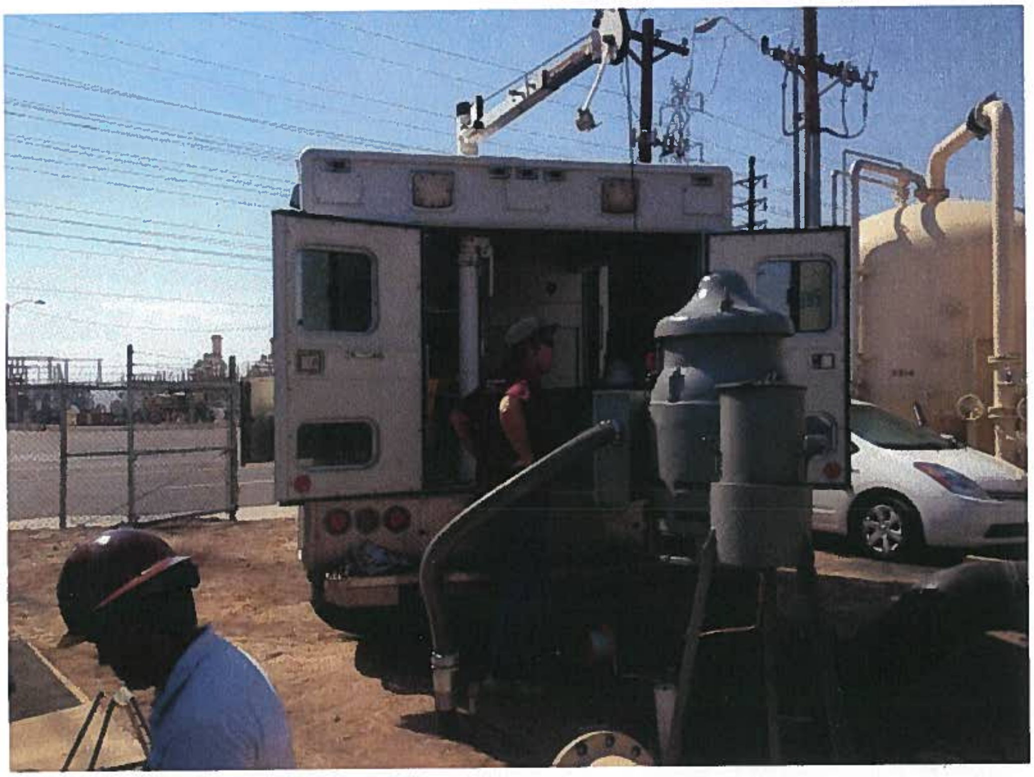
TECHNICAL MEMORANDUM

INVESTIGATIONS AT WELL RID-92



JUNE
2013

WEST VAN BUREN WQARF REGISTRY SITE
PHOENIX, ARIZONA

Prepared for: **Arizona Department of Environmental Quality**

Prepared by: **Synergy Environmental, LLC**

On Behalf of: **Roosevelt Irrigation District**

REGISTERED GEOLOGIST
CERTIFICATE NO.
26393
DENNIS H.
SHIRLEY
Date Signed 6/21/13
ARIZONA, U.S.A.
Expires 09/30/13

SYNERGY
ENVIRONMENTAL, LLC

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LIST OF ABBREVIATIONS

ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
bls	below land surface
COC	Contaminant of Concern
EPA	Environmental Protection Agency
ERA	Early Response Action
gpd/ft	gallons per day per foot
gpm	gallons per minute
LAU	Lower Alluvial Unit
MAU	Middle Alluvial Unit
M&A	Montgomery & Associates
µg/L	micrograms per liter
PVC	polyvinyl chloride
RID	Roosevelt Irrigation District
SCADA	Supervisory Control and Data Acquisition
SWE	Southwest Exploration Service, LLC
TCE	Trichloroethene
TM	Technical memorandum
UAU	Upper Alluvial Unit
VOC	Volatile Organic Compound
WQARF	Water Quality Assurance Revolving Fund
WVBA	West Van Buren Area

June 18, 2013

INVESTIGATIONS AT WELL RID-92

ROOSEVELT IRRIGATION DISTRICT
EARLY RESPONSE ACTION
WEST VAN BUREN AREA
WATER QUALITY ASSURANCE REVOLVING FUND SITE

1.0 INTRODUCTION

Synergy Environmental LLC (Synergy) prepared this Technical Memorandum (TM) to document the results of investigations conducted at well RID-92, which is located along 43rd Avenue about ¼-mile north from Buckeye Road in Phoenix, Arizona as shown in **Figure 1**. RID-92 is one of at least 23 RID wells located within the West Van Buren Area (WVBA) Water Quality Assurance Revolving Fund (WQARF) Site impacted by volatile organic compounds (VOCs). Based on the most recent sampling of RID-92 conducted on September 17, 2012 and April 2, 2013 by the Arizona Department of Environmental Quality (ADEQ), the following VOCs are observed in groundwater at this well:

Contaminant of Concern (COCs)	Concentration in micrograms per liter (µg/L)	
	September 2012	April 2013
Trichloroethene (TCE)	64	73.5
Tetrachloroethene (PCE)	13	14.7
cis-1,2-Dichloroethene (DCE)	7.0	7.58
1,1-Dichloroethene	4.7	5.17
1,1-Dichloroethane (DCA)	1.8	2.1
Chloroform	3.3	2.85

The RID-92 well investigation was conducted in accordance with the Phase 1 Well Investigation Work Plan, prepared by Montgomery & Associates (2010b) and dated November 24, 2010, and pursuant to the ADEQ approval of the RID Early Response Action

(ERA) Work Plan for the WVBA Site (ADEQ, 2010). The objectives outlined in the Phase 1 Well Investigation Work Plan were to:

- Demonstrate that well investigations can be conducted at minimal risk to RID and provide meaningful information for the ERA; and,
- Document existing construction and structural integrity of the wells.

To accomplish these objectives, the work plan outlined the following tasks to be conducted at each well under investigation:

- Well video survey(s) and, if necessary, well brushing;
- Spinner logging and depth-specific sampling under non-pumping conditions;
- 24-hour constant-rate aquifer test; and,
- Spinner logging and depth-specific sampling under pumping conditions.

The initial preparatory work to video and brush well RID-92 was conducted in November and December 2011, and the well investigation work was conducted beginning in February 2012 and completed in September 2012.

Well RID-92 was drilled and constructed in the current configuration in late 1958 and early 1959, and has been regularly operated as an irrigation supply well since installation. Records held by RID and included as **Attachment A** indicate the operating well at this location was a replacement for, or re-drill of, an existing well at the site. The current RID-92 well was constructed to a total reported depth of 500 feet below land surface (bls) with 20-inch diameter, 8-gauge steel casing using the cable-tool drilling/casing advancement method. The well casing was perforated from 180 to 488 feet bls using a Roscoe Moss hydraulic perforator. The perforations comprise horizontal slots 2-1/2-inch long by 3/16-inch wide. **Figure 2** provides a schematic diagram of the well completion.

The driller's log in **Attachment A** indicates the subsurface geology consists of unconsolidated alluvial sediments that are inferred to fully penetrate the Upper Alluvial Unit (UAU) and extend into the upper interval of the Middle Alluvial Unit (MAU). According to geologic interpretation developed in the Remedial Investigation Report (Terranext, 2012), the UAU is divided into two sub-layers consisting of an upper interval (termed UAU1) that is primarily inter-fingering sand and gravel lenses, and a lower interval (termed UAU2) where clay lenses increase and dominate the lithologic horizons. The transition between the UAU and MAU is characterized by a sequence of at least 40 feet of material often referred to as hard brown clay or sticky brown clay. MAU sediments are notably finer-grained than the overlying UAU deposits.

In vicinity of RID-92, Terranext (2012) infers the UAU1 interval is present from ground surface to approximately 295 feet bls and the underlying UAU2 horizon ranges from approximately 30 to 85 feet thick, or greater. The driller's log at RID-92 indicates the UAU1 extends to a depth of 293 feet bls where a significant clay horizon is encountered. The extent of the UAU2 layer and the UAU/MAU contact cannot, however, be ascertained from the driller's geologic log of RID-92 due to the lack of detail provided for the interval from 319 to 500 feet bls. With the exception of a 3-foot thick sand stringer, this interval is lumped together as "sandy clay and gravel" and fails to document the transition to dominantly fine-grained sediments characteristic of the MAU. In adjacent RID wells, the MAU contact was selected at 360 feet bls at RID-95 (one mile east of RID-92) and at 420 feet bls at RID-111R (about one mile northeast of RID-92). A schematic diagram and driller's log for the well is provided as **Figure 2.**

The operating production rate of the well was recently reported by RID as approximately 1,200 to 1,400 gallons per minute (gpm), which is notably less than surrounding RID wells in the WVBA Site. Well RID-92 is designated by Arizona Department of Water Resources registration number 55-607218 and has a registered pumping capacity of 1,971 gpm. Static water levels measured at RID-92 over the past five years ranged from about 97 to 112 feet bls. Interestingly, the static water level was reported to be 112 feet bls upon completion of the well in February 1959, equivalent to that observed in January 2013. Prior to the well investigation reported in this TM, there were no public data regarding pumping water level at RID-92.

The following elements are presented in this report: testing methodology; a description of field activities for the well investigation tasks; analysis and interpretation of results; and conclusions. Synergy prepared this TM in collaboration with Montgomery & Associates.

2.0 TESTING METHODOLOGY

The technique used to assess the vertical distribution of flow and water quality in well RID-92 comprised fluid-movement investigations conducted in association with wellhead and depth-specific water sampling operations. Fluid-movement investigations comprised: a) geophysical logging to assess the physical and chemical characteristics of the groundwater; and, b) spinner logging to measure the groundwater flow rate at all depths within the well casing. When evaluated in conjunction with laboratory analysis of depth-specific groundwater samples, these data allow determination of differences in water quality and flow rate associated with specific zones of inflow or outflow.

When a well is not used continuously, there is a potential for the well to provide a conduit for vertical movement of groundwater if a vertical hydraulic gradient exists in the portion of the aquifer penetrated or screened by the well. Thus, fluid movement investigations were conducted during both non-pumping and pumping conditions.

Weber Water Resources LC (Weber), Chandler, Arizona, conducted all pump work and the principal video surveys at well RID-92. Southwest Exploration Services, LLC (SWE), Gilbert, Arizona, conducted all depth-specific sampling and borehole geophysical logging, and calculated flow rate in the well using the spinner logging results. Synergy supervised aquifer testing, coordinated geophysical logging, and, in conjunction with Montgomery & Associates (M&A), selected depths for groundwater sampling, and conducted analysis of flow data and water quality results from the well investigations. TestAmerica, Inc., of Phoenix, Arizona conducted all laboratory chemical analyses.

Geophysical logging and groundwater sampling tasks were conducted in the following sequential order to permit consideration of all information in the selection of sampling depths:

1) Borehole Geophysical Logging – A combination probe provided continuous measurements for fluid temperature and conductivity. A three-arm caliper tool measured the diameter of the well casing. These data were used to calculate volumetric flow rates based on linear flow velocities measured with the spinner flow meter tool. A caliper log was obtained only under non-pumping conditions.
2) Borehole Spinner Flow Meter Logging – A spinner flow meter measured flow rates in the well. For non-pumping conditions, the spinner flow meter was used in the

following modes: 1) during downward travel at three separate constant speeds; and, 2) during upward travel at three separate constant speeds. For pumping conditions, the spinner flow meter was used in the following modes: 1) during downward travel at three separate constant speeds; and, 2) in a stationary position at selected depths.

3) Depth-Specific Water Sampling – Depths for sampling were selected in the field based on results of geophysical logging, and ADEQ was informed of the proposed depths prior to sample collection. Depth-specific groundwater samples were obtained using sampling tools lowered into the well via SWE's wire line. Groundwater samples were analyzed for VOCs by U. S. Environmental Protection Agency (EPA) Method 8260B and the following general chemistry constituents and parameters: total dissolved solids content; electrical conductivity; and pH. Analyses for general chemistry were conducted to evaluate changes in general groundwater chemistry between aquifer zones. In addition, field measurements for pH, electrical conductivity, and temperature were recorded for the groundwater samples obtained when recovered sample volumes were sufficient.

Aquifer testing is conducted during the purging and pumping operations for the fluid-movement investigation. In the case of RID-92, the very limited space available within the well site, after installation of a wellhead treatment system, constrained the ability to set a test pump and conduct a constant-rate aquifer pump test. Consequently, the aquifer testing was conducted using the existing production pump and well site electric and motor controls.

To the extent practicable, the field activities, sampling methods, laboratory analyses, and quality assurance procedures were conducted in accordance with protocols developed by ADEQ in the WVBA Field Sampling and Analysis Plan, Quality Assurance Project Plan and Site-Specific Health and Safety Plan (BE&K/Terranext, 2000a, b, and c). Wellhead and depth-specific groundwater samples submitted to the laboratory were analyzed using the following methods: VOCs using EPA Method 524.2; total dissolved solids (TDS) content using Standard Method 2540 C; electrical conductivity using Standard Method 2510 B; and pH using Standard Method 4500-H+. Groundwater pumped from well RID-92 during development and testing operations was piped to the discharge collection box within the well site; from the collection box, the water was conveyed to the existing RID lateral.

3.0 WELL INVESTIGATIONS

This section describes operations conducted at well RID-92 to provide data used for interpretation of well conditions. These operations include well video surveys, brushing of the casing, well development, geophysical logging, depth-specific sampling, and aquifer testing. Interpretation of the results of these operations is given in a subsequent section of the report.

3.1 PREPARATORY WORK: VIDEO SURVEYS AND BRUSHING

Weber removed the permanent pumping equipment from well RID-92 the week of November 7, 2011, to initiate well investigation activities. Subsequently, Weber conducted a video survey in the well on November 15, 2011 to assess conditions in the well. A copy of the report for this video survey is provided in **Attachment B**. Significant mineral deposits and bacterial encrustations were observed inside of the well casing with the buildup light to moderate in the upper interval of the well to a depth of 278 feet bls and moderate to heavy on the well casing from 278 to 413 feet bls, where fill material was encountered. The depth to water measured during video logging was 115.2 feet bls. RID determined that the encrustation should be removed to allow full access to the well and open the perforations. Removing the encrustation also reduced problems that would have resulted as the spinner tool moves up and down the well, such as blockage of the impeller or irregular tool movement.

Weber mobilized a cable-tool drill rig to the well site the week of November 21, 2011 to remove the encrustation by passing a steel-wire brush up and down the well on a wire line. Encrustation removed from the casing (via brushing) fell to the bottom of the well. Weber removed fill material from the well using a wire line bailer to a depth of approximately 435 feet bls. Bailing was terminated at this depth due to an obstruction within the well casing. The lowermost well casing is inferred to contain debris such as steel column pipe and possibly other downhole pumping equipment, as indicated when the bailer extracted a 6-foot long section of 10-inch diameter steel pipe.

Following brushing and bailing operations, a second video survey was conducted on December 8, 2011, to document the integrity of the casing and construction details for the well. A copy of the report for this video survey is provided in **Attachment C**. The casing integrity was sound although some corroded and washed perforations and two small vertical separations in the casing at a depth of about 310 feet bls were observed. The video survey indicated the post-brushing encrustation buildup was generally light and the perforations appeared to be partially open throughout the perforated interval. The depth to water measured during video logging was 110.2 feet bls, and the top of fill material was encountered at 433.3 feet bls. RID did not deem any well casing repair necessary. Following the December video survey, the well was left unequipped and a well cap was welded in place pending further well investigation activities. The well site was not accessible over the subsequent two months due to site construction work associated with installation of granular activated carbon (GAC) wellhead treatment units and appurtenant infrastructure and reconfiguration of electrical controls.

3.2 FLUID-MOVEMENT INVESTIGATIONS: NON-PUMPING CONDITIONS

Spinner logging operations and depth-specific sampling were conducted by SWE at RID-92 under non-pumping conditions from approximately 11:00 to 14:30 on February 24, 2012. The depth to water determined using the wire line fluid resistivity probe was 106 feet bls during logging operations. Caliper, temperature, fluid resistivity, and spinner flow meter logs were obtained; these logs are provided in **Attachment D**. Spinner logs comprised three upward and three downward traverses at approximately constant line speeds of 60, 80, and 100 feet per minute (fpm). However, results for the 60 fpm upward traverse were of very poor quality and were not reported by SWE.

Synergy staff observed logging operations, interpreted preliminary field results, and selected the following depths for groundwater samples: 220 and 320 feet bls. These depths correspond to minor inflection points noted on the temperature, resistivity, and/or spinner logs. ADEQ's oversight contractor, Terranext, observed the logging operations and was consulted in selection and justification for sample depths.

Synergy obtained depth-specific samples using the SWE sampling tool and submitted samples to TestAmerica for analysis of VOCs, TDS, and electrical conductivity. Results of laboratory chemical analyses for the depth-specific samples are given in **Attachment E** and summarized in **Table 1**. Because it is large, **Attachment E** is included only in the electronic version of this report, which is included in a sleeve at the back of this report.

Following spinner logging and depth-specific sampling, Weber equipped the well with a production pump, and RID contractors continued work to complete installation of the wellhead GAC treatment system. The RID-92 wellhead treatment system was started up on May 23, 2012 and operated in near-continuous mode to meet RID irrigation demands until early August when the well was shut down for completion of the well testing program. Well testing at RID-92 was not possible until RID-111R was brought on line and had operated continuously for 30 days to ensure RID water demands could be met and until a specialty Weber rig was available to set a test pump in the confined RID-92 well site.

3.3 TEST PUMP INSTALLATION AND AQUIFER TESTING

Weber mobilized to the RID-92 well site on August 6, 2012 to conduct spinner logging and depth-specific sampling operations under pumping conditions. Due to the very limited space available at this well site, Weber utilized a Smeal pump rig from Tucson to set the test pumping equipment and access tubes for conduct of the well investigations. The space limitations required use of the existing production pump and well electric motor controls. Weber pulled and replaced the well motor and installed a temporary wellhead assembly that allowed access tubes installed for well testing to extend above the wellhead. The pump intake was set at 280 feet bls in recognition of substantial drawdown of pumping water levels known to occur in this well. Discharge piping from the well was diverted directly to the RID system and was not treated during the duration of test pumping.

Based on the relatively deep pump setting and limited screened interval for borehole logging at RID-92 (from 180-433 feet bls), two access tubes were installed for the well testing program. A 3-inch diameter polyvinyl chloride (PVC) tube was set at a depth of 284 feet bls for logging/sampling tool access below the pump while a 2-inch access tube was set to a depth of 250 feet bls for sample tool access above the pump. Additionally, a 1-inch diameter PVC pipe was installed for sounder and transducer access. All equipment installed in the well or used for testing operations, including the access pipes, was cleaned using hot water and a high-pressure sprayer at an off-site location prior to mobilization to the site. A pressure transducer was installed in the well following installation of the pump motor and wellhead assembly.

RID-92 was started up at 13:44 on August 8, 2012 for a minimum 24-hour pumping period followed by a comparable recovery period. Water level data were downloaded at the end of the recovery period and found to be incomplete due to pumping water levels falling below the depth setting of the transducer. The pressure transducer was lowered and at 10:40 on August 11, 2012, the pump was restarted to obtain water level drawdown data for a minimum 48-hour pumping test. Toward the end of the pumping test, well testing activities were conducted by SWE on August 13, 2012. Following completion of logging and sampling activities, well RID-92 was shut down at about 16:00 on August 13, 2012 to monitor groundwater level recovery. Water level recovery was monitored until about 10:00 on August 15, 2012.

The groundwater pumping rate was measured by an electromagnetic flow meter and logged by the Supervisory Control and Data Acquisition (SCADA) system installed at the RID-92 well site. The initial extraction rate was 1,950 gpm, but the pumping rate declined by about 25 percent over the course of the 53.4-hour test. Average pumping rate for the entire test was about 1,490 gpm. Pre-pumping water level was 127.7 feet bls and the maximum depth to water during pumping was 223.6 feet bls. **Figure 3** is a groundwater level hydrograph for well RID-92 during the period that testing operations were conducted.

Water level monitoring was not conducted in nearby ADEQ monitor wells during the purging and pumping operations of RID-92 well testing program, as originally planned. Pressure transducers installed in these ADEQ monitor wells had been pulled in advance of the testing program, and it was determined that the M&A transducers had become tangled with passive diffusion bag samplers and other transducers installed in the wells. Some of the transducers had been damaged by field crews attempting to free the units. The transducers were not installed in August so as to avoid interference with ADEQ water level and water quality monitoring programs.

3.4 FLUID-MOVEMENT INVESTIGATIONS: PUMPING CONDITIONS

Logging under pumping conditions was conducted by SWE from 10:30 to 16:00 on August 13, 2012. The suite of logs obtained was the same as for testing conducted under non-pumping conditions, except spinner flow meter data were collected only during downward traverses; these logs are provided in **Attachment F**. As indicated above, the well site electric power and motor controls were used to operate the well during the pump test and could not be modulated to control the groundwater pumping rate. Consequently, the RID-92 pumping rate was initially 1,950 gpm and fell to below 1,500 gpm with declining pumping water level over the course of the 53.4-hour pumping test. **Figure 4** provides a time-series log of recorded RID-92 groundwater pumping rate measured by the in-line electromagnetic flow meter and recorded by the well site SCADA system.

Synergy staff observed logging operations, interpreted preliminary field results, and, in conjunction with M&A staff, selected the following depths for groundwater samples collected below the pump: 285, 332, and 354 feet bls. The samples depths generally corresponded to significant inflection points noted on the temperature, resistivity, and/or spinner logs. Sample collection began immediately following logging operations. Synergy obtained depth-specific samples below the pump through the 3-inch diameter access tube that terminated at 284 feet bls, using the SWE sampling tool. Wellhead samples were obtained before the start and after completion of depth-specific sampling operations. ADEQ's oversight contractor, Terranext, observed the logging operations and was consulted in selection and justification of sample depths.

The samples were delivered to TestAmerica for analysis of VOCs, TDS, and electrical conductivity. Results of laboratory chemical analyses are provided in **Attachment G** and summarized in **Table 1**. Because it is large, **Attachment G** is included only in the electronic version of this report, which is included in a sleeve at the back of this report.

In addition to these depth-specific samples, a groundwater sample was to be obtained in the depth interval above the pump intake through the 2-inch diameter access tube. This sample, however, was not collected because the six-foot long SWE sampling tool could not be lowered into the 2-inch tube due to hindrance from an electric panel protruding from the side of the motor. Following this round of depth sampling, Weber was asked to mobilize a pump rig to the site and rotate the motor over the hole to allow access to the 2-inch sample tube.

A second round of depth sampling under pumping conditions was conducted by SWE on August 22, 2012. Except for a brief period when the power was interrupted to rotate the wellhead, RID-92 was in continuous operation since August 16, 2012 prior to the sampling. Two depth-specific samples were collected including a sample above the pump at 250 feet bls obtained through the 2-inch diameter access tube and a sample below the pump at 285 feet bls obtained through the 3-inch diameter access tube. The samples were delivered to TestAmerica for analysis of VOCs, pH, TDS, and electrical conductivity. Results of laboratory chemical analyses are provided in **Attachment H** and summarized in **Table 1**.

Because it is large, **Attachment H** is included only in the electronic version of this report, which is included in a sleeve at the back of this report.

A third and final round of depth sampling under pumping conditions was conducted by SWE on September 10, 2012. RID-92 had operated continuously since August 22, 2012 prior to the third sample round. Two depth-specific samples were collected including a sample above the pump at 265 feet bls obtained through the 2-inch diameter access tube and a sample below the pump at 285 feet bls obtained through the 3-inch diameter access tube. The samples were delivered to TestAmerica for analysis of VOCs, TDS, and electrical conductivity. Results of laboratory chemical analyses are given in **Attachment I** and are summarized in **Table 1**. Because it is large, **Attachment I** is included only in the electronic version of this report, which is included in a sleeve at the back of this report.

4.0 ANALYSIS AND INTERPRETATION OF RESULTS

This section describes interpretations and analyses of the data obtained from RID-92 aquifer testing, geophysical logging, and depth-specific sampling. Results of depth-specific sampling and fluid-movement investigations often contain some contradictory information. Each phase of investigation provides unique information that was synthesized and combined together with data from other phases to arrive at a complete interpretation of well and aquifer conditions.

4.1 AQUIFER TEST

Groundwater level data collected from well RID-92 during the 53.4-hour aquifer test were processed and analyzed to determine aquifer transmissivity. Transmissivity is a measure of the ability of an aquifer to transmit groundwater; it is defined as the rate of groundwater movement under a 1:1 hydraulic gradient through a vertical section of an aquifer 1 foot wide and extending the full saturated thickness of the aquifer (Theis, 1935). Units for transmissivity in this report are gallons per day per foot width of aquifer (gpd/ft).

To process the data for analysis of transmissivity, the data for the 53.4-hour test were imported into the software AQTESOLV, which allows adjustment of drawdown data for variable flow rates for some analysis methods, such as the Cooper-Jacob (1946) method. To provide a valid analysis of recovery data subject to the effects of significantly variable pumping rate, recovery data may be adjusted using Agarwal (1980) equivalent time to a form that may be analyzed using methods applied to drawdown data. Transmissivity was calculated from the drawdown data using the Cooper-Jacob semi-logarithmic graphical procedure (Cooper and Jacob, 1946). Transmissivity was calculated from the residual drawdown data obtained during the recovery period using the Cooper-Jacob (1946) semi-logarithmic graphical procedure on data adjusted to Agarwal (1980) equivalent time. To account for unconfined aquifer conditions, the data were corrected for water table conditions prior to application of the Cooper-Jacob analysis (Jacob, 1944; Kruseman and De Ridder, 1990).

Results of the analyses are shown on **Figure 5**. An aquifer transmissivity of about 110,000 gpd/ft was calculated using the drawdown data obtained during the 53.4-hour aquifer test. An aquifer transmissivity of about 127,000 gpd/ft was calculated using the residual drawdown data obtained during the recovery period.

4.2 FLUID-MOVEMENT INVESTIGATIONS

Groundwater pumped from the wellhead represents a flow-weighted average of all of the intervals of the aquifer yielding groundwater to the well. Similarly, groundwater quality parameters measured at specific depths in the well represent the average quality of all groundwater entering the wellbore and traveling past the depth sampled, and do not represent chemical quality of groundwater in the aquifer at the depth sampled. Results of depth-specific samples can be analyzed in conjunction with flow data from spinner logging operations to calculate values for groundwater quality parameters that are representative for intervals between depth-specific sample locations.

Results of spinner logging operations are given in **Attachments D and F**. Results of laboratory chemical analyses for the depth-specific samples obtained during pumping and non-pumping conditions are summarized in **Table 1.** Depth-specific water quality data collected under non-pumping conditions show some variability; however, the spinner data for the well could not be analyzed to determine flow rate. Depth-specific water quality data collected under pumping conditions below the pump intake do not show significant variability. Thus, calculations of mass-flux are not feasible or not warranted for either non-pumping or pumping conditions.

4.2.1 Non-Pumping Conditions

Under non-pumping conditions, no net flow occurs in the well. However, vertical flow may occur as groundwater enters the well (inflow) from one or more screened intervals, while an equivalent volume of groundwater exits the well (outflow) through other screened intervals. The spinner, temperature, and fluid resistivity logs are given in **Attachment D**. SWE conducted the downward and upward traverses of the spinner flow meter at the same line speeds; thus, because the meter response varies with traverse direction, the downward traverse profiles were adjusted to roughly match the upward profiles at zones of no flow (**Attachment D**). Depths where the downward and upward profiles deviate from one another indicate zones of inflow or outflow. Where the downward profile deviates to the right of the upward profile, flow is upward; and conversely, where the upward profile deviates to the right of the downward profile, flow is downward.

Spinner logging of well RID-92 under non-pumping conditions was conducted on February 24, 2012. The spinner flow meter data obtained under non-pumping conditions were of poorer quality than the data obtained under pumping conditions. The spinner data are not interpretable because the two complete sets of traverses at 80 fpm and 100 fpm provided different results (**Attachment D**). Although the spinner curves suggest downward flow starting at a depth of about 130 to 155 feet bls, these depths are within blank casing where no flow existed. The temperature curve indicates generally decreasing temperature from a depth of about 137 feet bls (within blank casing) to a depth of about 242 feet bls, along with several inflection points in that interval, which suggests a possible zone of inflow to the well. However, the inflection points do not appear to correspond to inflection points on the spinner curves. From a depth of 242 feet bls to the total depth of the well, the temperature increases at about a uniform rate, consistent with the geothermal trend. Direction of flow, if present, cannot be determined from the temperature data.

VOCs were detected in both depth-specific samples obtained under non-pumping conditions (**Table 1**). The results indicate TCE and PCE concentrations were lower in the sample collected at 220 feet bls, compared to the sample obtained at a depth of 320 feet bls. Other VOCs, such as DCE isomers, 1,2-DCA, and chloroform were relatively similar, if not slightly higher in the depth sample from 220 feet bls, compared to the 320 feet bls depth sample. Although water quality differences appear to occur in these depth-specific intervals, calculation of mass flux is not feasible because flow rate in the well could not be determined.

4.2.2 Pumping Conditions

Spinner logging and depth-specific sampling under pumping conditions at well RID-92 was conducted on August 13, 2012. The test pump intake was installed to a depth of 275 feet bls, which is below the top of perforations at 180 feet bls. The pumping water level was reported to be about 223 feet bls. Therefore, flow in the well may have been moving both downward and upward to the pump intake. However, flow above the pump could not be detected by the spinner flow meter because the access tube was installed to a depth of 284 feet bls. Below the pump intake, the magnitude of the spinner flow meter response under pumping conditions generally increased upward from the bottom of the well, indicating upward flow. At some depths, the magnitude of the spinner flow meter response decreased with decreasing depth. This effect was likely a result of turbulence due to horizontal flow into the well and did not impact the overall interpretation of upward flow in the well.

A summary plot of the driller's log, calculated flow, interpreted flow, and depth-specific concentrations of TCE is provided in **Figure 6**. Calibration curves developed by SWE were used to calculate the volumetric flow rate in the well using the 60 fpm data. The principal results of the pumping spinner profiles are summarized as follows:

- No flow was detected at the bottom of the well.
- About 100 gpm entered the well in the depth interval from 410 feet bls to about 366 feet bls.
- About 130 gpm enters the well in the depth interval from about 366 to 356 feet bls.
- About 170 gpm enters the well in the depth interval from about 342 to 332 feet bls.
- The remaining 1,070 gpm (the discharge rate of 1,470 gpm at the wellhead minus cumulative 400 gpm flow that is moving up the well casing to pump intake) is inferred to enter the well above the pump and move downward to the pump intake.

The flow interpretation summarized above was used to select depths corresponding to changes in flow rate within the well; values for flow were assigned to these depths and interval flow rates were calculated to graphically illustrate where flow enters the well (**Figure 6**).

The results shown in **Table 1** indicate that VOCs were detected at varying concentrations at the RID-92 wellhead and in depth samples collected above and below the pump intake. With the exception of methyl ethyl ketone (MEK) and chloroform, the following trends are noted: VOC concentrations at the wellhead are consistently greater than observed in depth-specific samples, VOC concentrations detected above the pump intake are greater than concentrations detected below the pump intake, and VOC concentrations detected below the pump intake generally show little variation with depth. Calculated TDS concentrations are nearly identical in all samples.

Although there are clear and significant differences in the reported VOC concentrations in depth-specific samples and the composite water extracted from the well, the data do not conform to a rational mass balance. In other words, spinner logging and depth-specific sampling at well RID-92 indicate that higher VOC concentrations are in the extracted groundwater than are entering the well. The data set as a whole does not allow mass balance calculations and cannot be quantitatively interpreted in terms of the vertical distribution of groundwater quality.

Concentrations of chloroform and MEK reported in depth-specific samples do not correlate to VOC trends. MEK is observed at relatively substantial concentrations, predominantly in depth-specific samples below the pump setting obtained down the 3-inch diameter access tube. The source of MEK in the well is uncertain. Given that MEK is not detected in wellhead samples, the observed MEK in depth samples does not appear to be a significant overall contribution to groundwater quality. The source of MEK in groundwater samples obtained at depths of 250 feet bls, and greater, could be from the adjacent Western Area Power Administration (WAPA) facility located at 615 South 43rd Avenue, which is directly east of the RID-92 well site. Data reported in the Final RI Report (Terranext, 2012) indicate the presence of MEK in soil gas data obtained at the WAPA facility. Alternatively, the localized nature of MEK contamination may mean the compound originated from PVC pipe used for the 3-inch access tube that cross-contaminated the samples passing through the access tube. According to Weber, however, the PVC pipe was decontaminated prior to installation and assembled without the use of cement. With regard to chloroform, the observed concentrations are about the same regardless of the depth of the sample. The presence of chloroform in 2 of the 4 equipment blank samples indicates that the water supply used to decontaminate the sampling tool may have contributed to the observed presence of chloroform in depth-specific samples.

5.0 CONCLUSIONS

The objectives of the well investigation program, as described in the Phase 1 Well Investigation Work Plan (M&A, 2010b), were to document the existing construction and structural integrity of the wells that will be integrated into the ERA and to demonstrate that the well investigations can be conducted at minimal risk to RID and provide meaningful information for the ERA. The objectives were partially achieved by the RID-92 well investigation.

The condition of the RID-92 was determined by the post-brushing video survey. Although the well is over 50 years old, the casing integrity is reasonably sound, as demonstrated by visual inspection and the ability of the casing to withstand the brushing activities. Thus, similar investigations could likely be safely conducted on other RID wells. Additionally, the well investigation was conducted without adverse water supply consequences for RID. The RID-92 well testing program was facilitated through RID's recent installation and completion of a replacement well at RID-111, which provided increased RID production capacity so as to allow the well testing program to proceed in even the high water supply demand period.

The well investigation also provides information that substantiates the findings of well investigations conducted at wells RID-111R and RID-95 as part of the Phase 1 Well Investigation Work Plan (M&A, 2010b), as further discussed below:

- RID-92 produces water from the UAU only, and consistent with fluid movement investigations of wells RID-95 and RID-111R, the bulk of water extracted from the well is from the UAU1 interval. In the case of RID-92, approximately 73 percent of the water entered the well from above pump intake, which was set at 280 feet bls. The UAU1 interval is inferred to extend to a depth of 293 feet bls at RID-95. In newly-installed well RID-111R, which does not have the mineral encrustation and buildup seen in older RID wells like RID-92, the UAU1 interval contributed 82 percent of the total groundwater yield to the well (Synergy, 2013). Water was not observed entering the well below a depth of 410 feet bls.

- The estimated transmissivity of the UAU is large with values ranging from 110,000 to 127,000 gpd/ft, as determined by the aquifer test. These transmissivities are consistent with values determined by aquifer tests at other RID wells, which ranged from 54,000 to 189,000 gpd/ft at RID-95 (Montgomery & Associates, 2012) and from at least 109,000 gpd/ft to about 168,000 gpd/ft at RID-111R (Synergy, 2013).

- Water quality analyses indicate RID-92 is impacted by multiple VOCs that are COCs at the WVBA Site. Depth-specific samples indicate TCE and PCE concentrations are substantially larger in the UAU1 as compared to UAU2 interval, although the data when compared to wellhead concentrations do not allow mass balance determinations or quantitative interpretation of the vertical distribution of groundwater quality. Concentrations of other contaminants in depth-specific samples, such as MEK and chloroform, are not consistent with observed VOC trends in the aquifer and may be attributed to sources other than in regional groundwater.

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