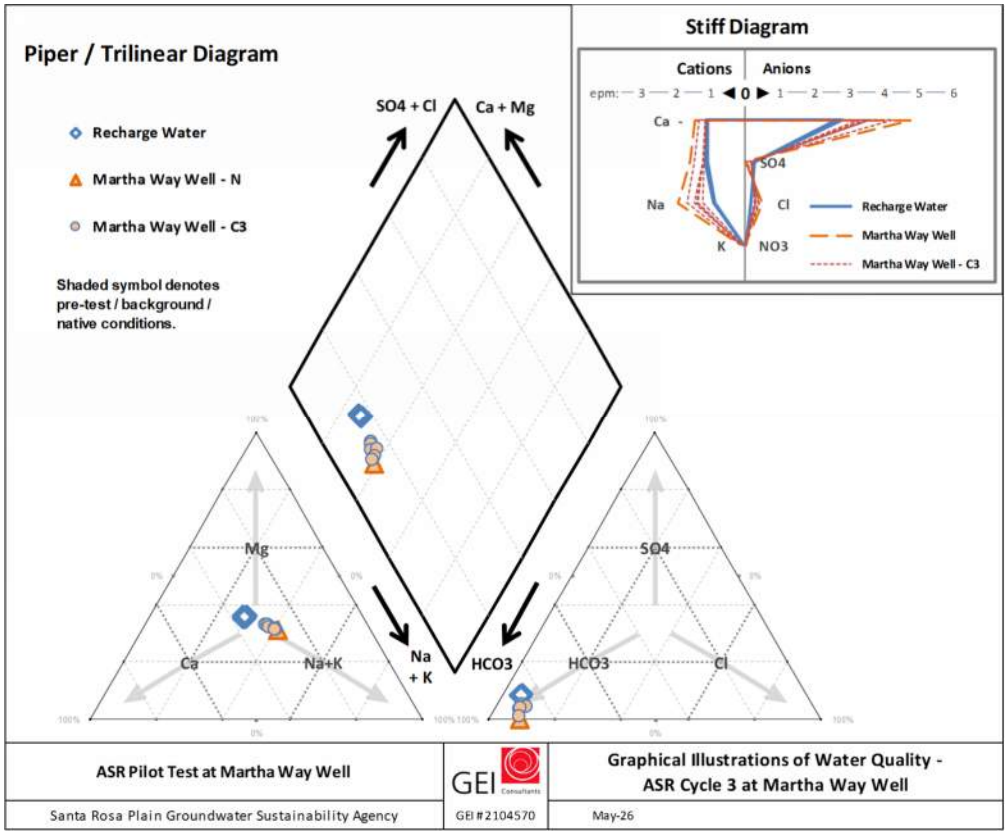


Figure 3-7. Graphical Illustrations of Water Quality – ASR Cycle 3 Water



All of these figures show the same progression in water quality, as expected, where various mixtures of recharge water and native groundwater plot linearly between the two sources of water. However, the orange-blue dots for storage and initial recovery pumping samples were expected to be dominated by the recharge water where the dots plotted on or closer to the cluster of recharge diamonds. The separation between the diamonds and the dots indicates that groundwater flow within the volcanic aquifer system is moving the recharge water downgradient from the Martha Way Well.

3.3.2. Water Quality Fluctuation with Time

The following sections describe and illustrate the variations in selected constituent during the pilot test.

Figure 3-8 is a time-series plot of TDS concentrations and pH. The TDS of the recharge water was fairly stable in four of the five samples with a range of 160 to 190 mg/L (average: 175 mg/L). The second sample during the 2nd recharge period was unusually high at 320 mg/L even though the electrical conductivity (298 µS/cm) was consistent with the other samples (288 to 307 µS/cm). The TDS for the Martha Way Well started at 350 mg/L, and as shown by the figure, started with a relatively low value during the storage period and start of the recovery period and increased thereafter. During the 1st ASR cycle, TDS increased from 220 to 300 mg/L, from 210 to 270 mg/L during the 2nd cycle, and from 150 to 280 mg/L during the 3rd cycle. The relatively lower values during the 3rd cycle suggest that previous recharge volumes and the higher 3rd volume of recharge water were still present in the volcanic rock aquifer.

As stated previously, the pH of the recharge water was somewhat more alkaline (8.0 to 8.2) than the native groundwater (7.6). During the pilot test, the pH of the stored/recovered water was generally highest at the beginning of each cycle (7.7 to 8.0) and decreased during the recovery pumping period (7.6 to 7.8), as shown by Figure 3-8.

Figure 3-9 is a time-series plot of iron and manganese. Iron and manganese were not detected in the recharge but were found at variable concentrations during the ASR pilot test. Iron was detected in the sample of native groundwater at 12,000 µg/L, which exceeded its secondary MCL of 300 µg/L by a factor of 240. This high iron concentration is probably due to the corrosion of the low-carbon steel casing and screen since the iron concentration was 250 µg/L during March 2010 during the initial testing groundwater production from both screens (new). During the three ASR cycles, the highest iron concentrations, which also exceeded the secondary MCL, occurred in two of the three storage samples (924 and 1050 µg/L) and at the start of recovery pumping period (337 to 822 µg/L). Iron was detected at 280 µg/L in the other storage sample. Thereafter, the iron concentrations varied between 42-J[5] and 92 µg/L (mean: 70 µg/L) in the recovery pumping samples.

[5] A J-concentration represents the identification of a constituent above the method detection limit of the laboratory analysis but below the report limit, which is a value that can be reproduced with a high degree of confidence and accuracy.

Figure 3-8. Chemograph of TDS and pH

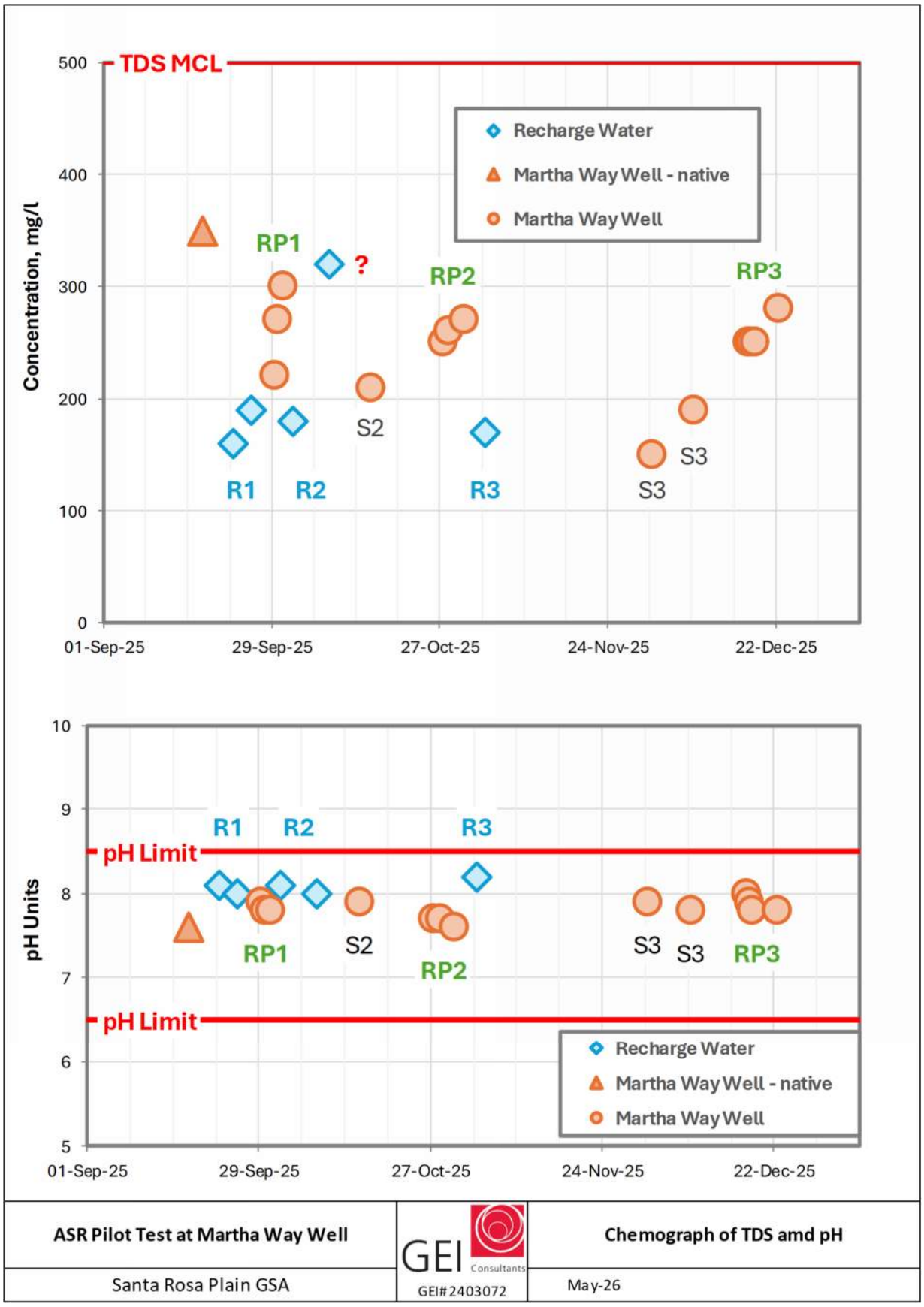
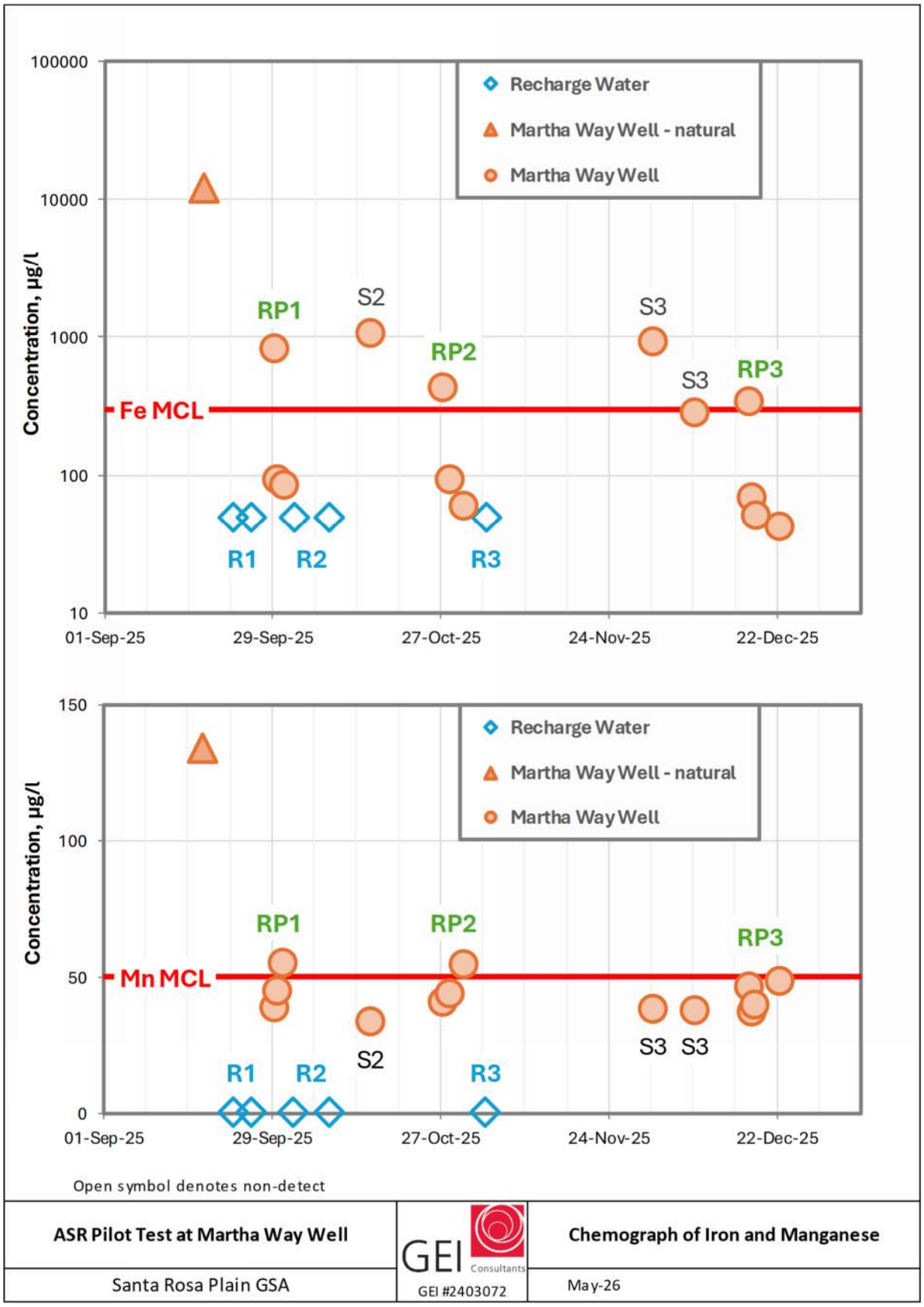


Figure 3-9. Chemograph of Iron (top) and Manganese (bottom)



Manganese was detected in the sample of native groundwater at 134 µg/L, which exceeded its secondary MCL of 50 µg/L. The manganese concentration was 67 µg/L during March 2010 during the testing of groundwater production from both screens (new). During the three ASR cycles, manganese concentrations were relatively low in storage samples (34 to 38 µg/L) and in the first samples during recovery pumping (39 to 46 µg/L) but increased and exceeded the MCL during the 1st and 2nd during recovery pumping periods (55 µg/L) and approached the MCL during the 3rd recovery pumping period (48 µg/L).

Figure 3-10 is a time-series plots of total concentrations of disinfection byproducts (DBPs), including trihalomethanes (four THMs) and haloacetic acids (five HAAs). These DBPs that result from the oxidation of organic matter in the source of recharge water by chorine disinfection. THMs and HAAs were present in the recharge water at concentrations (<25 µg/L) considerably lower than their respective primary MCLs (80 and 60 µg/L) and in 9 samples from the Martha Way Well at lower concentrations (<10 µg/L). Some of the THMs and HAAs were detected in samples from the Martha Way Well during the 1st and 2nd ASR cycles and in samples from the 3rd storage period, as discussed below. THMs and HAAs were not detected in samples from the 3rd recovery pumping period.

The total THM concentrations in the recharge water ranged from 15 to 22 µg/L and were comprised of all four THMs: chloroform (31% on average), bromodichloromethane (31%), dibromochloromethane (25%), and bromoform (4%). For the Martha Way Well, total THM concentrations were highest (11 µg/L) at the start of the 1st recovery pumping period and decreased thereafter but spiking slightly in storage samples and the start of the 2nd recovery pumping period. THMs were not detected in four samples from the 3rd recovery pumping period.

Chloroform was the dominant THM in samples from the Martha Way Well, occurring in 9 of 13 samples at generally declining concentrations from 7.9 to 1.1 µg/L. Bromodichloromethane was present twice at 1.7 and 1.0 µg/L and dibromochloromethane was present once at 1.2 µg/L.

The total HAA concentrations in the recharge water ranged from 5.8 to 8.2 µg/L and were comprised of three of five HAAs: dichloroacetic acid (46% on average), trichloroacetic acid (29%), and dibromoacetic acid (25%). Monobromoacetic acid and monochloroacetic acid were not detected in the recharge water.

For the Martha Way Well, total HAA concentrations varied from 1.1 to 3.2 µg/L in 8 of 13 samples. Dichloroacetic acid was the dominant HAA, occurring at concentrations between 1.1 and 2.0 µg/L. Trichloroacetic acid was present in two samples at concentrations of 1.2 and 1.4 µg/L. Dibromoacetic monobromoacetic acid, and monochloroacetic acid were not detected at the Martha Way Well.

Figure 3-10. Chemograph of Disinfection Byproducts



3.3.3. Other WQ Constituents

Other water quality constituents are discussed below.

- Odor Secondary MCL: 3 TON
  - Recharge Water: Odor exceeded the secondary MCL for odor (3 TON[6]) in two of five samples, including 7.1 TON for the first samples from the 1st and 2nd recharge periods. These results may be related to the installation of the new conveyance piping. The second samples were both 2.9 TON, less than the MCL. Odor was not detected in the sample for the 3rd recharge period.
  - Martha Way Well: Odor was not detected in the native sample of groundwater, but pilot test samples varied between non-detect (2) and an extreme value of 40 TON. Most values ranged from 1.7 to 14 TON with a median of 6.7 TON.

- Total Organic Carbon (TOC) No MCL
  - Recharge water: TOC varied between 0.6 and 0.7 mg/L.
  - Martha Way Well: TOC was 0.8 mg/L in the native groundwater sample and varied from 0.6 to 1.0 mg/L during the ASR pilot test.

- Fluoride (F) Primary MCL: 2 mg/L
  - Recharge water: Fluoride varied between 0.08 and 0.09 mg/L.
  - Martha Way Well: Fluoride was found at 0.16 mg/L in the native groundwater and varied from 0.11 to 0.18 mg/L during the pilot test.

- Nitrate as nitrogen NO_3) Primary MCL: 10 mg/L
  - Recharge water: Nitrate varied from 0.2 to 0.3 mg/L.
  - Martha Way Well: Nitrate was not detected in any sample.

- Boron (B) No MCL
  - Recharge water: Boron was 0.2 mg/L.
  - Martha Way Well: Boron was found at 0.4 mg/L in the native groundwater and varied from 0.3 to 0.4 mg/L during the pilot test.

- Silica (SiO_2) No MCL
  - Recharge water: Silica varied between 17 and 18 mg/L.
  - Martha Way Well: Silica was found at 101 mg/L in the native groundwater and varied from 45 to 80 mg/L during the pilot test.

- Aluminum (Al) Secondary MCL: 1,000 µg/L
  - Recharge water: Aluminum was not detected in the recharge water.
  - Martha Way Well: Aluminum was found at 1,700 µg/L in the native groundwater, but pilot test samples included seven non-detects. Detections ranged from 67 and 239 mg/L during the test.

[6] Threshold Odor Number

- Arsenic (As) Primary MCL: 10 µg/L
  - Recharge water: Arsenic was not detected in the recharge water.
  - Martha Way Well: Arsenic was found at 1.0 µg/L in the native groundwater and varied between 1.5 and 2.0 µg/L in 10 samples from the pilot test. Arsenic was not detected in the last three samples from the 3rd recovery pumping period.

- Chromium (Cr) Primary MCL: 50 µg/L for Cr (III), 10 µg/L for Cr (VI)
  - Recharge water: Chromium (III) was detected at concentrations between 0.4 and 0.6 µg/L and chromium (VI) was detected 0.4 and 0.5 µg/L.
  - Martha Way Well: Chromium (III) was found at 1.8 µg/L while chromium (VI) was not detected in the native groundwater. During the pilot test, chromium (III) was not detected in eight samples, but was sporadically detected between 0.4 and 0.8 µg/L in five samples. These detections occurred in the first samples for the 1st and 2nd recovery pumping periods and in the three storage samples (2nd and 3rd periods).

- Lead (Pb) Primary MCL: 15 µg/L
  - Recharge water: Lead concentrations varied from 0.2-J to 0.4-J µg/L.
  - Martha Way Well: Lead was found at 0.5 µg/L in the native groundwater and varied between 0.05-J and 0.20-J µg/L in seven samples from the pilot test. Lead was not detected in most of the latter time samples during recovery pumping (6).

- Selenium (Se) Primary MCL: 50 µg/L
  - Recharge water: Not detected in the five samples.
  - Martha Way Well: Not detected in the 14 samples.

- Uranium (U) Primary MCL: 15 pCi/L /L
  - Recharge water: Not detected in the five samples.
  - Martha Way Well: Not detected in the 14 samples.

4. Summary, Conclusions, and Recommendations

An ASR pilot test was conducted on the Martha Way Well – an 8-inch diameter, 870-foot-deep, low-carbon steel casing with two sections of slotted screen (80-slot) totaling 230 feet between depths of 500 to 620 and 750 to 860 feet. The Martha Way Well is located on the east side of the City of Santa Rosa. The pilot test began on September 22 and ended on December 22, 2025, and results of the pilot test allow for the following conclusions.

This project was funded by a grant from the California Department Water Resources under the Sustainable Groundwater Management Program for implementation of projects within the Santa Rosa Plain. ASR was identified in the 2021 Groundwater Sustainability Plan (Sonoma Water) as a Group 3 Project to achieve sustainability although the Martha Way Well was not specifically identified in the GSP.

4.1. Summary

- The Martha Way Well was installed and tested during 2010 as part of a City-wide study of groundwater resources to establish a backup water supply to supplement their supply of potable water from the wholesale water supply agency (Sonoma Water). The Martha Way Well was not integrated into the potable water supply and was not equipped with a pump or power supply.
- The well was rehabilitated and equipped with temporary equipment, including a submersible pump capable of producing 200 gpm, a conveyance pipe into the well for recharge water, and tubes for a City-owned transducer and for manual WL measurements.
- The City installed a temporary water service at the well to provide potable water for recharge from the City's distribution system. The Russian River is the primary source of the potable water via a nominal 100-foot deep Raney collector system and a large pipe conveyance system (aqueduct) operated by Sonoma Water.
- DtW was approximately 35 feet bgs prior to the ASR pilot test and recharge operations at 78 gpm (average) produced 3.1 to 3.5 feet of drawup (rise in WL). Nearly 2.26 M-gallons (6.94 acre-feet) of potable water were recharged to the volcanic rock groundwater system during three recharge periods (20 days total).
- Recovery pumping produced 14 feet of WL drawdown while pumping nearly 2.52 M-gallons of water (7.72 acre-feet) from the Martha Way Well at an average rate of 195 gpm. The recovered volume of water is about 13% greater than the recharged volume. An additional 0.23 M-gallons were produced during backflush pumping during the recharge periods and while sampling during the storage periods.
- DtW was approximately 25 feet bgs at the end of the ASR pilot test and the 10-foot WL rise is likely due to WL recovery when the two Farmer Lane wells ceased operations for the season during mid-November and due to natural recharge since the entire recharge volume plus 13 percent was pumped from the well.
- The recharge water exhibited a mixed-cation-bicarbonate character where magnesium and calcium were the dominant cations over sodium. The TDS was relatively dilute at 175 mg/l (average).

- Disinfection by-products were present in the recharge water at concentrations considerably less than MCLs, including all four trihalomethanes and three of five haloacetic acids. The maximum THM concentration was 22 µg/L versus the MCL of 80 µg/L. The maximum HAA was 8.2 µg/L versus the MCL of 60 µg/L.
- The Martha Way Well produces a native sodium-dominated mixed-cation-bicarbonate groundwater with a TDS of 350 mg/l.
- The overall WQ characteristics at the Martha Way Well changed during the pilot test – stored water was a mixture of native groundwater and recharge water but well did not exhibit the full character of the recharge water as was expected. Recovery pumping shifted the WQ character of the well back to the characteristic of the native groundwater.
- Arsenic was present in the native groundwater of the Martha Way Well prior to the pilot test at a concentration of 1 µg/L. During the pilot test, arsenic concentrations increased slightly but remained at 2 µg/L or less during the entire pilot test.
- Iron was present in the native groundwater sample at an unusual concentration of 12,000 µg/L, greater than its secondary MCL of 300 µg/L. This extreme value was probably due to the long-term inactivity at the low-carbon steel well (casing and screen). Iron was present in three of four native groundwater samples during 2010 at concentrations (340 to 650 µg/L) that exceeded the MCL. Iron concentrations varied from 280 to 1,050 µg/L during the three storage periods (median: 630 µg/L), all above the MCL; and varied from 42 to 92 µg/L during the three recovery pumping periods (median: 70 µg/L).
- Manganese was present in the native groundwater sample at a concentration (134 µg/L) greater than its MCL of 50 µg/L. Manganese was present in four native groundwater samples during 2010 at concentrations (58 to 82 µg/L) that exceeded the MCL. Manganese concentrations varied from 34 to 46 µg/L during the three storage periods (median: 40 µg/L); and varied from 37 to 55 µg/L during the three recovery pumping periods (median: 45 µg/L).
- THM and HAA concentrations were lower in the samples from the storage and recovery pumping periods. Chloroform was the primary THM detected in the recovered water (average: 95 percent of the total THM concentration). Dichloroacetic acid was the primary HAA detected in the recovered water (average: 90 percent of the total HAA concentration). THMs and HAAs were not detected in samples (4) from the 3rd recovery pumping period.

4.2. Conclusions

- Pilot testing shows ASR at the Martha Way Well is hydraulically feasible, although the recharge rate (<80 gpm) did not stress the recharge capacity of the volcanic aquifer system, as evidenced by the partially mixed character[7] of the stored water. The character of the stored water did shift toward the recharge character but did not fully resemble the recharge water, which indicates a rapid movement of native groundwater within relatively continuous fractures or voids of the volcanic aquifer.
- **Preliminary Estimate of Recharge Capacity**: 300 gpm, based on the conservative estimate of specific recharge 20 gpm/ft-du and 15 feet of available drawup with a 10-foot buffer between the ground surface and the recharge WL (i.e., pre-ASR WL greater than or equal to 25 feet bgs). Specific recharge values from the pilot test varied from 21 to 24 gpm/ft-dd. The estimated recharge capacity is comparable to a previous estimate of 390 gpm (Pueblo Water Resources, 2012). A somewhat higher rate might be possible early in the wet season when WLs are greater than 25 feet bgs, probably less late in the wet season when the WLs are high (less than 25 feet bgs) due to natural recharge. The above recharge rate over a 4-month period (December through March) would deliver more than 52 M-gallons or 160 acre-feet into the volcanic rock aquifer system. The initial startup of an ASR program should include step-recharge testing to evaluate the actual recharge capacity.
- The low-carbon steel casing and screen will require frequent maintenance, including backflush pumping and rehabilitation, to remove scale (iron oxides), which will likely clog the well screen and permeability of the aquifer around the well.
- Storage of the recharge water did not mobilize arsenic or other trace metals above primary MCLs.
- Water produced from ASR operations may require operational considerations (pump-to-waste) or treatment to address iron and possibly manganese.

[7] ASR operations will create a mixture of recharge water and native groundwater around the ASR well and the character of this mixture will vary proportionately depending on the movement of the stored water and its replacement by native groundwater.

4.3. Recommendations

An ASR program should include additional work prior to ASR operations:

- Complete a video survey of well to further define conditions.
- Further rehabilitation of well via brushing, swabbing, and air-lift pumping, including setting the intake of the air-lift pipe at the bottom of the well to remove any accumulation of fill.
- Evaluation of the Martha Way Well to determine the depth-specific flow capacity of the two screen intervals (spinner logging or tracer dyes). If the lower screen is not productive, consider abandoning it with a backfill (pea gravel with bentonite cap in blank casing or cement grout for permanent destruction).
- Installation of two observation wells (OW), based on the evaluation of depth-specific recharge capacity, including one well in the greenway along Yulupa Avenue and one well on the south side of Montgomery High School. WLs in these wells in conjunction with WLs from the Slater Well would be used to determine the direction and gradient of groundwater flow and to track the migration of the recharge water.
- Installation of two OWs, located 50 to 100 feet downgradient of the Martha Way Well, including a shallow OW in the upper sand aquifer system and a deep OW to further refine the hydraulic parameters of the volcanic rock aquifer system and to collect samples of the native groundwater-recharge water mixture. The shallow OW will provide data to quantify the hydraulic connection between the upper sand aquifer and the deep volcanic aquifer systems. Borehole logging of the deep OW should also focus on the existence and sizes of fractures and other voids using a specialized caliper logging tool or an acoustic televiewer system. In addition, the deep OW screen length should match the ASR well to ensure the recharge can enter the OW.
- As an alternative to the installation of the nearby deep observation well, another option would be to install a new ASR well and use the Martha Way Well as the observation well. The ASR well should be constructed with stainless steel casing and screen to prevent corrosion which will reduce the long-term maintenance of the well. Install the shallow OW, as mentioned above.
- Evaluate the local water distribution system to determine whether the system can deliver an adequate supply of potable water to existing residential customers concurrently with a recharge operation at 300 gpm, possibly as high as 400 gpm.
- Evaluate whether the Martha Way Well will require on-site treatment for iron and manganese or whether the well would be used simply for recharge and another downgradient well(s), such as the two wells along Farmers Lane, would be used for recovery pumping and possibly for the treatment.
- Submit a second Notice of Intent package (updated Technical Report and Technical Addendum) to obtain a Notice of Applicability (permit) for further ASR testing and/or operations.
- The ASR recharge operation should include a conveyance system to the top of the screen (500 feet) so the flow of recharge water is beneath the scaly blank casing to minimize the erosion of scale which could block the screen and reduce recharge capacity.

5. References

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Appendix A – Well Completion Report

File Original with DWR

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

DWR USE ONLY – DO NOT FILL IN

STATE WELL NO./STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

Page 1 of 2

Owner's Well No. Martha No. e0104763

Date Work Began 12/10/2009 Ended 3/17/2010

Local Permit Agency Somona County Permit & Resource Management

Permit No. WEL09-0393 Permit Date 11/13/2009

GEOLOGIC LOG

ORIENTATION (X) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD Reverse Circulation FLUID ___

DEPTH FROM SURFACE FL	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
50	70	Green Gravel & Sand
70	100	Sand
100	130	Sand & gravel
130	140	Blue clay, sand, & gravel
140	160	Blue clay
160	170	Blue clay, some gravel
170	180	Blue clay
180	190	Hard purple clay
190	220	Volcanic rock & gravel
220	230	Volcanic rock
230	270	Volcanic rock & hard blue clay
270	290	Volcanic rock
290	330	Volcanic rock, some blue clay
330	350	Sand, gravel, & blue clay
350	360	Volcanic gravel & little clay
360	430	Sand, gravel, & blue clay
430	450	Volcanic rock, blue clay, & gravel
450	460	Volcanic rock, sand, & blue clay
460	480	Volcanic rock & blue clay
480	500	Blue & red clay, hard
500	530	Volcanic rock & blue clay
530	540	Volcanic rock & blue clay, hard
540	590	Volcanic rock & blue clay
590	600	Volcanic rock
600	660	Volcanic rock & blue clay
660	700	Volcanic rock & gravel
700	710	Volcanic rock & red rock
710	720	Some Volcanic rock & red rock
720	730	Red clay & some blue clay
730	740	Red clay, blue clay, some volcanic rock

TOTAL DEPTH OF BORING 1074 (Feet)

TOTAL DEPTH OF COMPLETED WELL 870 (Feet)

WELL OWNER

Name City of Santa Rosa Park & Recreation

Mailing Address 100 Santa Rosa Ave

Santa Rosa (CITY) Ca (STATE) 95404 (ZIP)

WELL LOCATION

Address 1284 Martha Way;East end of Martha Way right of way

City Santa Rosa Ca (STATE) 95405 (ZIP)

County Somona County

APN Book ___ Page ___ Parcel ___

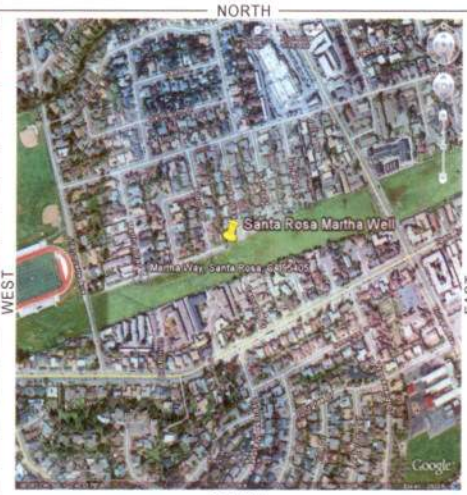
Township 7N Range 7W Section 19

Latitude 38 (DEG.) 26 (MIN.) 22.83 (SEC.) NORTH

Longitude 122 (DEG.) 40 (MIN.) 33.9 (SEC.) WEST

LOCATION SKETCH

NORTH



WEST EAST

SOUTH

Illustrate or Describe Distance of Well from Roads Buildings, Fences, Rivers etc and attach map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (X)

X NEW WELL

MODIFICATION/REPAIR

___ Deepen

___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (X)

WATER SUPPLY

___ Domestic X Public

___ Irrigation ___ Industrial

MONITORING X

TEST WELL ___

CATHODIC PROTECTION ___

HEAT EXCHANGE ___

DIRECT PUSH ___

INJECTION ___

VAPOR EXTRACTION ___

SPARGING ___

REMEDIATION ___

OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER Unknown (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL 18 *(Ft.)* & DATE MEASURED 2/21/10-3/17/10

ESTIMATED YIELD 350 (GPM) & TEST TYPE Pump

TEST LENGTH See Attached (Hrs.) TOTAL DRAWDOWN 24 *(Ft.)*

** May not be representative of a well's long-term yield.*

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (inches)	CASING (S) TYPE (-) BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	OUTSIDE DIAMETER (inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
							See Attached			
							Well Construction			
							Diagram			

DEPTH FROM SURFACE Ft.	to Ft.	ANNULAR MATERIAL TYPE CEMENT (X)	BENTONITE (X)	FILL (X)	FILTER PACK (TYPE/SIZE)
					See Attached
					Well Construction
					Diagram

ATTACHMENTS (X)

X Geologic Log

X Well Construction Diagram

X Geophysical Log(s)

___ Soil/Water Chemical Analyses

___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Layne Christensen Company (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

ADDRESS 11001 Etiwanda Ave CITY Fontana STATE Ca ZIP 92337

Signed ___ (WELL DRILLER/AUTHORIZED REPRESENTATIVE)

DATE SIGNED 3/23/2010

C-57 LICENSE NUMBER 510011

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

File Original with DWR

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

Page 2 of 2

Owner's Well No. Martha No. e0104763

Date Work Began 12/10/2009 Ended 3/17/2010

Local Permit Agency Somona County Permit & Resource Management

Permit No. WEL09-0393 Permit Date 11/13/2009

DWR USE ONLY – DO NOT FILL IN

STATE WELL NO./STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

GEOLOGIC LOG

ORIENTATION (X) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD Reverse Circulation FLUID ___

DEPTH FROM SURFACE FT.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
740	750	Rocks & gravel
750	760	Rocks
760	770	Some gravel & hard black rock
770	780	Some gravel & hard rock
780	790	Gravel rocks
790	800	Gravel Rock , little sand
800	810	Black rock, little gravel
810	820	Black rock & gravel
820	830	Black rock & sand
830	840	Black rock & gravel
840	860	Volcanic rock
860	870	Black rock
870	880	Black & red gravel rocks
880	900	Volcanic rock
900	910	Black rock & gravel
910	920	Black rock
920	940	Black rock & gravel
940	970	Black rock & sand
970	1074	Black rock

TOTAL DEPTH OF BORING 1074 (Feet)

TOTAL DEPTH OF COMPLETED WELL 870 (Feet)

WELL OWNER

Name City of Santa Rosa Park & Recreation

Mailing Address 100 Santa Rosa Ave

Santa Rosa (CITY) Ca (STATE) 95404 (ZIP)

WELL LOCATION

Address 1284 Martha Way;East end of Martha Way right of way

City Santa Rosa Ca 95405

County Somona County

APN Book ___ Page ___ Parcel ___

Township 7N Range 7W Section 19

Latitude 38 DEG. 26 MIN. 22.83 SEC. NORTH Longitude 122 DEG. 40 MIN. 33.9 SEC. WEST

LOCATION SKETCH

NORTH



SOUTH

Illustrate or Describe Distance of Well from Roads Buildings, Fences, Rivers etc and attach map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (X)

X NEW WELL

___ MODIFICATION/REPAIR

___ Deepen

___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (X)

WATER SUPPLY ___ Domestic X Public ___ Irrigation ___ Industrial

MONITORING X

TEST WELL ___

CATHODIC PROTECTION ___

HEAT EXCHANGE ___

DIRECT PUSH ___

INJECTION ___

VAPOR EXTRACTION ___

SPARGING ___

REMEDIATION ___

OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___

ESTIMATED YIELD ___ (GPM) & TEST TYPE ___

TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)

** May not be representative of a well's long-term yield.*

CASING (S)

DEPTH FROM SURFACE Ft. to Ft.	BORE-HOLE DIA. (inches)	TYPE (-) BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	OUTSIDE DIAMETER (inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
						See Attached Well Construction Diagram			

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft. to Ft.	TYPE CE-MENT (X)	BEN-TONITE (X)	FILL (X)	FILTER PACK (TYPE/SIZE)

ATTACHMENTS (X)

X Geologic Log

X Well Construction Diagram

X Geophysical Log(s)

___ Soil/Water Chemical Analyses

___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

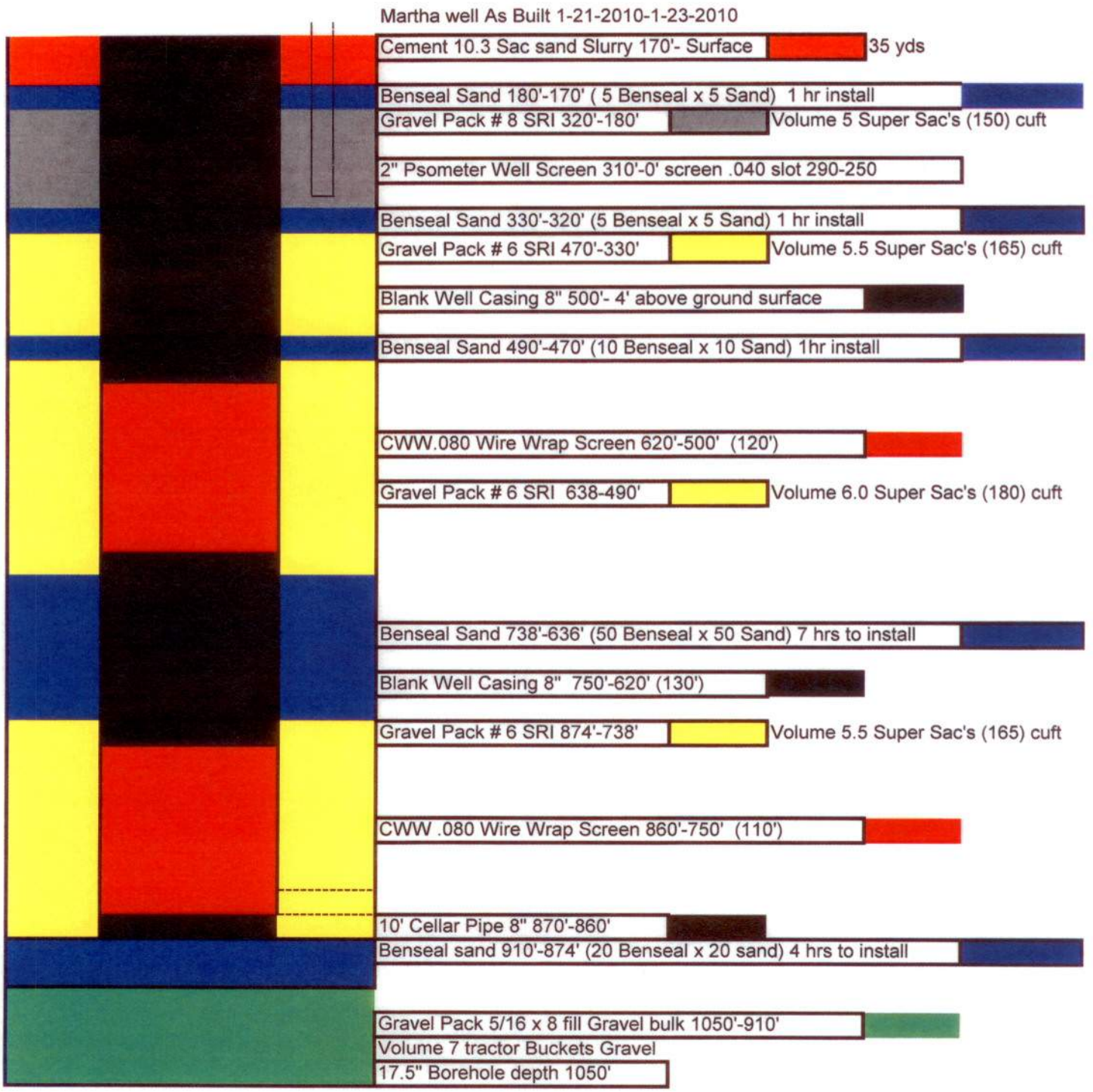
I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Layne Christensen Company (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

ADDRESS 11001 Etiwanda Ave CITY Fontana STATE Ca ZIP 92337

Signed ___ (WELL DRILLER/AUTHORIZED REPRESENTATIVE) DATE SIGNED 3/23/2010 C-57 LICENSE NUMBER 510011

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM



NOTE: Ben seal Sand Mixture is 1.7 cuft dry volume
Once seal had hydrated it averaged (2.2)-(2.5) cu ft/ft based upon borehole soundings.

welenco

5201 Woodmere Drive, Bakersfield, CA 93313-- www.welenco.com--(800) 445-9914
California Contractor's License No. 722373

ELECTRIC - GAMMA RAY - TEMPERATURE LOG

FILING NO.

COMPANY Layne Christensen Company

WELL Martha Well

FIELD Santa Rosa

STATE California COUNTY Sonoma

LOCATION:
Albert and Martha Way, Santa Rosa

OTHER SERVICES:
Caliper
Spec. GR

JOB NO.
12798

SEC: 19 TWP: 7N RGE: 7W LAT.: 38° 26' 22.6" LONG.: 122° 40' 35.4" MERIDIAN.: Mt. Diablo

Permanent Datum: Ground Level , **Elev.** 221 **Ft.** **Elev.: K.B.** ____ **Ft.**
Log Measured From: Ground Level , 0 **Ft. Above Perm. Datum** **D.F.** ____ **Ft.**
Drilling Measured From: Ground Level **G.L.** 221 **Ft.**

Run	One			
Date	Jan. 13, 2010			
Depth-Driller	1074 Ft	Ft	Ft	Ft
Depth-Logger	1077 Ft	Ft	Ft	Ft
Top Logged Interval	0 Ft	Ft	Ft	Ft
Btm. Logged Interval	1075 Ft	Ft	Ft	Ft
Casing-Driller	20 In @ 50 Ft	In @ Ft	In @ Ft	In @ Ft
Casing-Logger	20 In @ 50 Ft	In @ Ft	In @ Ft	In @ Ft
Bit Size	17.5 In	In	In	In
Time On Bottom	0000			
Type Fluid In Hole	Gel			
Density / Viscosity				
pH / Fluid Loss	ml	ml	ml	ml
Source of Sample	Tank			
Rm @ Measured Temp.	11.6 @ 75 °F	@ °F	@ °F	@ °F
Rmf @ Measured Temp.	10.6 @ 75 °F	@ °F	@ °F	@ °F
Rmc @ Measured Temp.	@ °F	@ °F	@ °F	@ °F
Source Rmf / Rmc	meas			
Rm @ BHT	@ °F	@ °F	@ °F	@ °F
Time Since Circulation	13 Hr	Hr	Hr	Hr
Max. Rec. Temp.	73 °F	°F	°F	°F
Van No. / Location	LV-1 Bfld			
Recorded By	Dan Ihde			
Witnessed By	Steve Gillman			

Miscellaneous Information

A recreational GPS accurate to +/- 45 feet set for Datum NAD27 was used to calculate Latitude, Longitude & Elevation values. The Section, Township, and Range then determined using the TRS program (TRS accuracy is not guaranteed). The TRS program converts Latitude and Longitude to Section, Township, and Range. The NOTICE at the bottom of this heading also applies.

Drilled by: Layne Christensen

NOTICE

All interpretations are opinions based on inferences from electrical and other measurements and we do not guarantee the accuracy or correctness of any verbal or written interpretation, and we shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages or expenses incurred or sustained by anyone resulting from any interpretation made by one of our officers, agents or employees. These interpretations are also subject to our General Terms and Conditions as set out in our current Price Schedule.

welenco, inc. January 13, 2010

Layne Christensen Company Martha Well Jan 13, 2010 Job Ticket: 12798

ELECTRIC - GAMMA RAY - TEMPERATURE LOG

DEPTHS

Single Page

0 64 Inch Normal (ohmmeter²/m) x10 2000

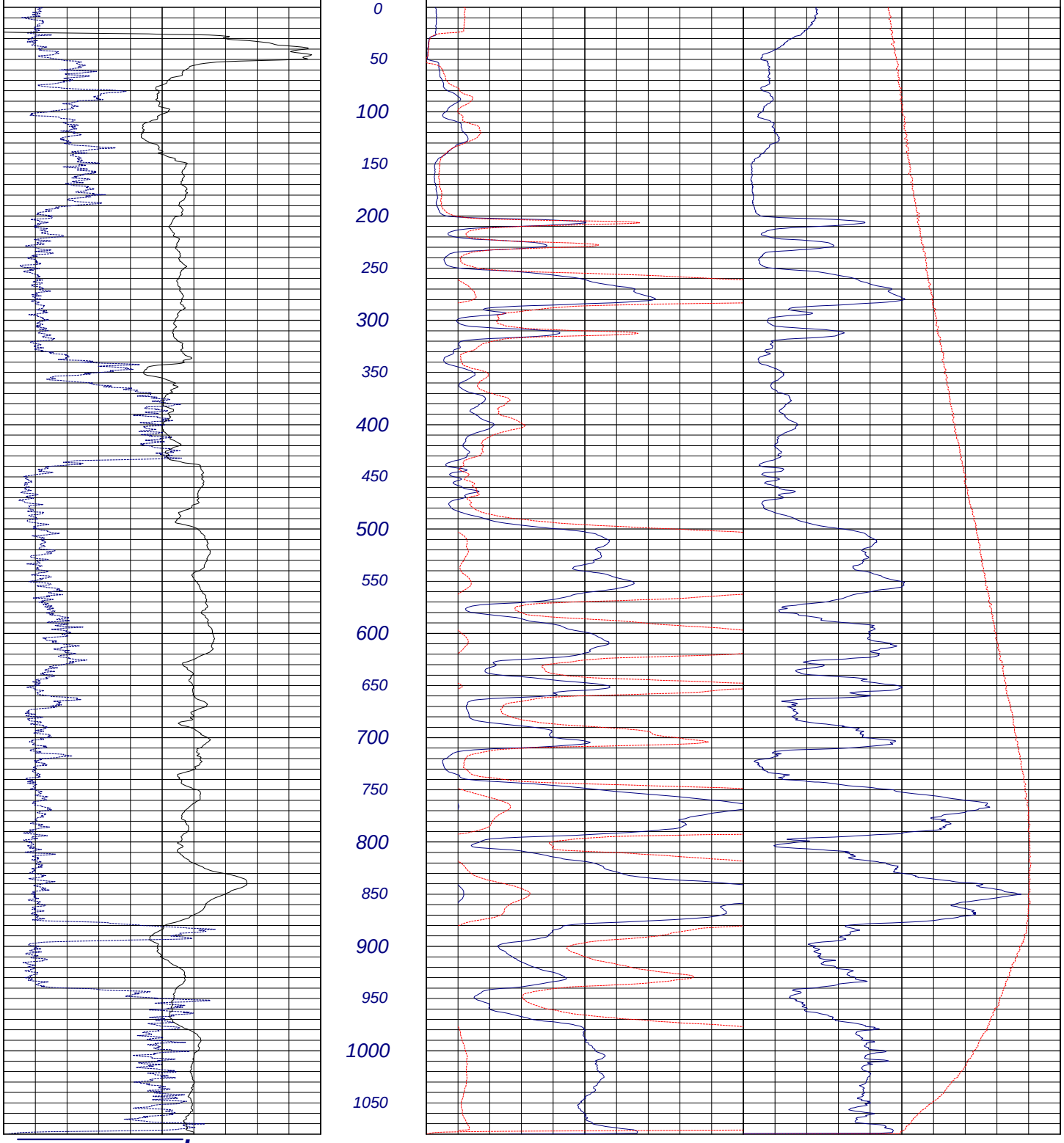
0 64 Inch Normal (ohmmeter²/m) 200

< - S.P. (10 mV/div) + >

0 16 Inch Normal (ohmmeter²/m) x10 2000 | 10 Single Point (ohms) 60

0 Gamma Ray (api) 150

0 16 Inch Normal (ohmmeter²/m) 200 | 64 Temperature (ºF) 74



welenco
CA. Contractor's License: 722373
Phone: (800) 445-9914 Fax: (661) 834-2550 Email: welenco@welenco.com Web: www.welenco.com
(Prepared with Log Print, a professional software application developed by welenco, inc.)

City of Santa Rosa Test Well – Martha Way

Site Name: Martha Way Test Well
Street Location: 1284 Martha Way, Santa Rosa California, 95405
APN: 014-342-015
Latitude: N 38°26'23.0"
Longitude: W 122°40'33.7"
Surface Elevation: 212'



Surface Completion

Drill Equipment:	DR-10K-1	**Logged by:**	ECON
Drill Method:	Reverse Rotary	**Professional Geologist:**	Chris Johnson
Driller:	Richard Crosby	**Total Depth of Test Well:**	870'
Drilling Started:	11/13/09	**Total Depth of Piezometer:**	300'
Drilling Completed:	01/12/10	**Depth of Conductor:**	50'
Sampling Completed:	01/12/10	**Conductor Casing Diameter:**	30"
Well Completed:	01/25/10	**Test Hole Diameter:**	17.5"
Well Developed:	02/20/10	**Well Casing Material:**	Low Carbon Steel
Pumping Test Started:	02/21/10	**Well Casing Diameter:**	8"
Pumping Tests Completed:	03/17/10	**Cellar:**	10'
DWR Submitted:	03/23/10	**Number of screened sections:**	2
		Screen Type:	8" Diameter Continuous Wire Wrap, 0.08" Slot
		Well Head Completion:	Locked Steel Enclosure

Ground Water Samples Collected:
03/02/10, 03/08/10, 03/11/10, 03/12/10, 03/17/10

Initial Water Level: -
Static Water Level: 19' on 2/24/10

Findings reported in (citation): ECON. 2011. *Martha Way Test Well Construction Report, Santa Rosa, California.*

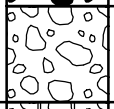
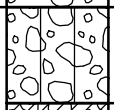
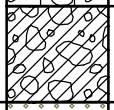
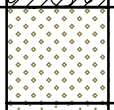
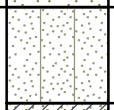
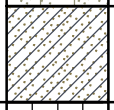
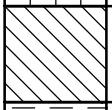
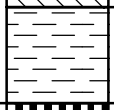
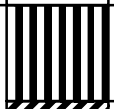
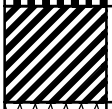
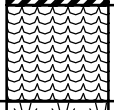
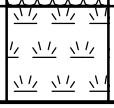
Drilled For: Mike Prinz
69 Stony Circle
Santa Rosa, CA 95401
707-543-4288

Drilled by: Steve Gillman
11001 Etiwanda Ave.
Fontana, CA 92337
909-390-2833

Managed by: Andy Rodgers
241 S Main St.
Sebastopol, CA 95472
707-823-2324

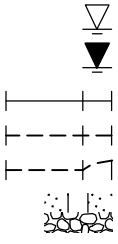
E-logging by: Mark Sharpless
5201 Woodmere Dr.
Bakersfield, CA 93313
661-834-2550

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS					TYPICAL NAMES
COARSE GRAINED SOILS MORE THAN HALF IS COARSER THAN NO. 200 SIEVE	GRAVELS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS WITH OR WITHOUT SAND, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS WITH OR WITHOUT SAND, LITTLE OR NO FINES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, SILTY GRAVELS WITH SAND
				GC	CLAYEY GRAVELS, CLAYEY GRAVELS WITH SAND
	SANDS MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, WITH OR WITHOUT GRAVEL, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS WITH OR WITHOUT GRAVEL, LITTLE OR NO FINES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, WITH OR WITHOUT GRAVEL
				SC	CLAYEY SANDS, WITH OR WITHOUT GRAVEL
FINE GRAINED SOILS MORE THAN HALF IS FINER THAN NO. 200 SIEVE	SILTS AND CLAYS LIQUID LIMIT 50% OR LESS			ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTS WITH SANDS AND GRAVELS
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, CLAYS WITH SANDS AND GRAVELS, LEAN CLAYS
				OL	ORGANIC SILTS OR CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS LIQUID LIMIT GREATER THAN 50%			MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
				OH	ORGANIC SILTS OR CLAYS OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS				PT	PEAT AND OTHER HIGHLY ORGANIC SOILS

☐ Soil sample not attempted

12-16-23 (39) Blows/6 inches: Blows required to drive sampler a one-half foot interval using hammer weight of 140 pounds falling 30 inches. (SPT N value): Sum of blows from 2nd and 3rd interval.



First encountered saturated soil

Measured/Static Groundwater Level

Defined boundary between lithologic units

Approximated boundary between lithologic units

Estimated gradational boundary between lithologic units

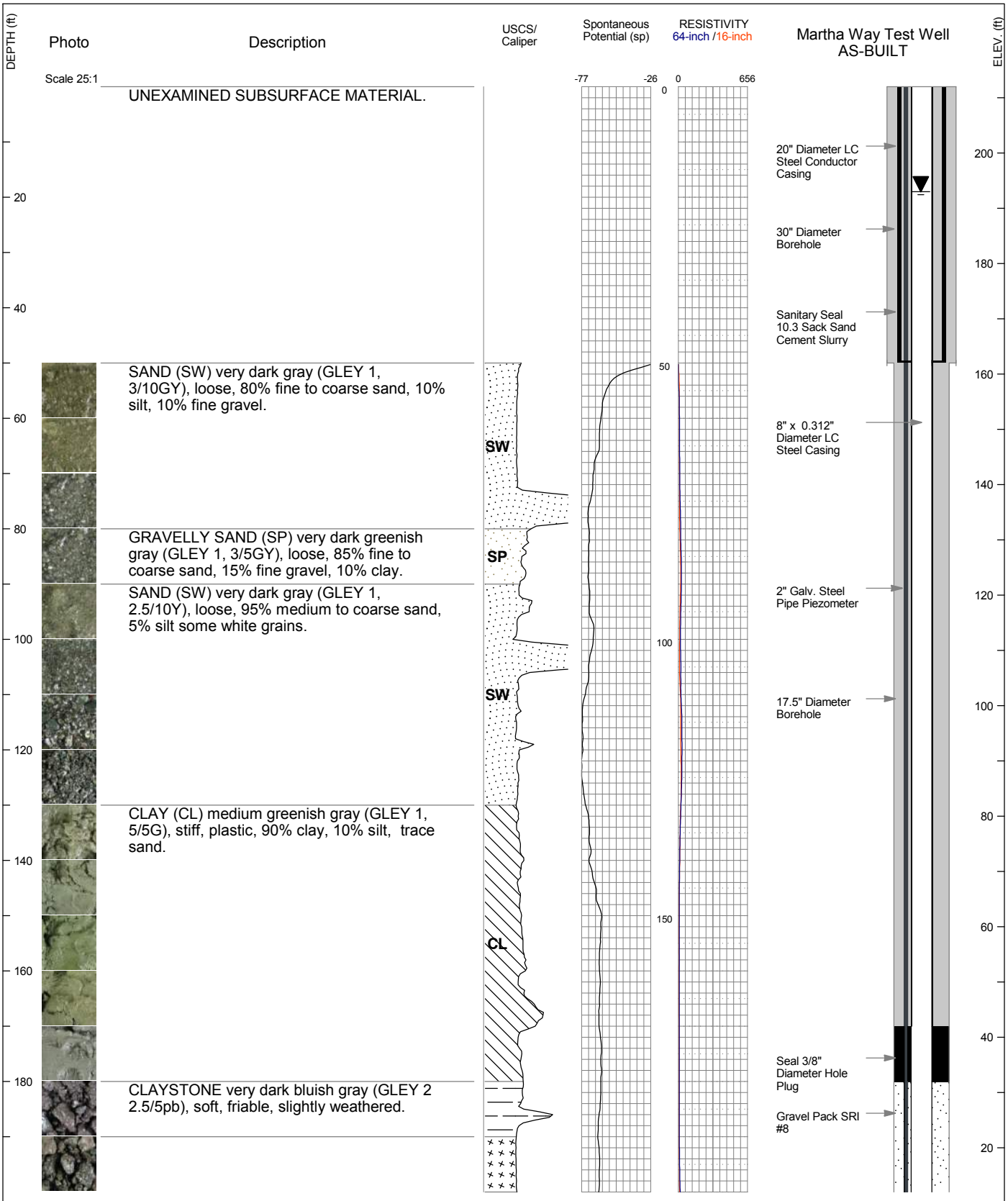
Sand- or Gravelpack and/or Slough - Well Completion to TD

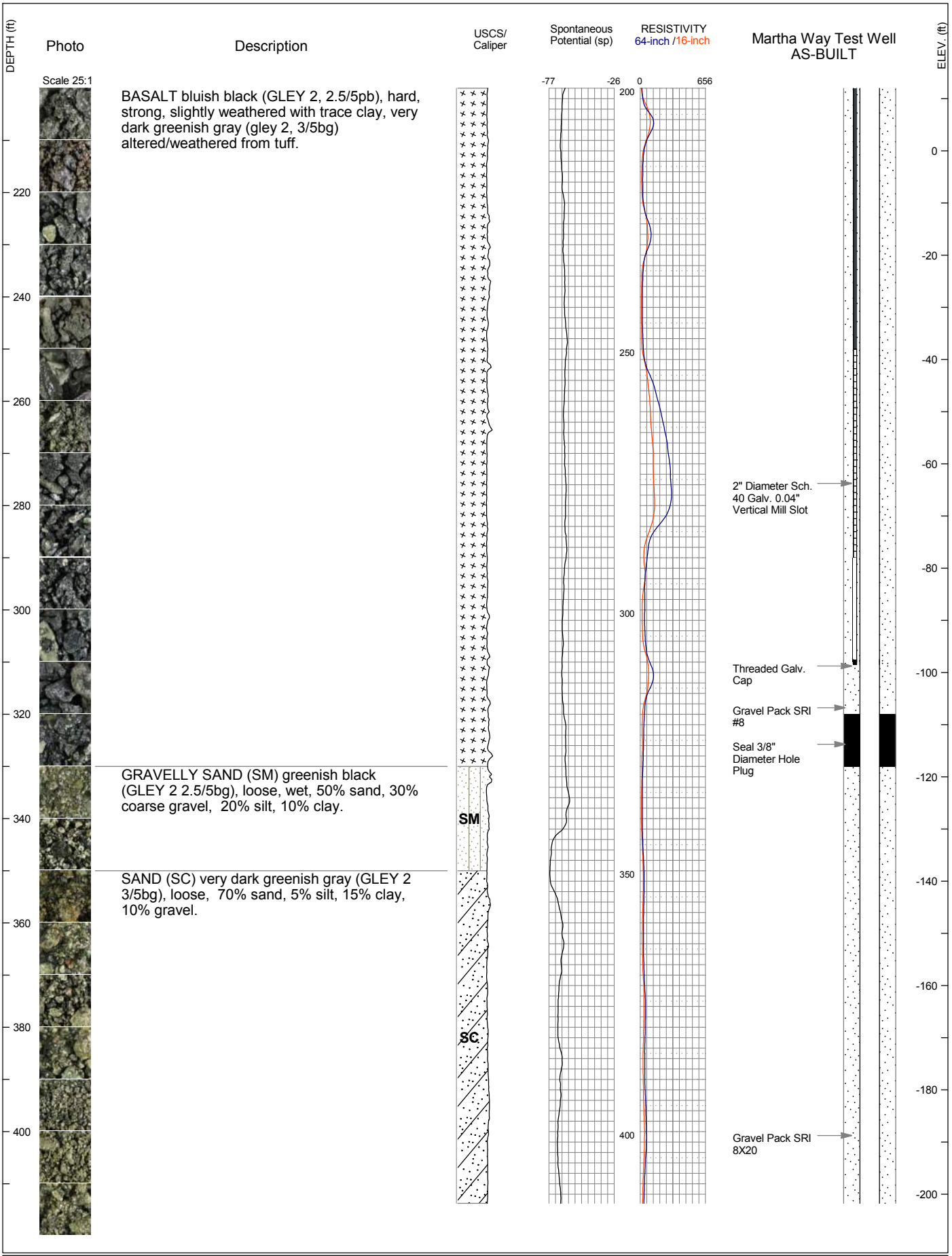
ECON

Log Symbols and Explanation

City of Santa Rosa Public Works
Martha Way Test Well
1284 Martha Way
Santa Rosa, CA 95401

ECON
241 S Main Street
Sebastopol, CA 95472
Telephone: 707.823.2324




DEPTH (ft)
Photo
Description
USCS/ Caliper
Spontaneous Potential (sp)
RESISTIVITY 64-inch /16-inch
Martha Way Test Well AS-BUILT
ELEV. (ft)
Scale 25:1
BASALT bluish black (GLEY 2, 2.5/5pb), hard, strong, slightly weathered with trace clay, very dark greenish gray (gley 2, 3/5bg) altered/weathered from tuff.
GRAVELLY SAND (SM) greenish black (GLEY 2 2.5/5bg), loose, wet, 50% sand, 30% coarse gravel, 20% silt, 10% clay.
SAND (SC) very dark greenish gray (GLEY 2 3/5bg), loose, 70% sand, 5% silt, 15% clay, 10% gravel.
SM
SC
-77
-26
0
656
2" Diameter Sch. 40 Galv. 0.04" Vertical Mill Slot
Threaded Galv. Cap
Gravel Pack SRI #8
Seal 3/8" Diameter Hole Plug
Gravel Pack SRI 8X20

DEPTH (ft)

Photo

Scale 25:1

Description

SAND (SC) very dark greenish gray (GLEY 2 3/5bg), loose, 70% sand, 5% silt, 15% clay, 10% gravel.

BASALT black (GLEY 1 2.5/n), hard, moderately strong, slightly weathered, vesicular with siltstone, grayish green, friable, weak, moderately weathered/altered .

SANDY SILT (ML) greenish black (GLEY 1 2.5/10y), dense, wet, fine to coarse grained, larger grains are mainly white, some green, smaller grains are red.

BASALT bluish black (GLEY 2 2.5/5pb), hard, moderately strong, fresh with 5% siltstone, dark greenish gray (gley1, 4/5g), soft, plastic, slightly weathered/altered from volcanic .

USCS/ Caliper

SC

ML

Spontaneous Potential (sp)

-77 -26

RESISTIVITY 64-inch /16-inch

0 656

Martha Way Test Well AS-BUILT

Gravel Pack SRI 8X20

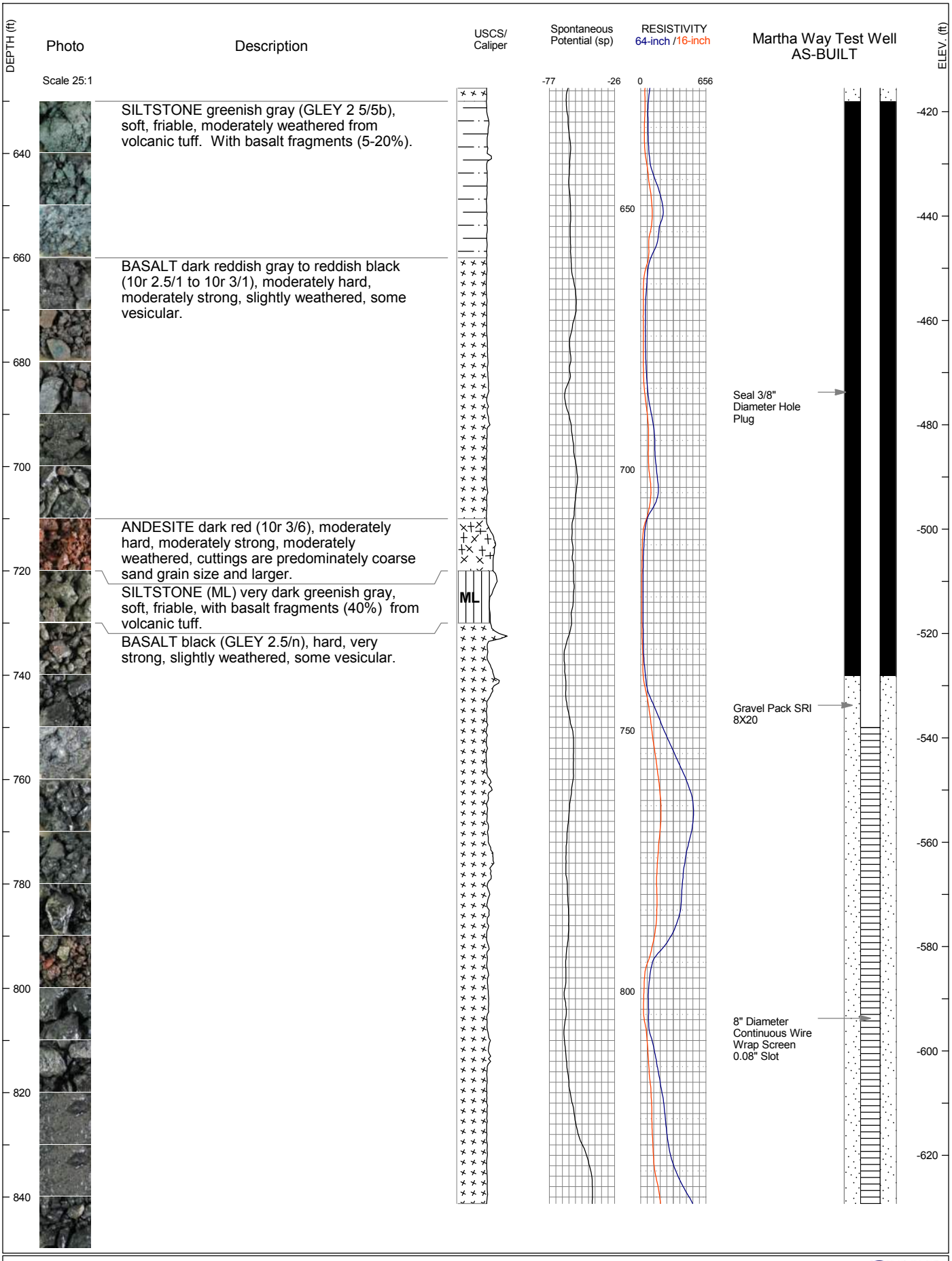
Seal 3/8" Diameter Hole Plug

Gravel Pack SRI 8X20

8" Diameter Continuous Wire Wrap Screen 0.08" Slot

ELEV. (ft)




DEPTH (ft)
Photo
Description
Scale 25:1
USCS/ Caliper
Spontaneous Potential (sp)
RESISTIVITY 64-inch /16-inch
-77
-26
0
656
Martha Way Test Well AS-BUILT
ELEV. (ft)
SILTSTONE greenish gray (GLEY 2 5/5b), soft, friable, moderately weathered from volcanic tuff. With basalt fragments (5-20%).
BASALT dark reddish gray to reddish black (10r 2.5/1 to 10r 3/1), moderately hard, moderately strong, slightly weathered, some vesicular.
ANDESITE dark red (10r 3/6), moderately hard, moderately strong, moderately weathered, cuttings are predominately coarse sand grain size and larger.
SILTSTONE (ML) very dark greenish gray, soft, friable, with basalt fragments (40%) from volcanic tuff.
BASALT black (GLEY 2.5/n), hard, very strong, slightly weathered, some vesicular.
ML
640
650
660
680
700
720
740
750
760
780
800
820
840
-420
-440
-460
-480
-500
-520
-540
-560
-580
-600
-620
Seal 3/8" Diameter Hole Plug
Gravel Pack SRI 8X20
8" Diameter Continuous Wire Wrap Screen 0.08" Slot

DEPTH (ft)

Photo

Description

Scale 25:1

BASALT black (GLEY 2.5/n), hard, very strong, slightly weathered, some vesicular.

50% ANDESITE dark reddish gray (2.5yr 3/2), moderately hard, moderately strong, moderately weathered, some vesicles and 50% basalt, black (gley 1 2.5/n), moderately hard, moderately strong, moderately weathered.

BASALT black (GLEY 1 2.5/n), hard, strong, fresh.

USCS/ Caliper

Spontaneous Potential (sp)

RESISTIVITY 64-inch /16-inch

-77 -26 0 656

Martha Way Test Well AS-BUILT

8" Diameter Continuous Wire Wrap Screen 0.08" Slot

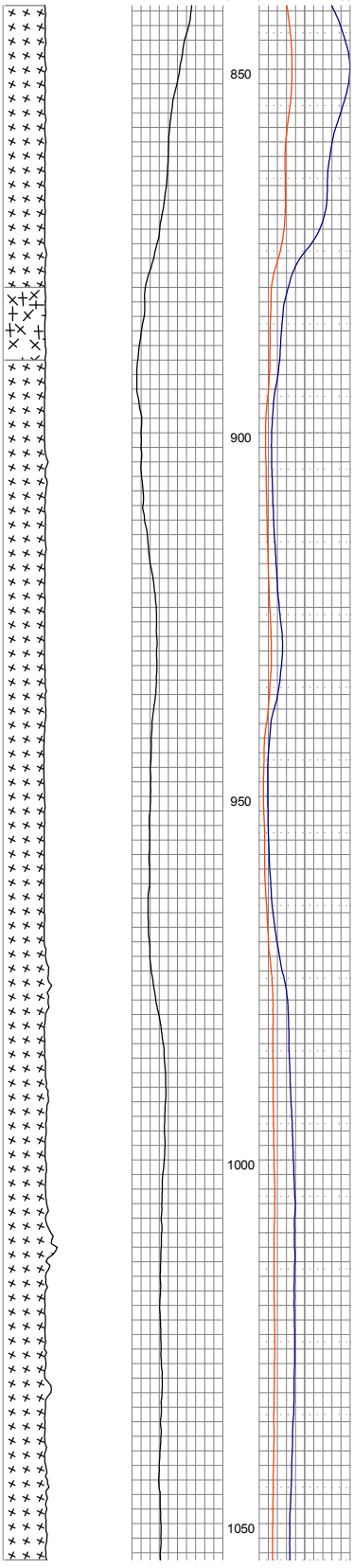
Bull Nose Cap

Seal 3/8" Diameter Hole Plug

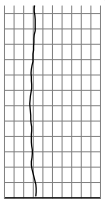
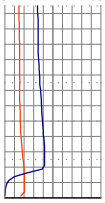
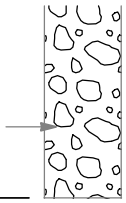
Gravel Fill (NORCAL)

ELEV. (ft)







DEPTH (ft)	Photo	Description	USCS/ Caliper	Spontaneous Potential (sp)	RESISTIVITY 64-inch /16-inch	Martha Way Test Well AS-BUILT	ELEV. (ft)
	Scale 25:1			-77 -26	0 656		
1060		BASALT black (GLEY 1 2.5/n), hard, strong, fresh.				Gravel Fill (NORCAL) 	-860
1080							

Appendix B – Video Survey

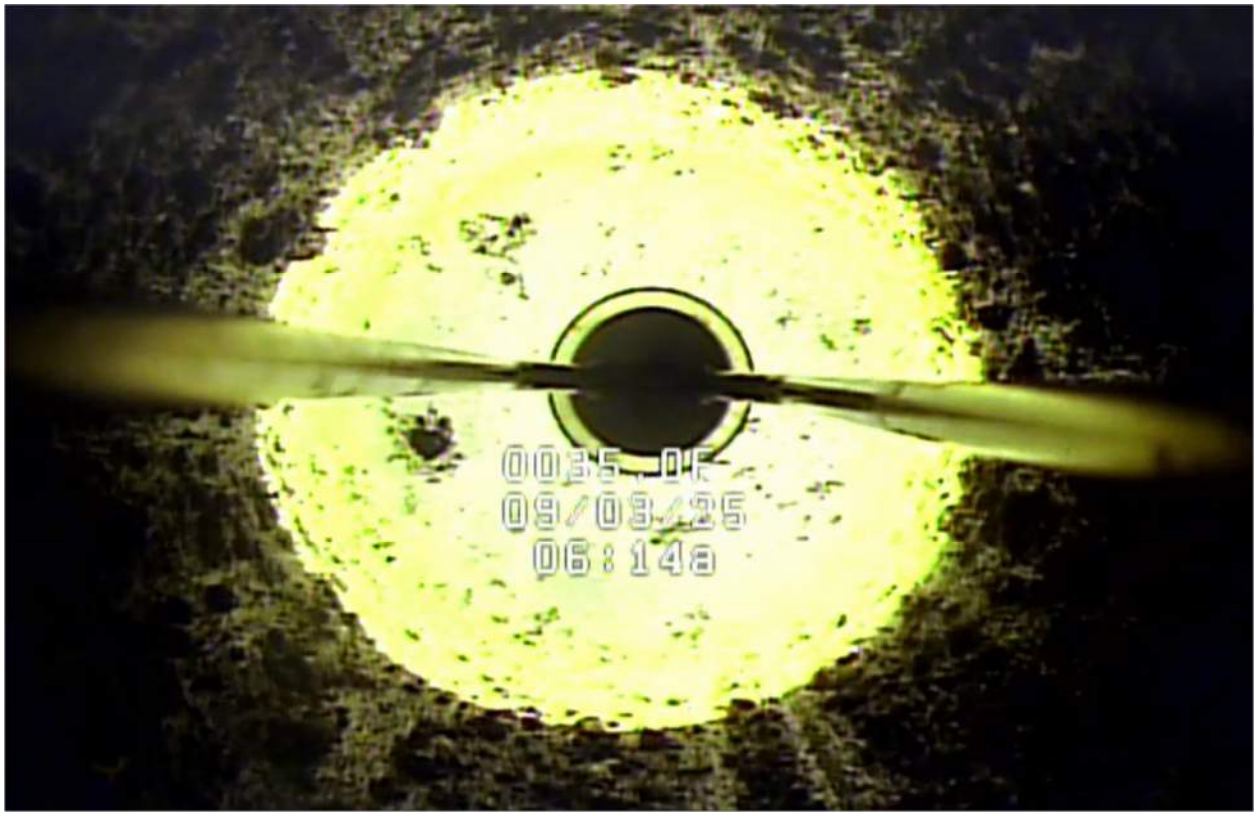




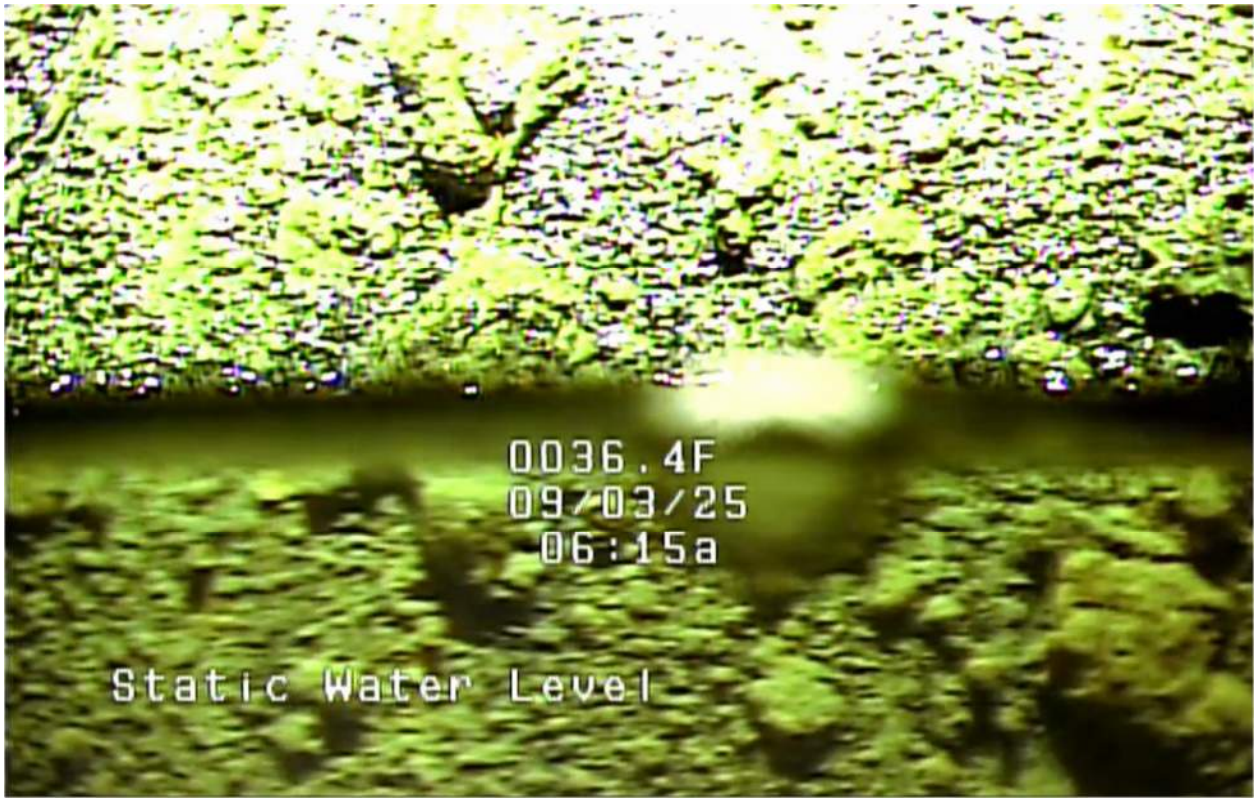
Vertical view



Side View



Light in water at 35.0’ **Light touched water at 34.8’** **Light fully submerged at 35.2’**



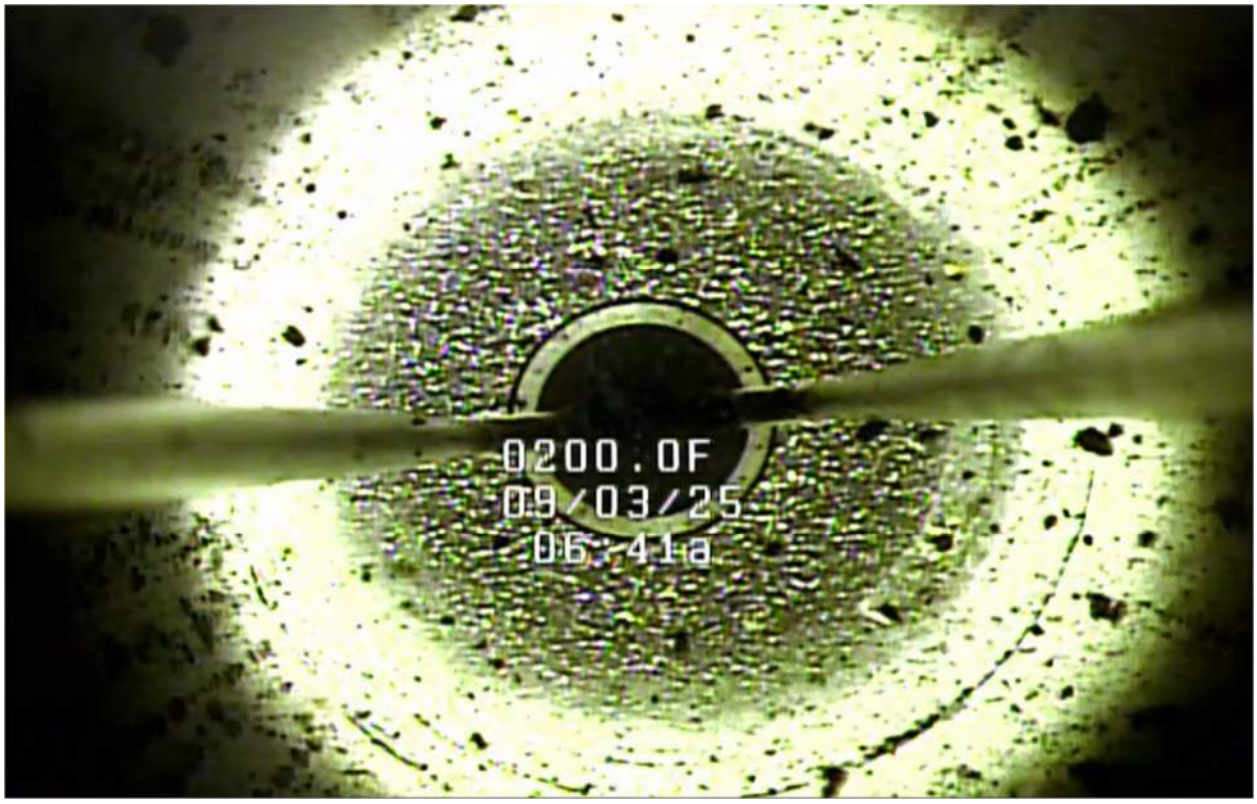
Side View: Static WL in well at 36.4'

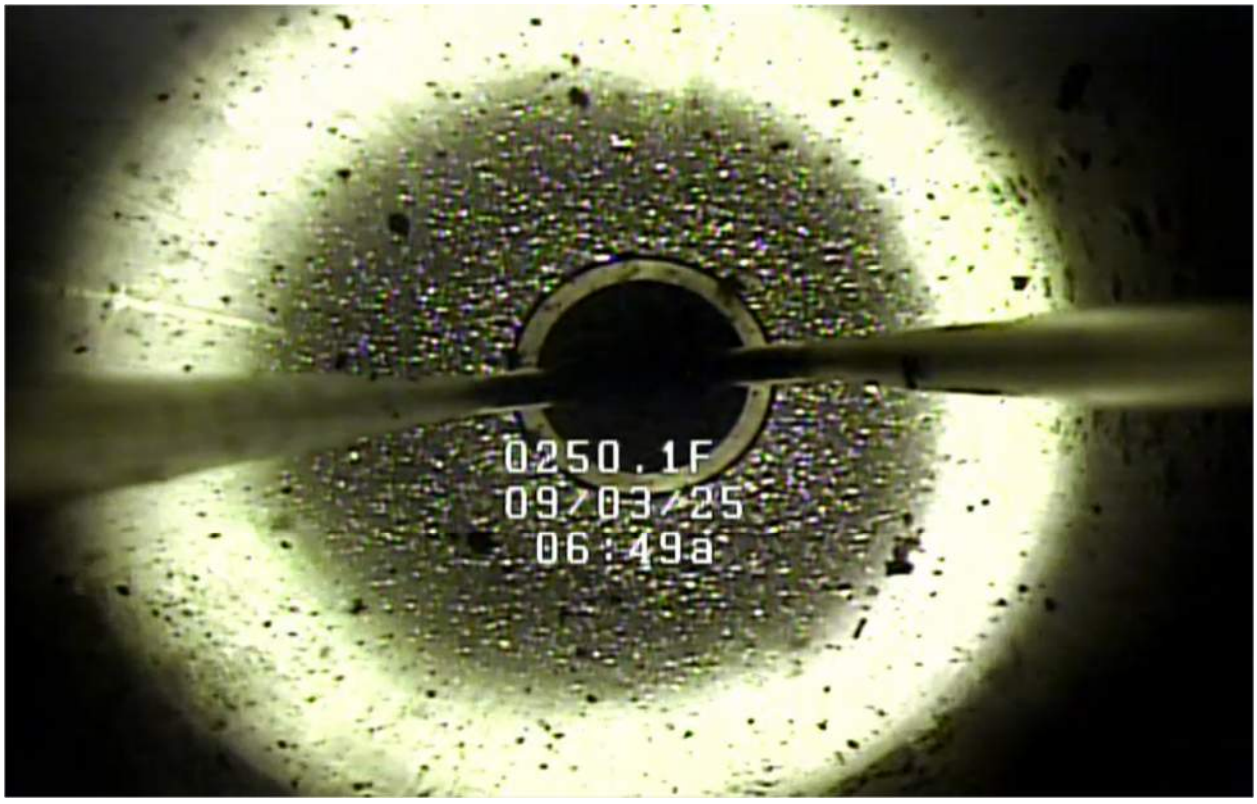


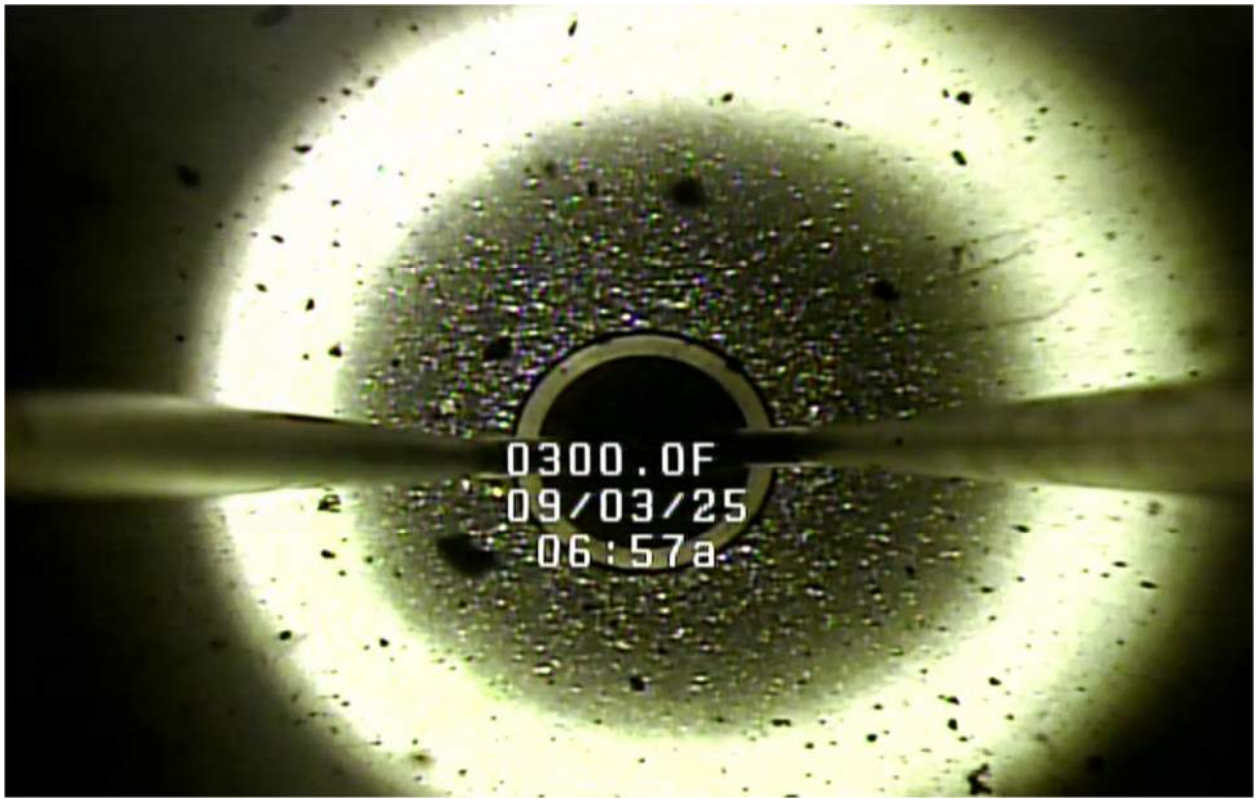
Rust scale on sidewall disturbed by camera system and particles falling to bottom of well

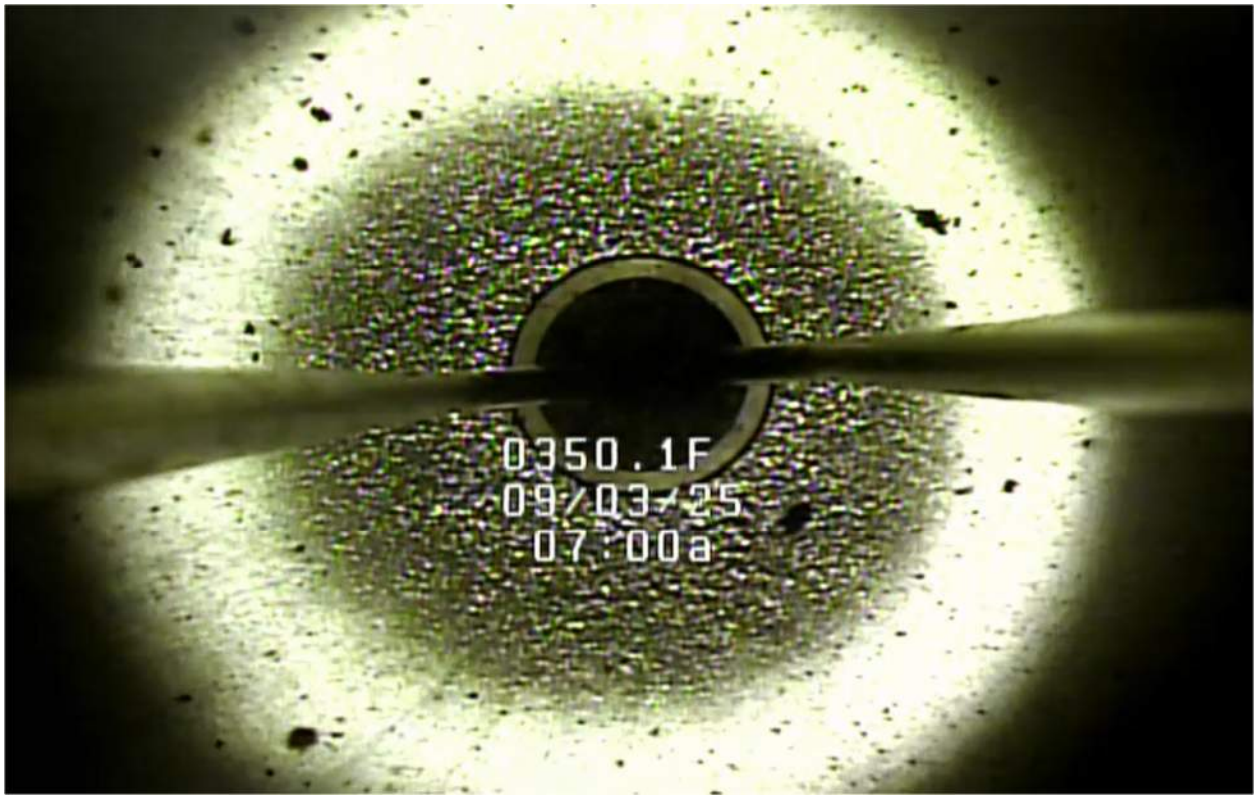

0100.0F
09/03/25
06:27a

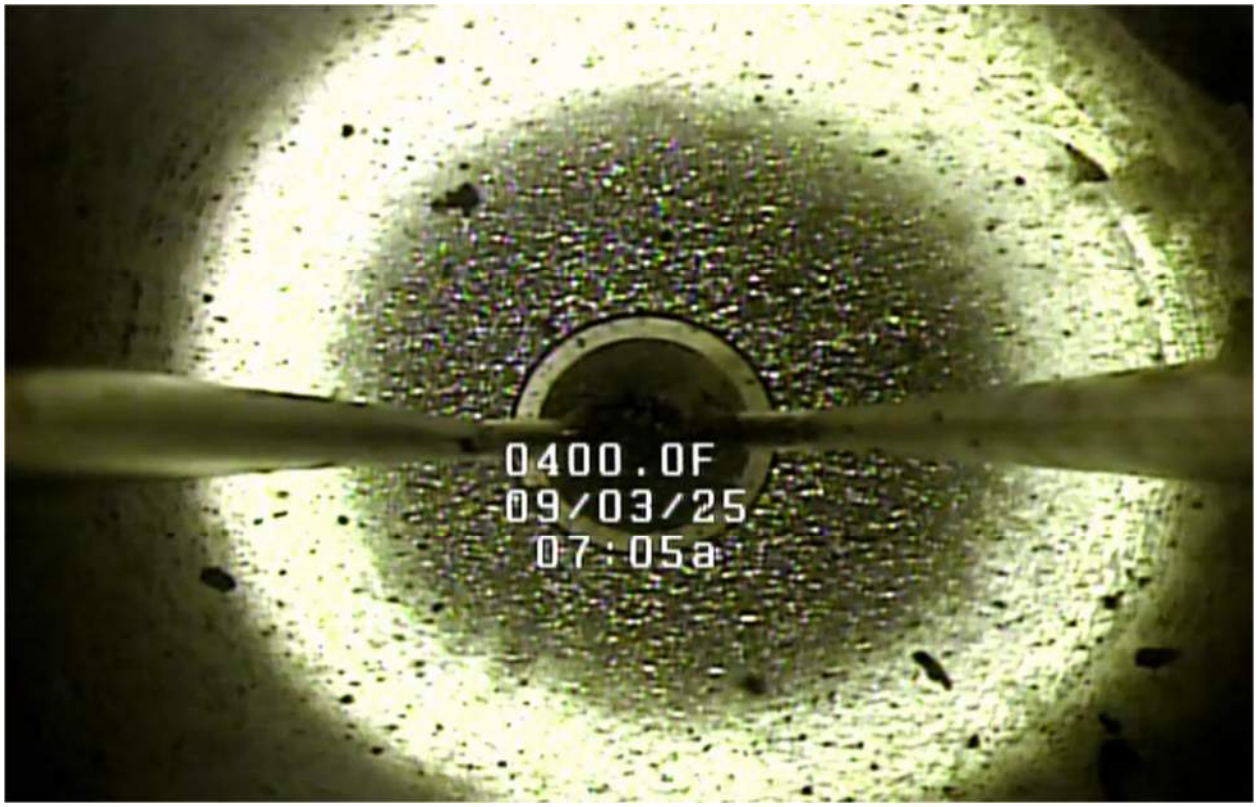

0150.0F
09/03/25
06:35a

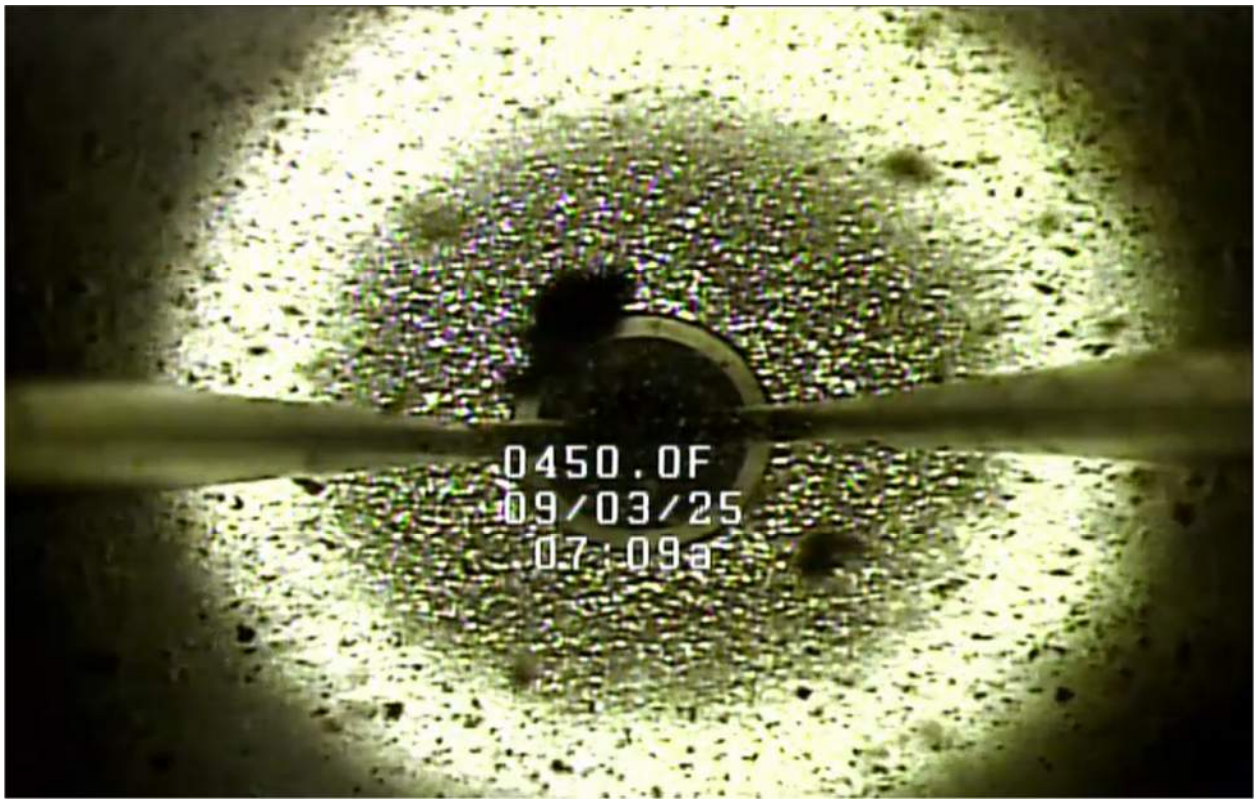

0200.0F
09/03/25
06:41a

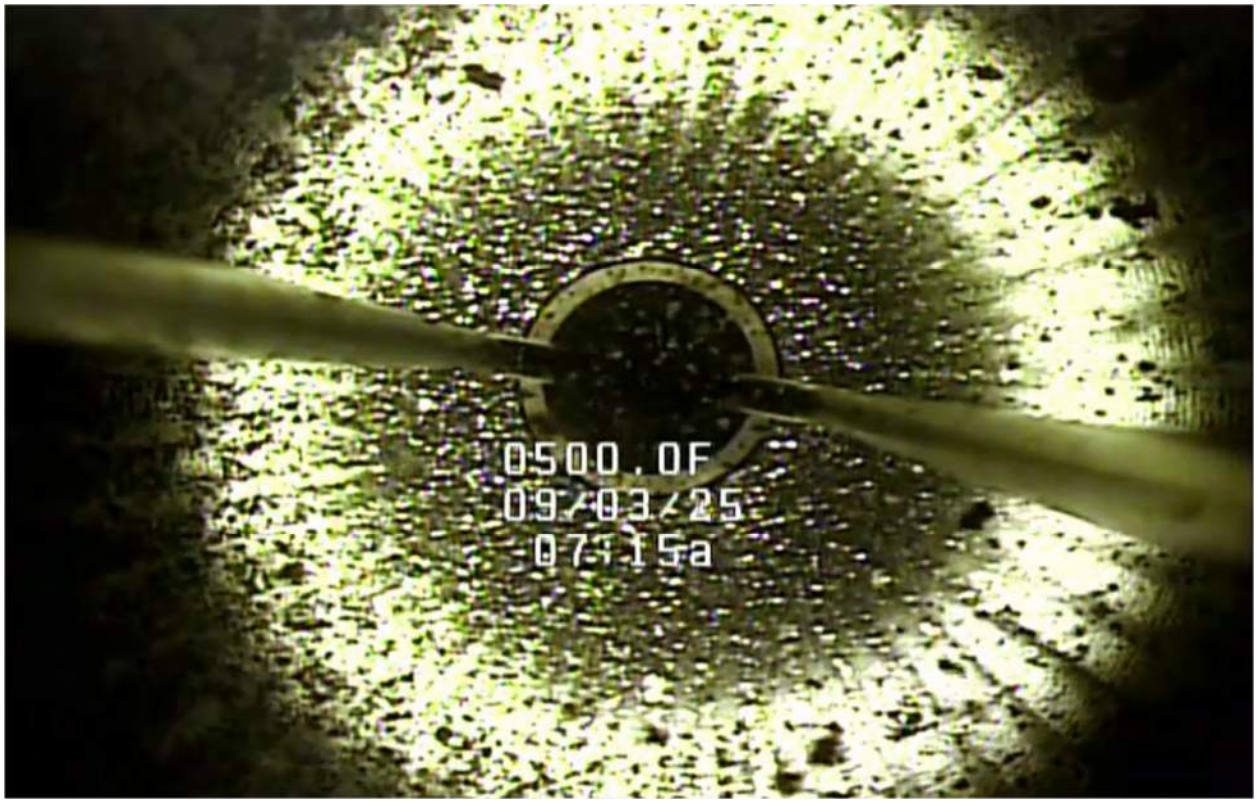

0250.1F
09/03/25
06:49a


0300.0F
09/03/25
06:57a


0350.1F
09/03/25
07:00a


0400.0F
09/03/25
07:05a


0450.0F
09/03/25
07:09a



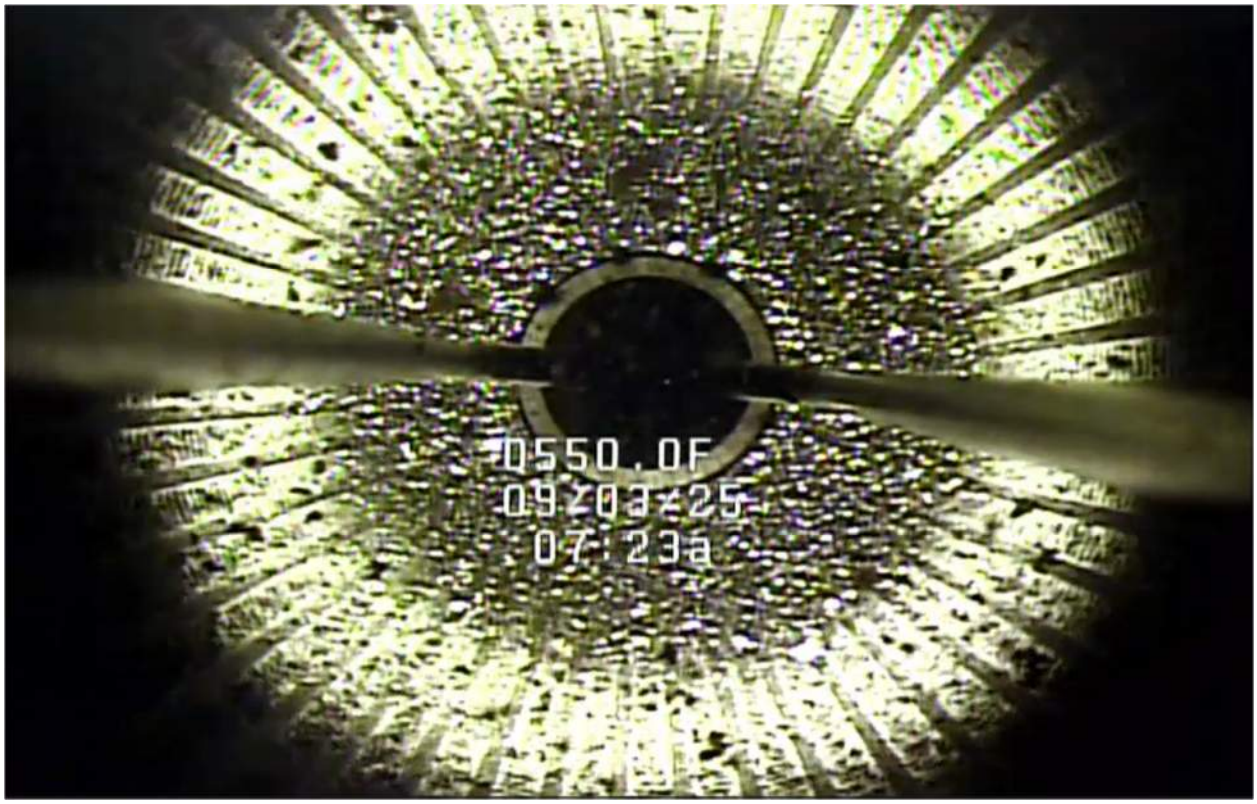
Top of Upper Screen



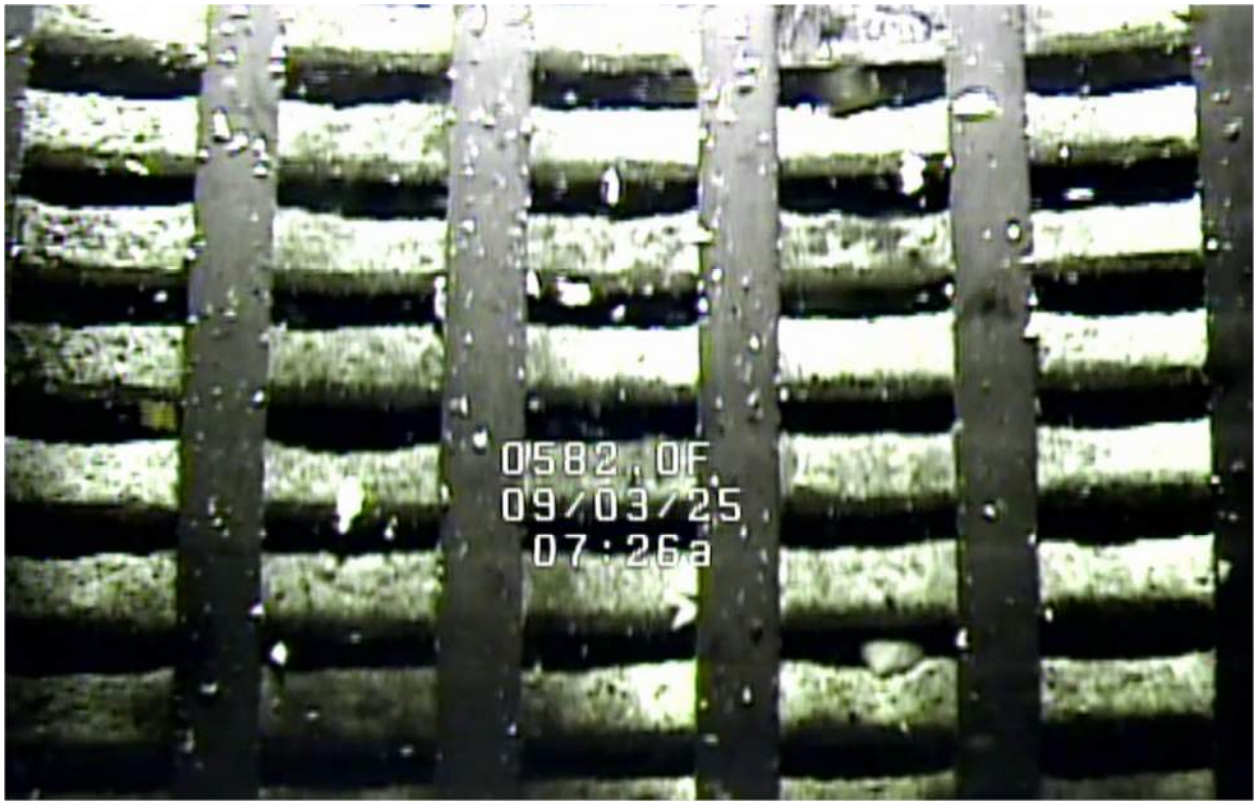
Side View: Top of Upper Screen



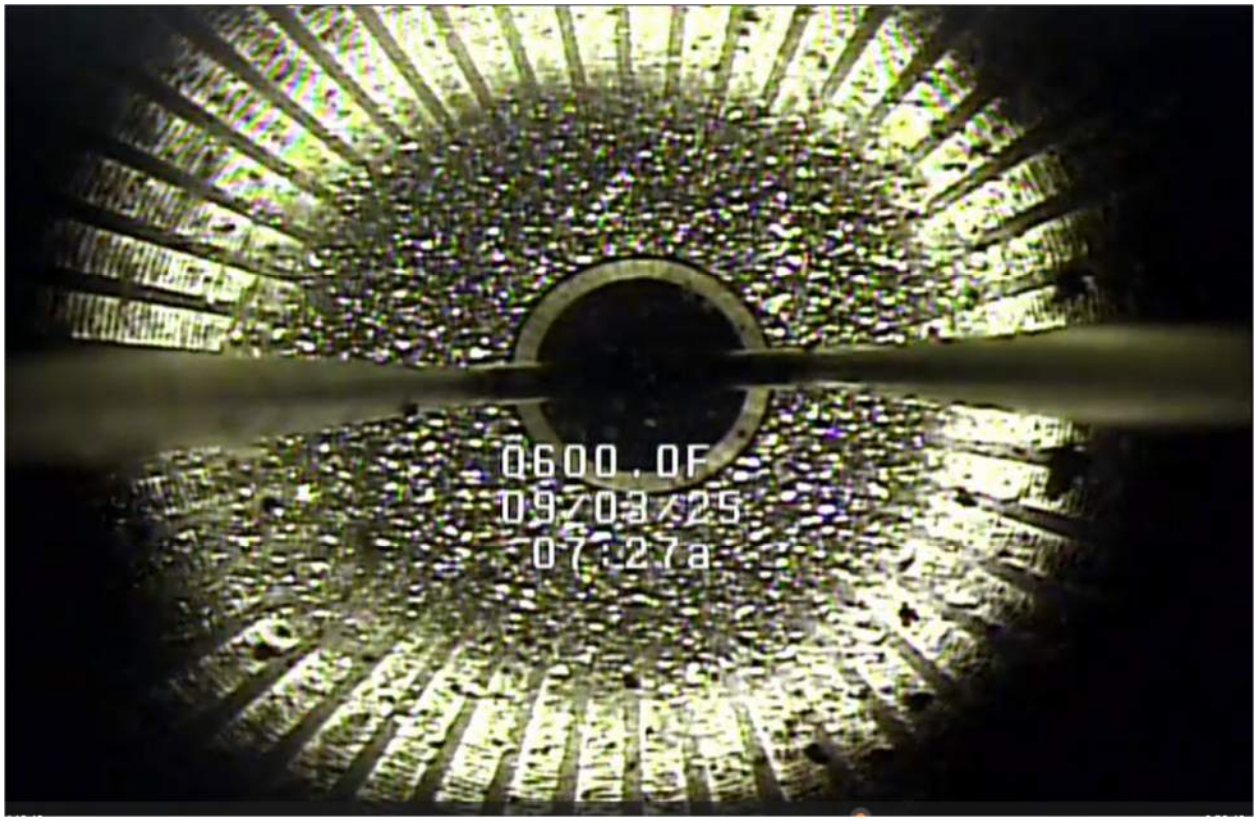
Side View

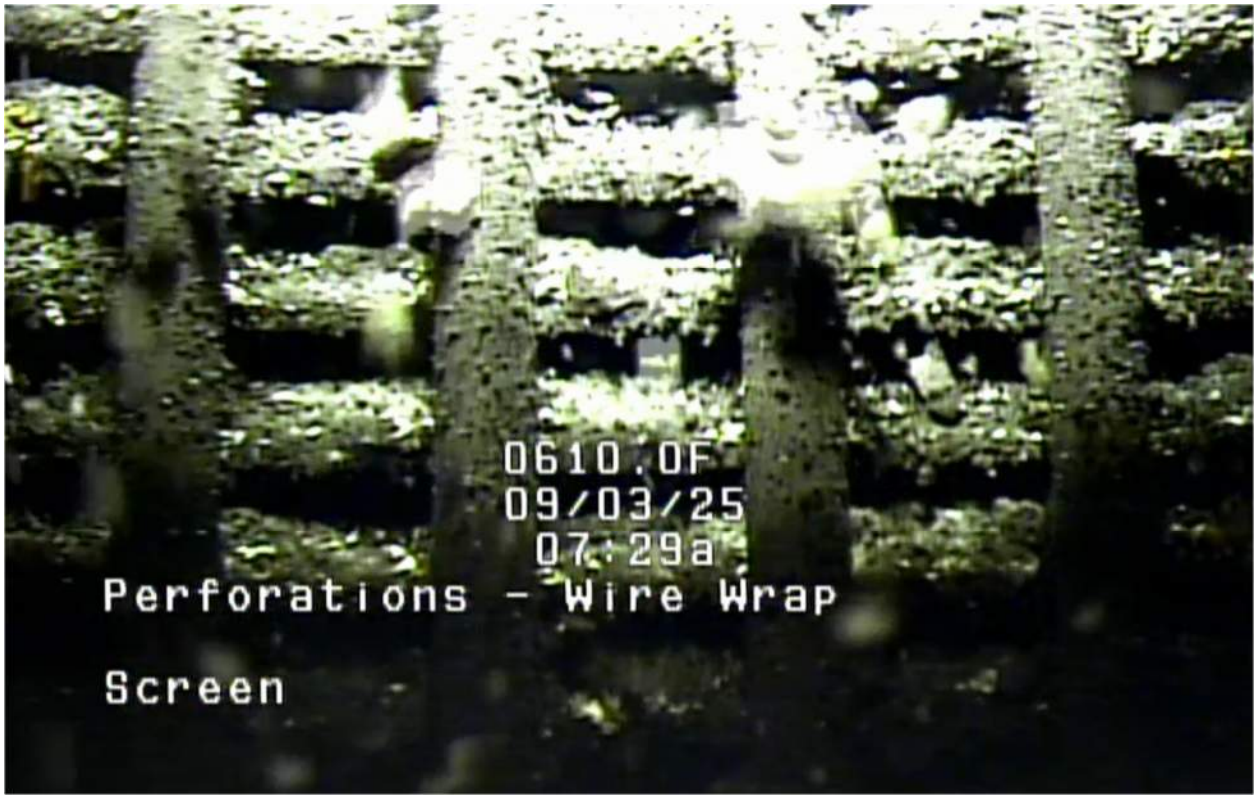


Screen at 550’

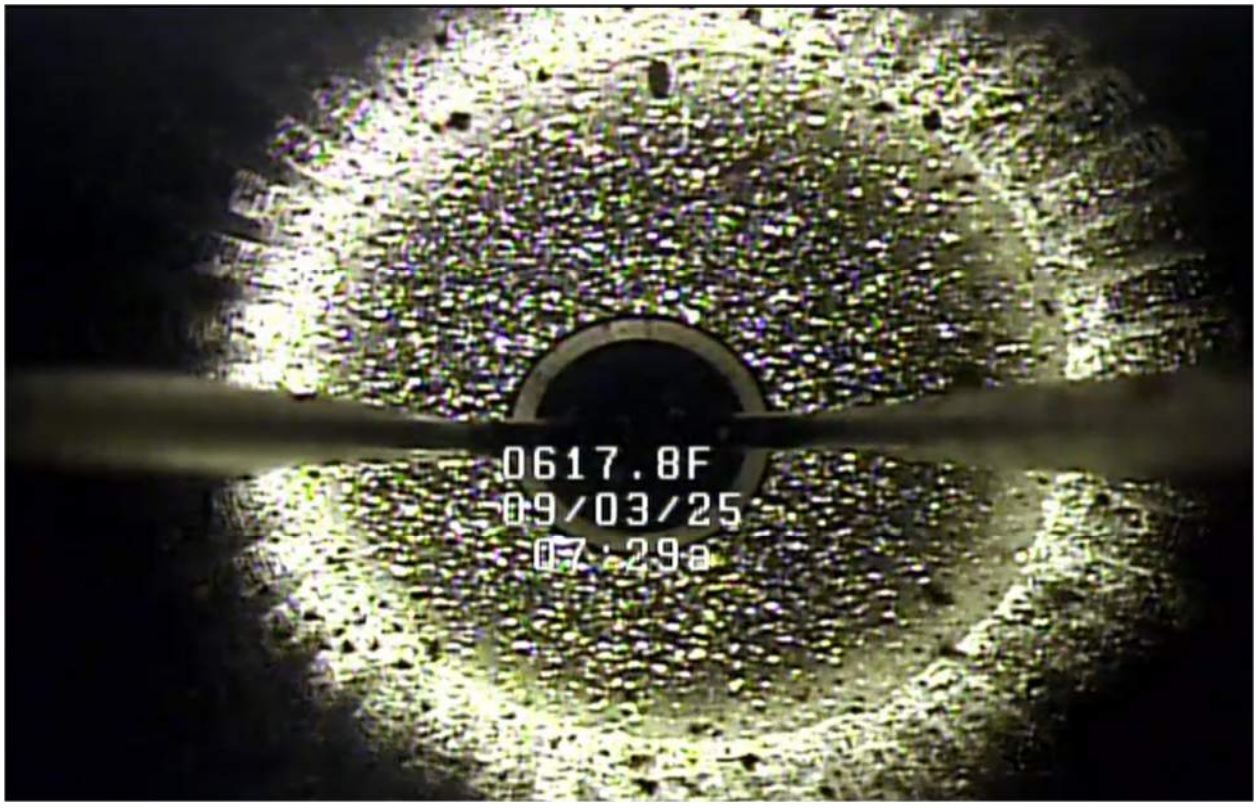


Side View: Screen at 582'

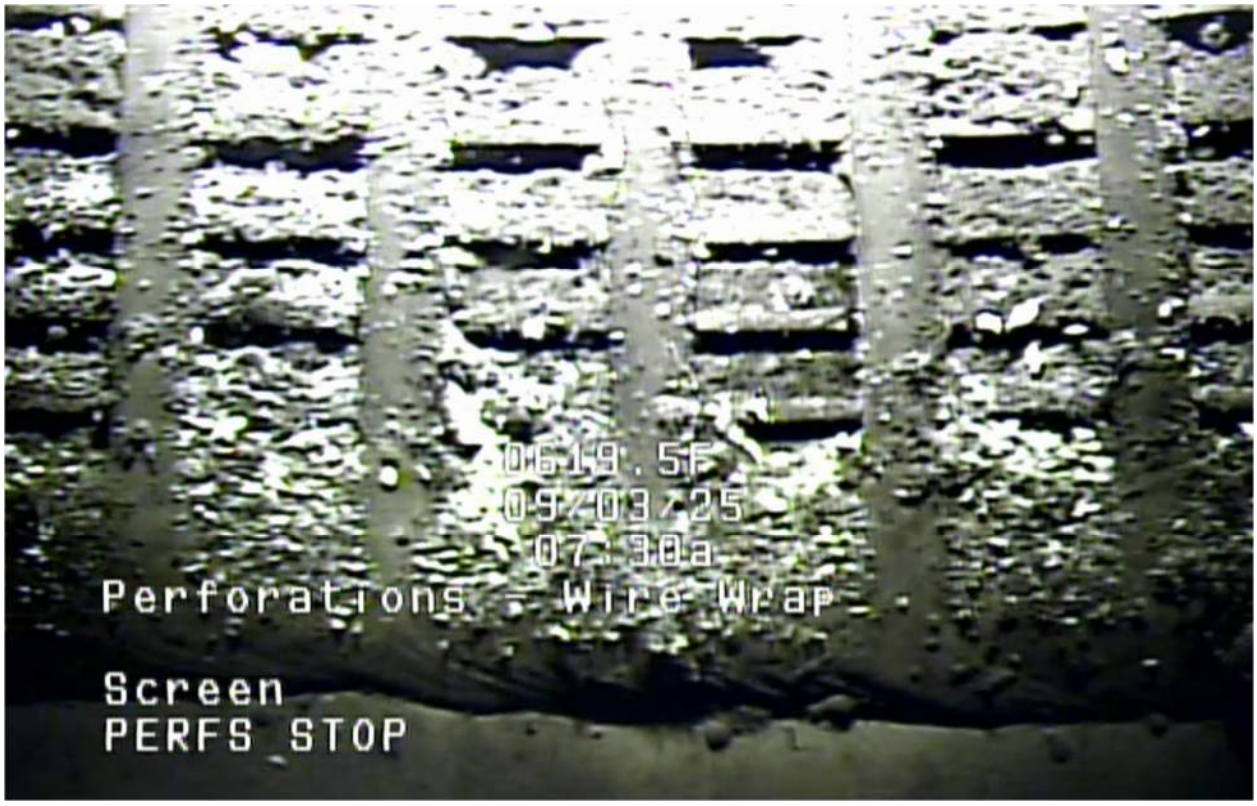




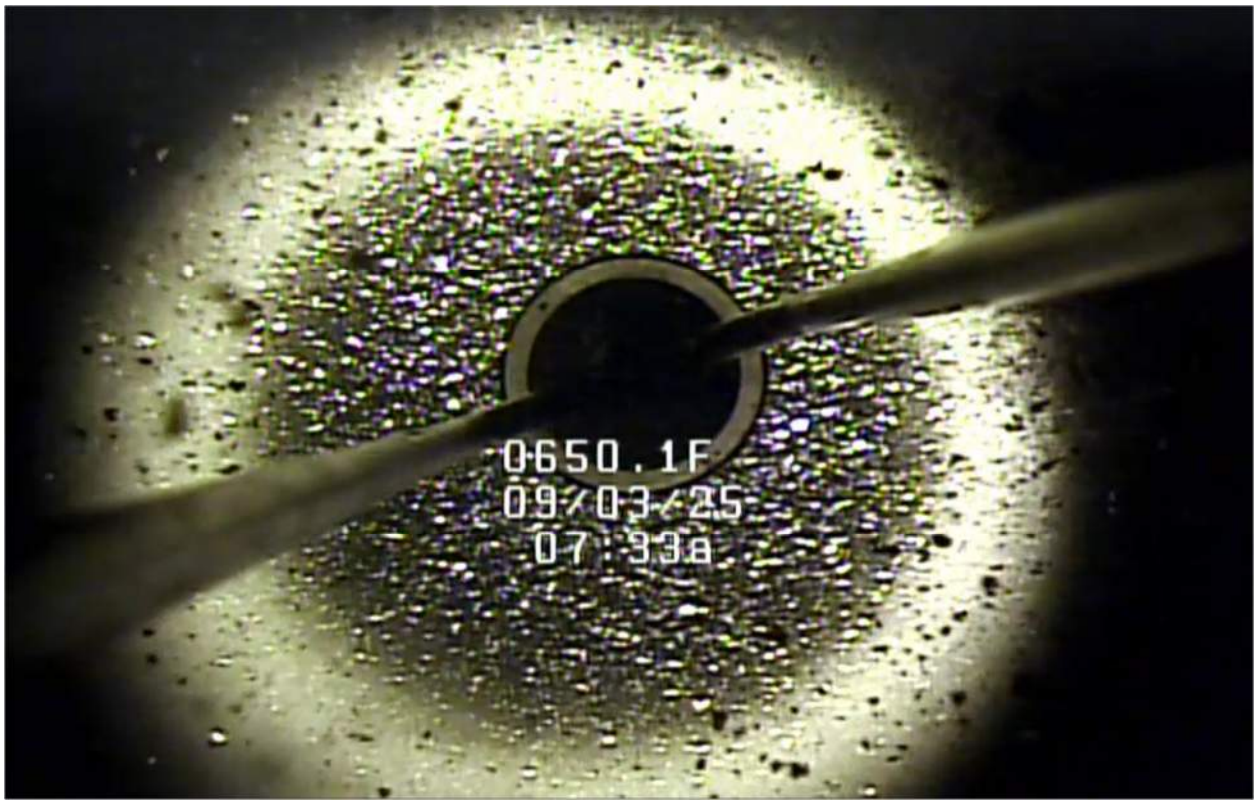
Side View: Screen at 610'



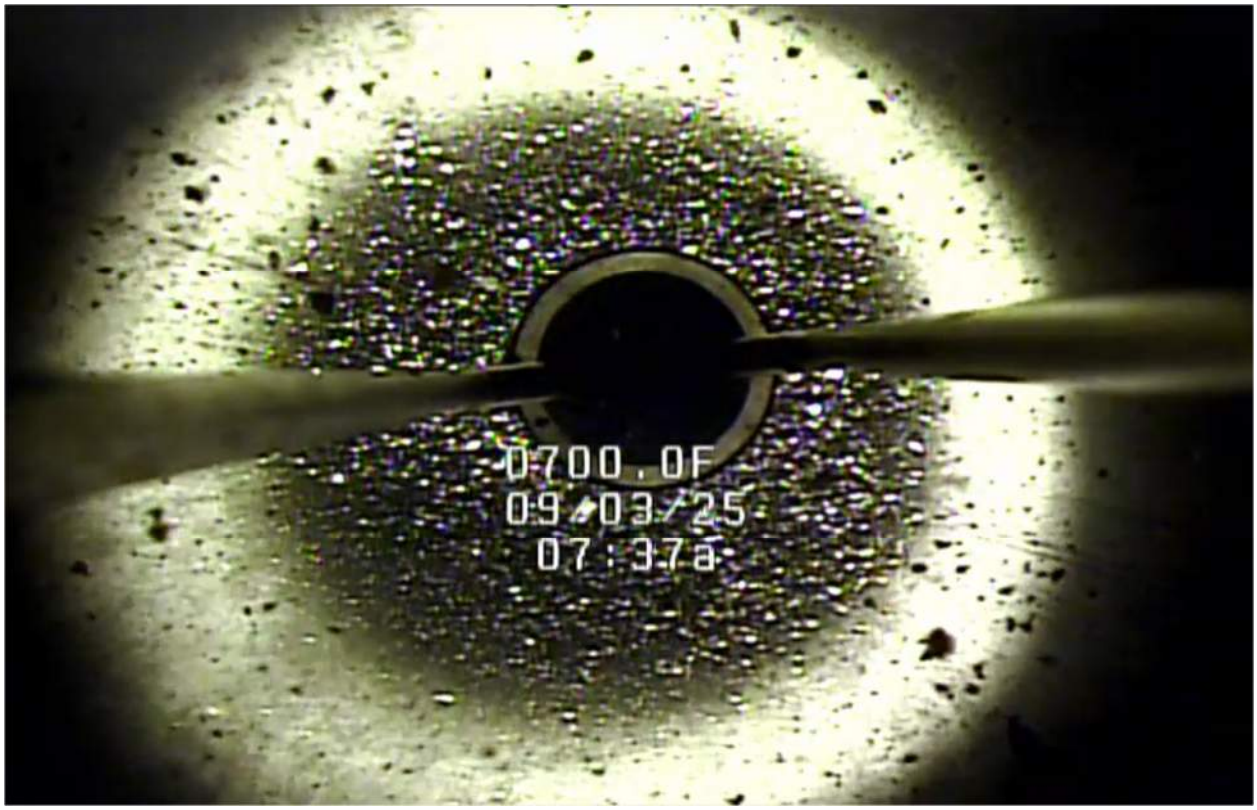
Bottom of Upper Screen

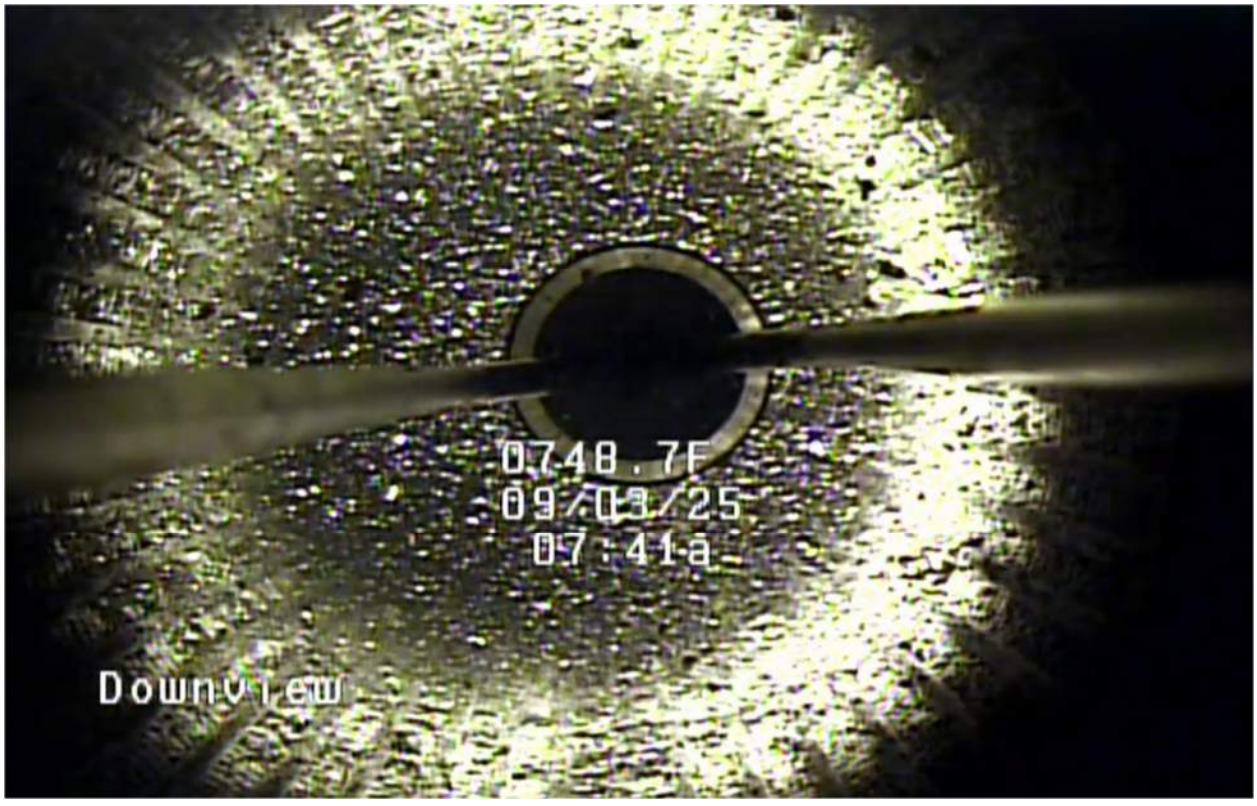


Side View: Bottom of Upper Screen at 619.5'

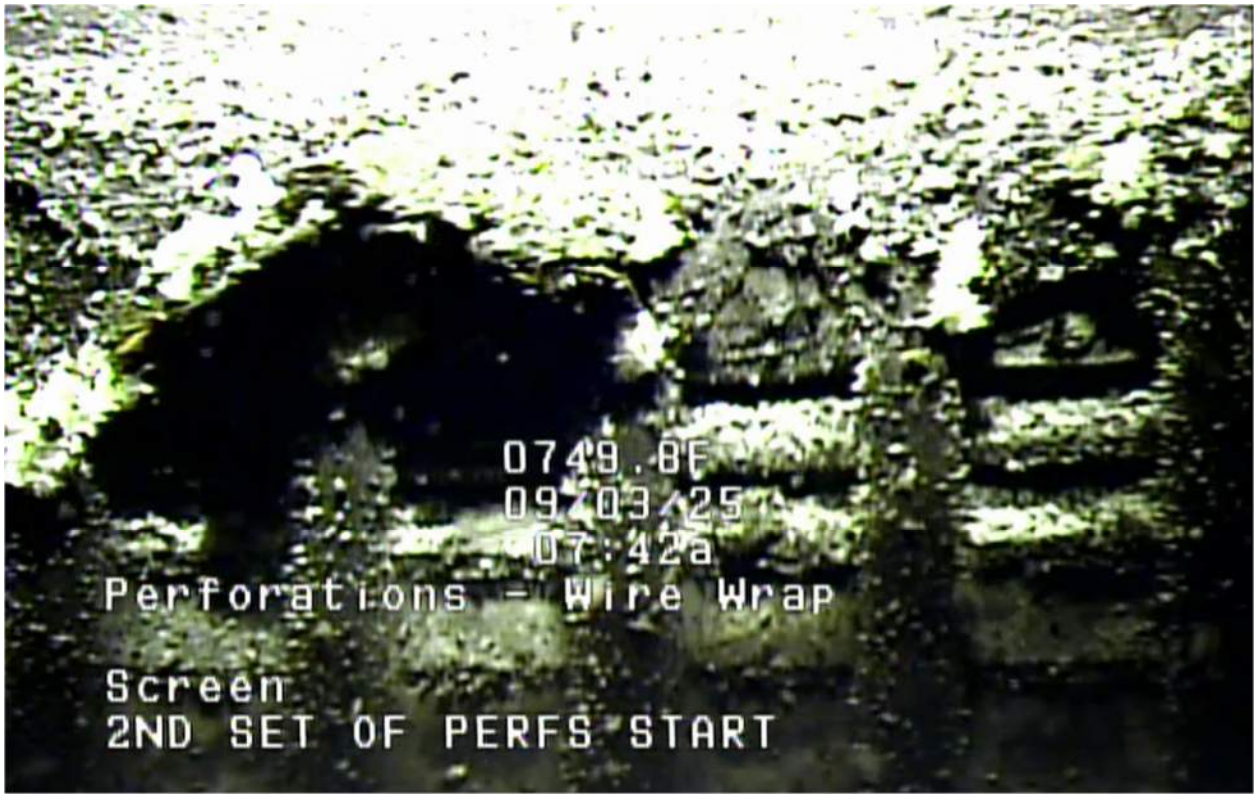


Blank casing at 650.1'

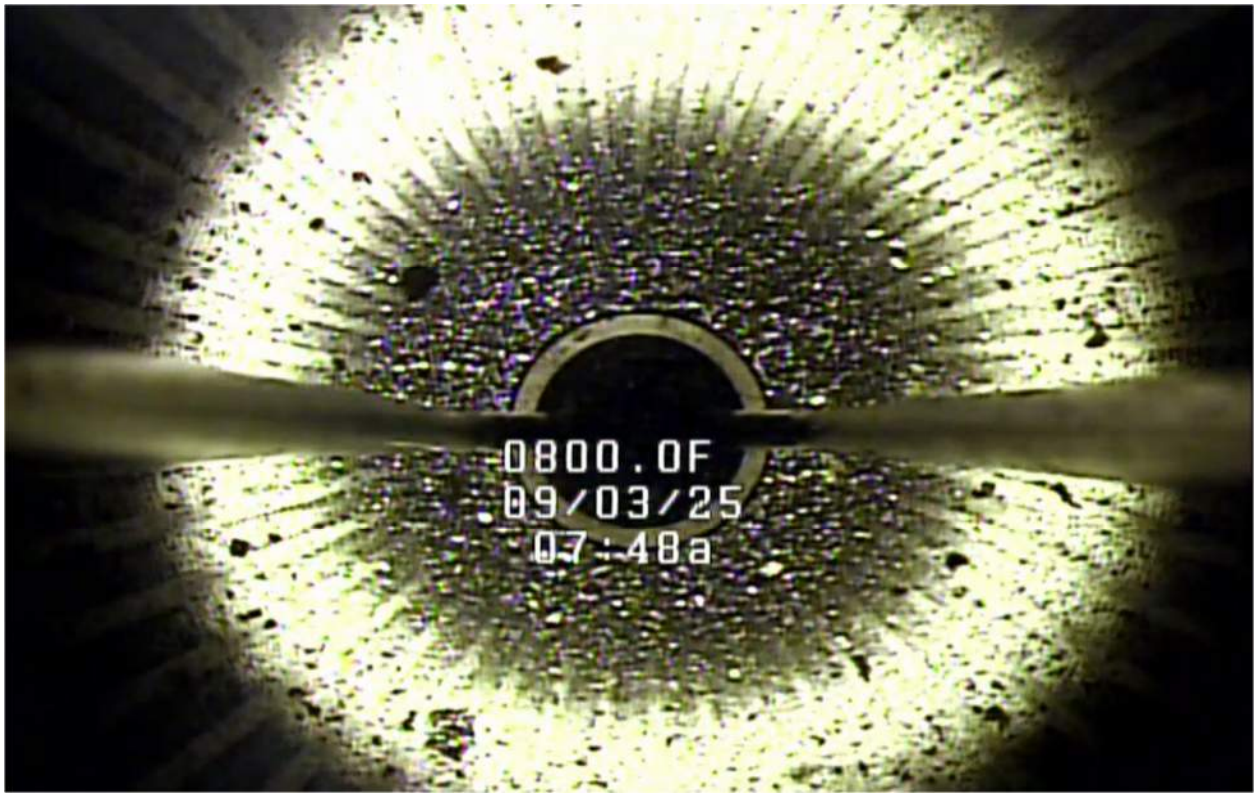


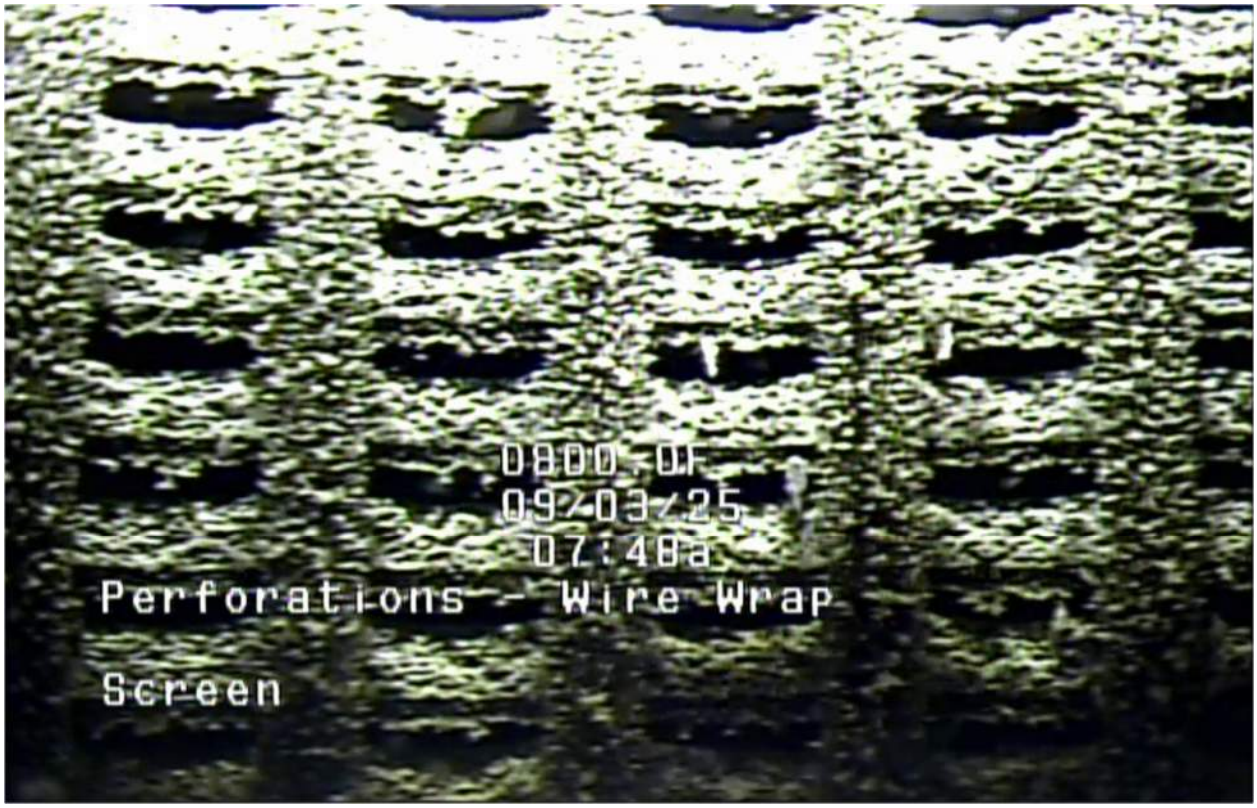


Top of Lower Screen at 748.7'

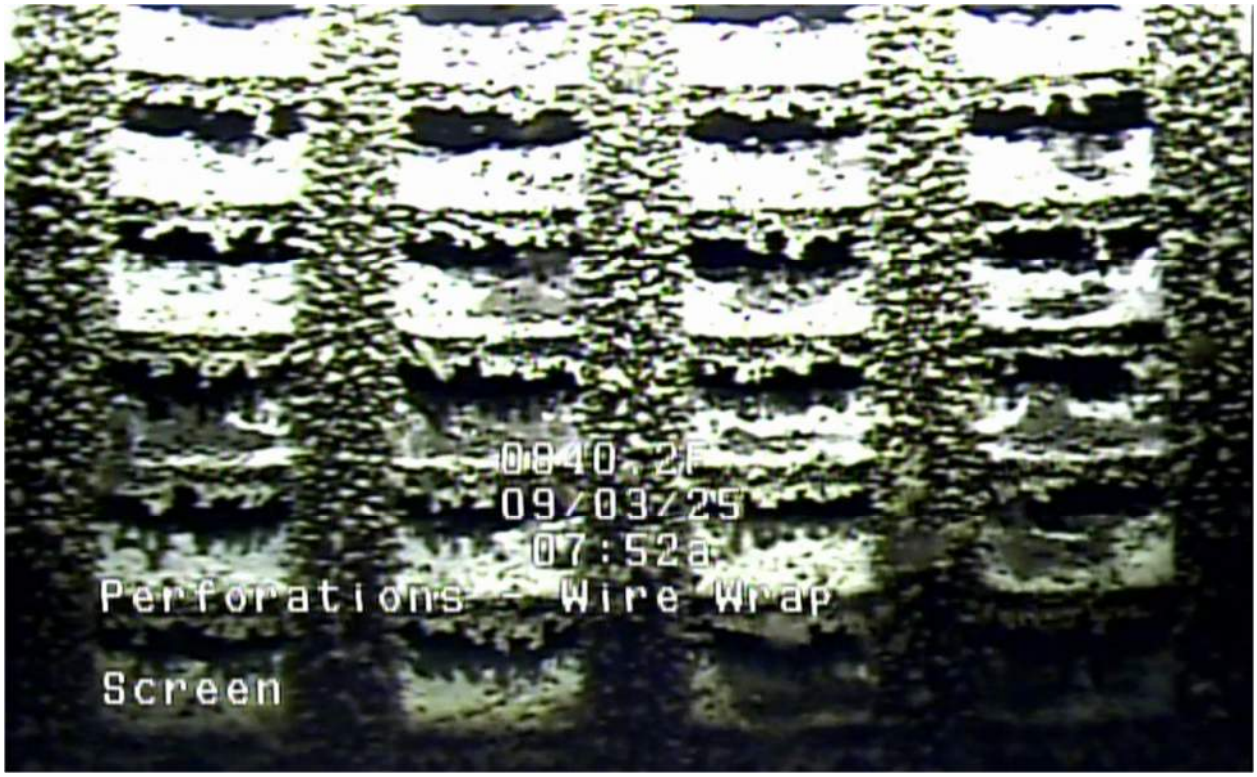


Side View: Top of Lower Screen at 749.8'





Side View: Screen at 800'



Side View: Screen at 840.2'



Camera lens depth = 843.2’ so fill depth = 843.2’ plus 1.4’ (distance between lens and light) = 844.6’ for top of fill. Lower screen bottom reportedly at 860’ and blank casing reportedly extends to 870’ so total fill depth is 25’, including 15’ of screen and 10’ of casing.