CHPRC-03054
Revision 0

Initial Analysis of the 100-HR-3 RUM Aquifer Test

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

CHPRC-03054
Revision 0

Initial Analysis of the 100-HR-3 RUM Aquifer Test

Date Published
September 2016

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

P.O. Box 1600
Richland, Washington 99352

APPROVED
By Julia Raymer at 3:44 pm, Sep 21, 2016

Release Approval Date

Approved for Public Release;
Further Dissemination Unlimited

TRADEMARK DISCLAIMER

Reference herein to any specific commercial product, process, or service by tradename, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

This report has been reproduced from the best available copy.

Printed in the United States of America

TECHNICAL MEMORANDUM

Initial Analysis of the 100-HR-3 RUM Aquifer Test

Prepared for:	S. Balone (DOE) E. Dagan (DOE)
Prepared by:	B. Mayhew (TerraGraphics) K.A. Ivarson (CHPRC) R. Mackley (CHPRC)
CCs:	K. Wiemelt (CHPRC) M. Doornbos (CHPRC) G.M. Drewett (CHPRC) Correspondence Control – MSIN – G3-39

Date:	September 1, 2016
Doc ID:	CHPRC-03054, REV. 0

1 Background and Objectives

Hexavalent chromium [Cr(VI)] contamination is present in the first water-bearing unit of the Ringold Formation Upper Mud (RUM) at the 100-H Area. The source of contamination is hypothesized to be Cr(VI)-contaminated groundwater in the overlying unconfined aquifer being forced down into the lower aquifer by high hydraulic heads within the overlying shallow unconfined aquifer during reactor operations (HW-77170, *Status of the Ground Water Beneath Hanford Reactor Areas January, 1962 to January, 1963*). This theory is supported by the fact that the RUM at 100-H exhibits a relatively thin zone of silt and clay material, separating the two aquifers. This material also exhibits a substantial sand and gravel fraction, making the competency of the RUM material as an aquiclude questionable. At other locations (i.e., within the 100-D and 100-K Areas), this analogous portion of the RUM exhibits a much finer texture and correspondingly lower apparent hydraulic conductivity, indicating that it is an effective aquiclude at those locations.

Aquifer pumping within the first water-bearing unit of the RUM was conducted to evaluate the aquifer hydraulic properties, assess potential for contaminant migration, and identify locations of apparent communication between the unconfined aquifer, RUM aquifer, and Columbia River. The aquifer pumping test included the following objectives:

- Determine the radius of influence of pumping at each test well.
- Determine the connectivity of the RUM aquifer across 100-H.
- Determine if the RUM aquifer is leaky, confined, or semiconfined.
- Determine if the RUM aquifer is connected to the Columbia River.
- Determine hydraulic parameters of the aquifer (transmissive sediments that make up the first water-bearing unit within the RUM).

- Determine performance characteristics (e.g., specific capacity) of the test wells.
- Confirm the conceptual site model.

The conceptual model of the contaminated portion of the first water-bearing unit of the RUM is that this unit is a leaky, semiconfined aquifer in varying degrees of communication with both the Columbia River to the east and the overlying unconfined aquifer unit. Observations of hydraulic head responses to changes in river stage in the two aquifer units, as well as hydraulic head responses to pumping activities in the RUM unit, will provide the qualitative basis for assessing the apparent communication between these units.

2 RUM Aquifer Pumping Test

Aquifer pumping tests were conducted on five wells (199-H3-2C, 199-H3-10, 199-H3-9, 199-H4-12C, and 199-H4-90) within the 100-H Area, all of which are completed in the RUM unit. The relative locations of these wells are presented in Figure 1. Water level monitoring was conducted at all of the existing RUM wells in the 100-H Area, as well as at numerous wells that are completed in the unconfined aquifer, as shown in Figure 1. Both step and constant rate tests were conducted on the selected wells with the exception of well 199-H4-12C, which did not have a constant rate test conducted (Section 2.1).

RUM wells 199-H3-2C, 199-H3-9, and 199-H4-12C are currently connected to the HX pump and treat (P&T) system, and are operating as extraction wells HE09, HE13, and HE10, respectively.
RUM extraction wells were not operating during aquifer testing unless the well was being tested for aquifer response, although limited P&T operations continued in the unconfined aquifer.

2.1 Study Design

The initial test design provided six pumping rate steps during the step drawdown testing at each pumping location (SGW-59756, *100-H Area RUM Aquifer Pump Test Plan*). Each step was planned for a two hour period. The number of steps for the extraction wells was reduced to five due to known historic pumping rates during operation and the capabilities of the existing pump. Upon completion of the test, the RUM aquifer was allowed to recover for at least 24 hours. Water levels were monitored throughout the test and recovery periods. The overall schedule of the aquifer pumping tests is provided in Table 1.

Following recovery, a constant rate pumping test was conducted at a rate selected from the results of the step test(s). The constant rate test for each well was 24 hours. It was determined that a constant rate test in well 199-H4-12C would not add any additional information regarding the aquifer properties or hydraulic connections based on the initial evaluation of the testing data for the surrounding wells and the available long-term pumping data; the constant rate test at that location was not performed.

Each constant rate pump test was intended to be conducted with no variation in flow rates. During testing, pumping rates were held within a half-gallon per minute (gpm) of the prescribed rate, with the exception of pumping at well 199-H4-90. During the constant rate test at this well, workers measured a decrease in flow rate and, after correcting the pump to compensate, noticed the water level dropping quickly towards the level of the pump intake. The pump was left at a lower rate, 5 gpm instead of 8 gpm, for about an hour to see if the water level would recover. The well successfully recovered during that hour, and the flow rate was adjusted back to 8 gpm. After turning the pump back up to 8 gpm, the well held a satisfactory water level for the remainder of the test.

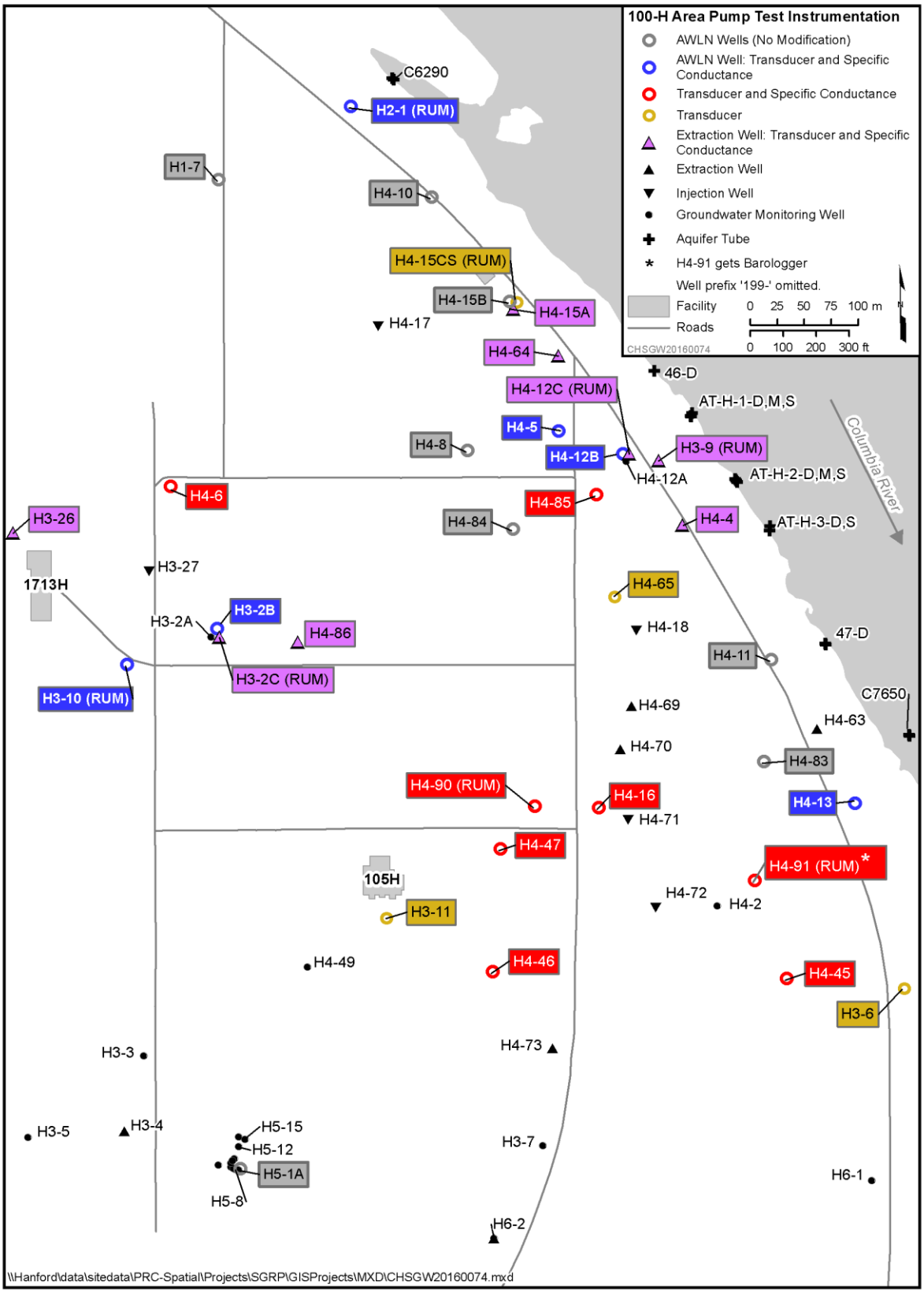


Figure 1. Location of RUM Wells and Monitoring Stations

Table 1. Schedule of Pumping

Pumping Well	199-H3-2C	199-H3-10	199-H3-9	199-H4-12C	199-H4-90
Initial Recovery	5/16/16	6/14/16	5/23/16	6/20/16	7/5/16
Step Test 1	5/17/16 9:01 14.4 gpm	6/15/15 09:12 6.4 gpm	5/24/16 0754 6.0 gpm	6/21/16 7:07 7.5 gpm	7/6/16 08:11 1.3 gpm
Step Test 2	11:01, 23.3 gpm	11:12, 12.5 gpm	09:58, 8.9 gpm	09:35, 15.0 gpm	10:15, 2.5 gpm
Step Test 3	13:01, 27.8 gpm	13:12, 22.5 gpm	11:55, 10.6 gpm	11:32, 22.5 gpm	12:09, 3.8 gpm
Step Test 4	15:01, 31.0 gpm	15:12, 25.0 gpm	13:55,11.5 gpm	13:30, 27.0 gpm	14:15, 4.5 gpm
Step Test 5	Not applicable	17:12, 27.5 gpm	15:55,12.0 gpm	15:30, 30.0 gpm	16:15, 5.0 gpm
Step Test 6	Not applicable	19:12, 31.3 gpm	Not applicable	Not applicable	18:15, 6.3 gpm
Step Test Recovery	5/17/16 17:01	6/15/16 21:12	5/23/16 17:54	6/21/16 17:32	7/6/16 20:11
Constant Rate Start	5/19/16 07:22 31 gpm	6/17/16 07:30 35 gpm	5/26/16 06:56 12 gpm	Not applicable	7/8/16 06:51 8 gpm
Constant Rate Recovery	5/20/16 07:22	6/18/16 07:30	5/27/16 06:56	Not applicable	7/9/16 06:51

Upon completion of the constant rate pumping tests, the RUM aquifer was allowed to recover as planned. Data were collected during the entire pumping and recovery periods (for both the step test and constant rate test), primarily through the use of downhole instruments with data loggers capable of recording water levels, temperature, and specific conductance. Instruments were placed in both the pumping wells and selected observation wells (Figure 1).

100-HX P&T system extraction and injection wells in the 100-H Area were flow controlled (to the extent possible) during the testing period to limit interference with the aquifer testing. Injection wells (and associated P&T system well designations) that were off during each pumping and recovery period included 199-H4-73 (HJ02), 199-H4-72 (HJ03), 199-H4-71 (HJ04), 199-H4-18 (HJ05), 199-H3-27 (HJ06), and 199-H4-17 (HJ14). Extraction wells in the unconfined aquifer, located in the vicinity of a test well, were turned off during the pumping and recovery period. The remaining unconfined aquifer extraction wells in the 100-H Area were set to a specific flow rate.

2.2 Data Collection

Data loggers were installed in various wells, including those completed in the unconfined and RUM aquifers, as shown in Figure 1. In total, 37 wells were used for data collection during aquifer testing. Water levels and specific conductance measurements were generally collected at the eight wells completed in the RUM aquifer. Water levels were collected, without specific conductance, at seven unconfined aquifer wells.

Installed data loggers were set to collect data at 1-minute intervals. For those wells instrumented as part of the automated water level network (AWLN), most data were collected at 5-minute intervals with the

exception of loggers that faced electrical issues. Some variation in the data collection schedule occurred due to sampling schedules, pumping test schedules, holidays, and available personnel.

2.3 Data Reduction

A variety of small irregularities in test conditions occurred during the RUM aquifer test, but they did not affect testing, data collection, or data usability. The vast majority of data was collected from transducers placed in individual wells, the AWLN, and the HX P&T system, with a small amount of data collected by hand measurements. Data corrections were made, when necessary, for any discrepancies concerning time shifts, data logger types, barometric conditions, and river effects using a variety of analytical methods.

Most data irregularities from this process consisted of conflicts with other actions at the P&T facility, small data collection errors, and one delay for a safety concern that was quickly rectified. Issues for each individual well test are discussed in the following subsections.

One widespread data issue that affected many wells was inconsistent time zones throughout the data loggers. The test was conducted after daylight saving time had started, and AWLN well loggers are set to record data using Pacific standard time, while the data loggers installed for this specific test were shifted an hour forward on Pacific daylight time. Wells connected to the P&T system collect data on Pacific daylight time. The variation in time zones for the different loggers was corrected during data processing and had no effect on data usability.

Data from Priest Rapids Dam were also used as a proxy for river stage data (ECF-Hanford-13-0028, *Columbia River Stage Correlation for the Hanford Area*) because the H river gauge proved unreliable.

2.3.1 Monitoring Well 199-H3-10

During testing of well 199-H3-10, the HX P&T system was shut down and restarted multiple times. The shutoff periods were conducted as part of the operational testing for new well connections to the HX system.

The transducer for well 199-H3-10 was set at 16.6 m below ground surface (bgs) or 3.9 m below the average depth to water. Pumping during the step test drew the water below 16.6 m on the first level of the test and continued to depths of ~26 m bgs. Thus, no transducer data were recovered for the step test. This issue was noticed during the step test, but there was insufficient time to move the transducer before the 24-hour constant rate test commenced. Additional manual water level measurements were collected in the field to compensate for the lack of transducer data. A similar issue was discovered for 199-H4-90, but the transducer was moved before the first test began.

The in-line flow meter available was found to be not calibrated to acceptable accuracy. A measured bucket and stopwatch were used to record flow rates.

2.3.2 Monitoring Well 199-H4-90

The transducer in well 199-H4-90 was moved to a lower depth, following the issue discovered during well 199-H3-10 testing, to account for the amount of drawdown observed during the pump tests. The transducer in well 199-H4-90 was originally set at 18 m bgs but was moved to 28.2 m bgs, or 0.3 m from the bottom of the well, on June 29, 2016.

During initial recovery and the first stage of the step test on well 199-H4-90, extraction well 199-H3-26 (HE37) was set at 53 gpm while it should have been set at 0 gpm. This was corrected at ~0845 on the morning of July 6, 2016 and possibly affected data during the first step of the test for well 199-H4-90, which started at 0811 on July 6, 2016.

The transfer station experienced an unplanned shutdown during the step test on 199-H4-90. The impact of this shutdown on test observations has not been defined.

The in-line flow meter available was not calibrated to acceptable accuracy. A measured bucket and stopwatch were used to record flow rates.

2.3.3 Extraction Well 199-H3-2C (HE09)

The first planned step test flow rate of 7.8 gpm during the well 199-H3-2C step test was not conducted because the pump was not capable of holding the rate. Four steps in flow rate were completed because of time constraints. The extraction well 199-H3-9 pump was also found to be unable to sustain the lowest planned flow rate.

2.3.4 Extraction Well 199-H3-9 (HE13)

During the step test of well 199-H3-9, the first level was not conducted because the pump was unable to sustain the prescribed rate of 3.0 gpm. Instead, the first flow rate was set at 6 gpm, and an additional higher flow rate was added to the end of the test at 14 gpm.

2.3.5 Well 199-H4-12C (HE10)

No constant rate test was conducted on well 199-H4-12C. There exists a substantial body of historical data at similar pump rates from this well since it is part of the HX extraction system. It was determined that the constant rate test would not add to the understanding of the aquifer or well conditions.

3 Preliminary Results

The preliminary analysis of an initial portion of the 100-HR-3 RUM pumping test results is a qualitative analysis, based on inspection of multiple drawdown/recovery time series. This inspection has provided answers to a number of the objectives stated in Section 1. The test area has been segregated into three zones as described in the test plan: along the river to the northeast of the reactor, the inland northwestern portion of the study area, and the southern part of the test area (Figure 2). In the various zones, connections between multiple RUM wells, connections between RUM wells and the river, and connections between the RUM and unconfined aquifer were evaluated and identified.

3.1 Zone 1

This zone is located inland and focused on the two RUM wells (199-H3-2C and 199-H3-10), along with various unconfined aquifer wells. Inspection of the water level data shows a distinguishable hydraulic connection between the two RUM test wells in the zone. During test pumping at 199-H3-2C, there was an immediate pressure response from nearby RUM well 199-H3-10 (Figure 3), located ~100 m away. A reciprocal response in well 199-H3-2C was also identified during the 199-H3-10 test (Figure 4).

The next closest RUM well (199-H4-90), located ~400 m to the southeast, did not exhibit a visible response to pumping at either well (199-H3-2C or 199-H3-10). This lack of response may indicate limited connectivity of the RUM aquifer but could also be a limitation of the pump test parameters (e.g., flow rate and duration). Additional evaluation will be conducted to determine if a response would have been expected at a distance of ~400 m, based on RUM aquifer properties.

Based on initial evaluation of the results, clearly identifiable pressure response does not appear in the unconfined wells located in zone 1 during the pumping of 199H3-2C and 199-H3-10. Well data in Zone 1 were slightly easier to interpret pressure response in the unconfined wells than in Zone 2 because the influences of the Columbia River and barometric pressure on most wells were not significant.

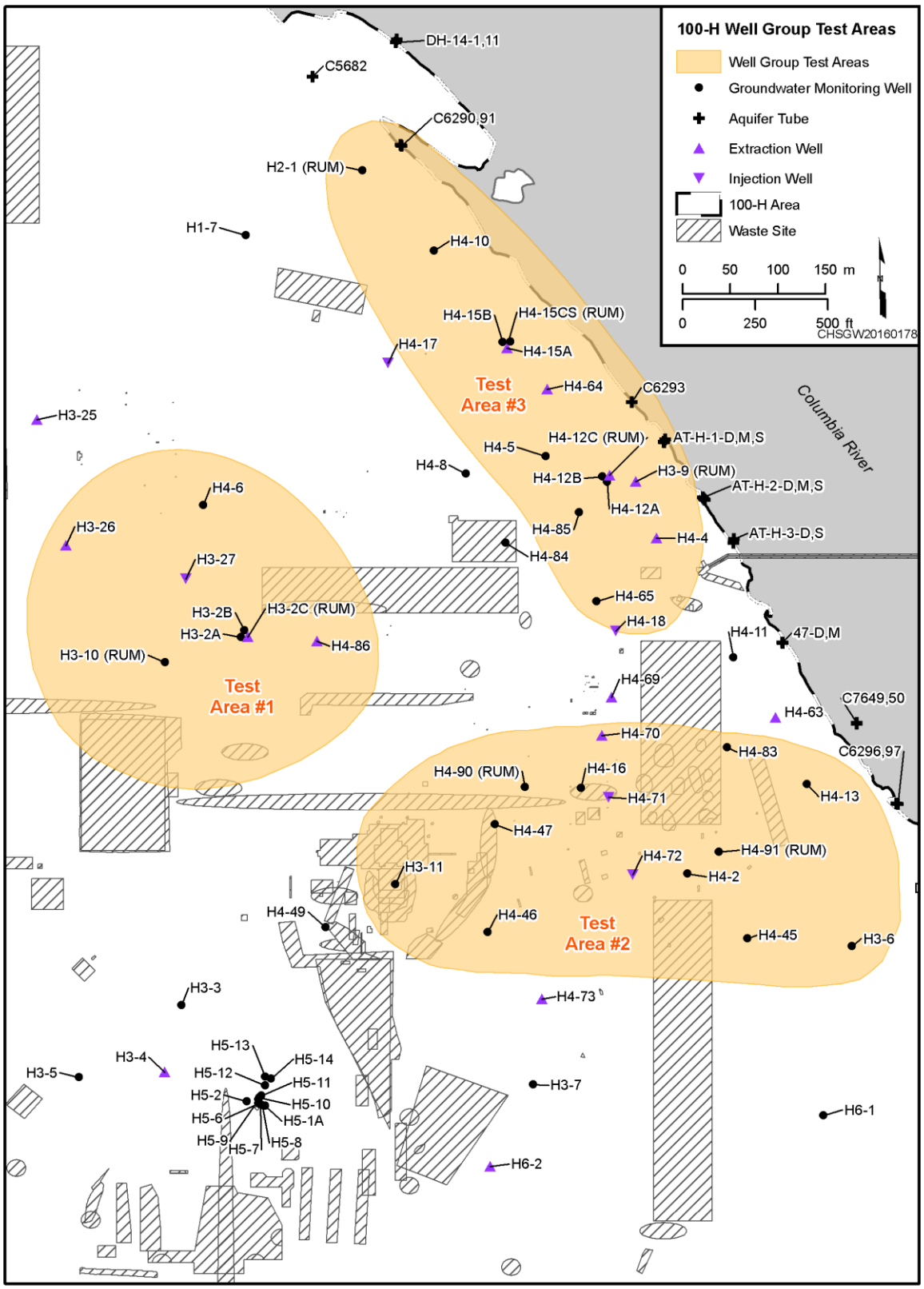
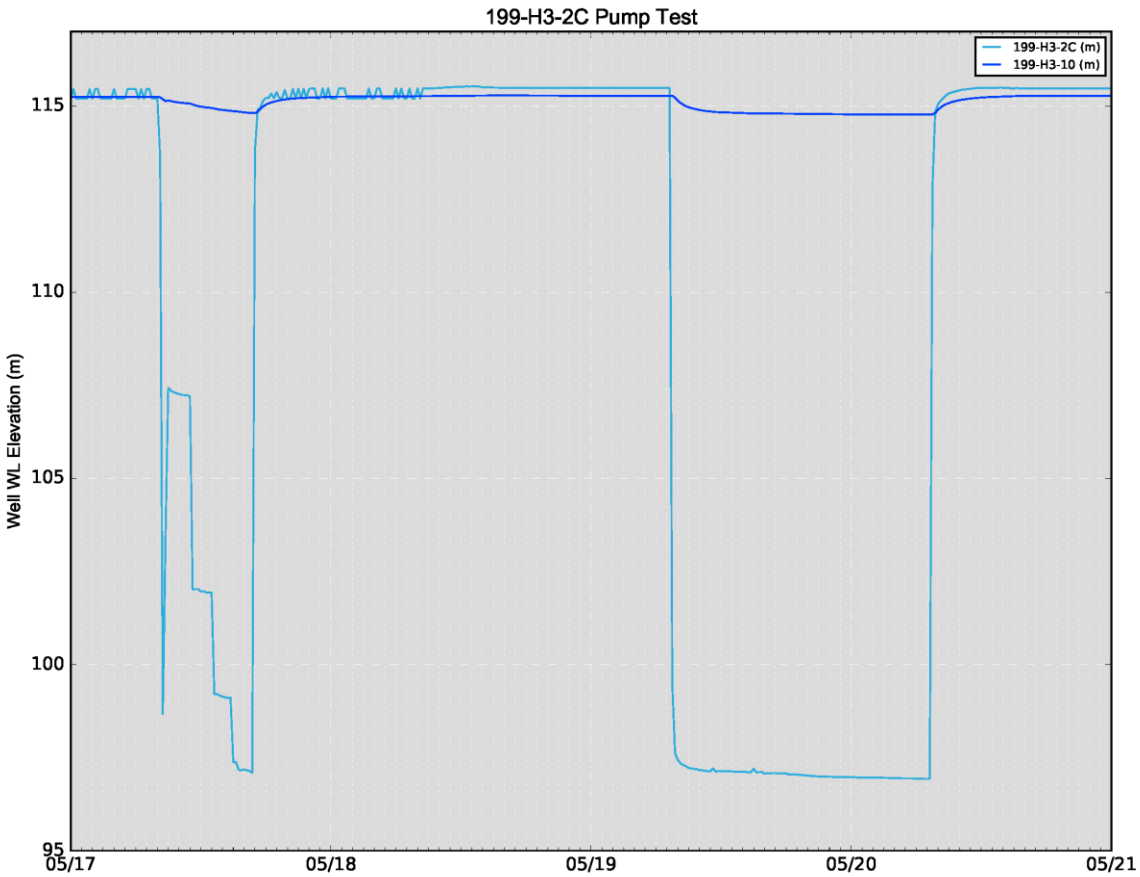
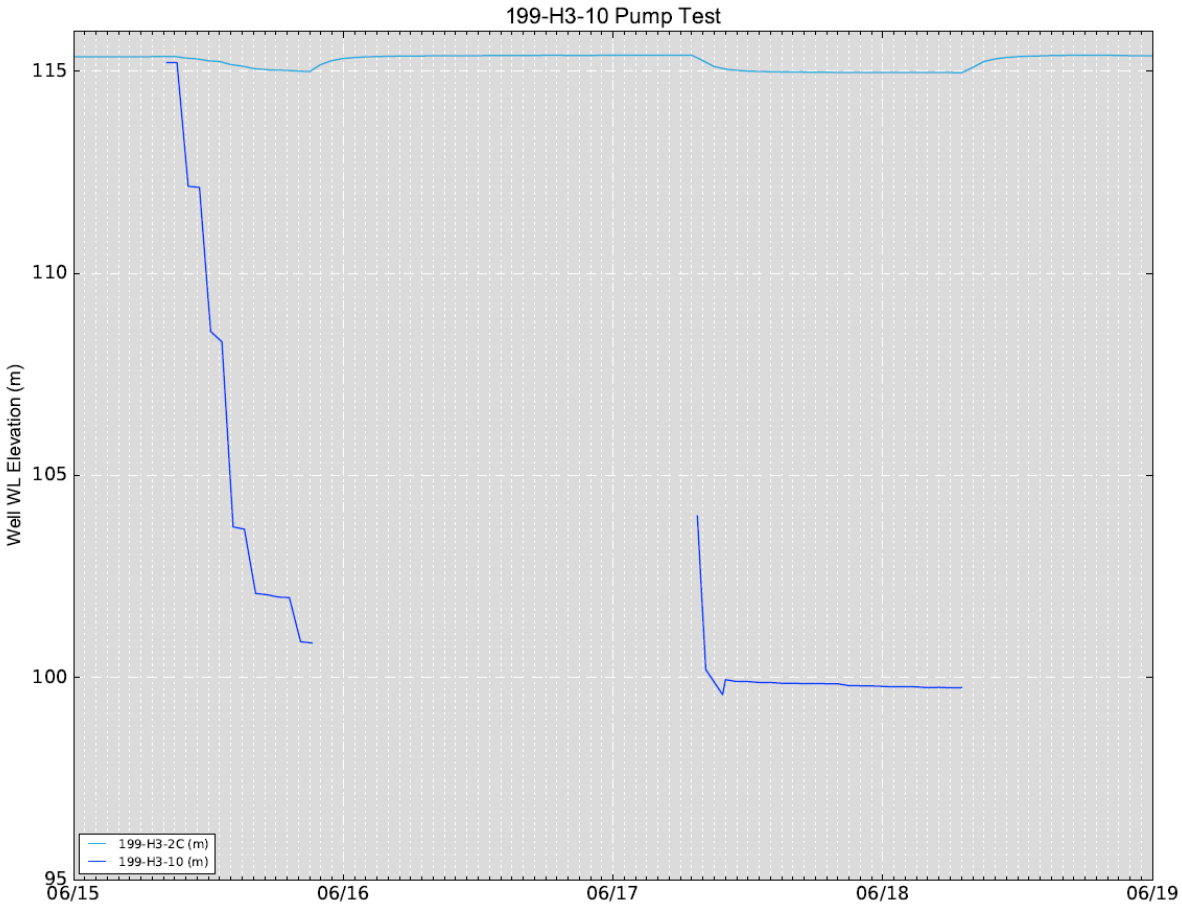


Figure 2. General Well Group Test Areas



Note: The initial spike at the beginning of the step test is due to nonideal test conditions.

Figure 3. Water Elevation Changes during 199-H3-2C Step and Constant Rate Pumping Tests and Response in Nearby Well 199-H3-10



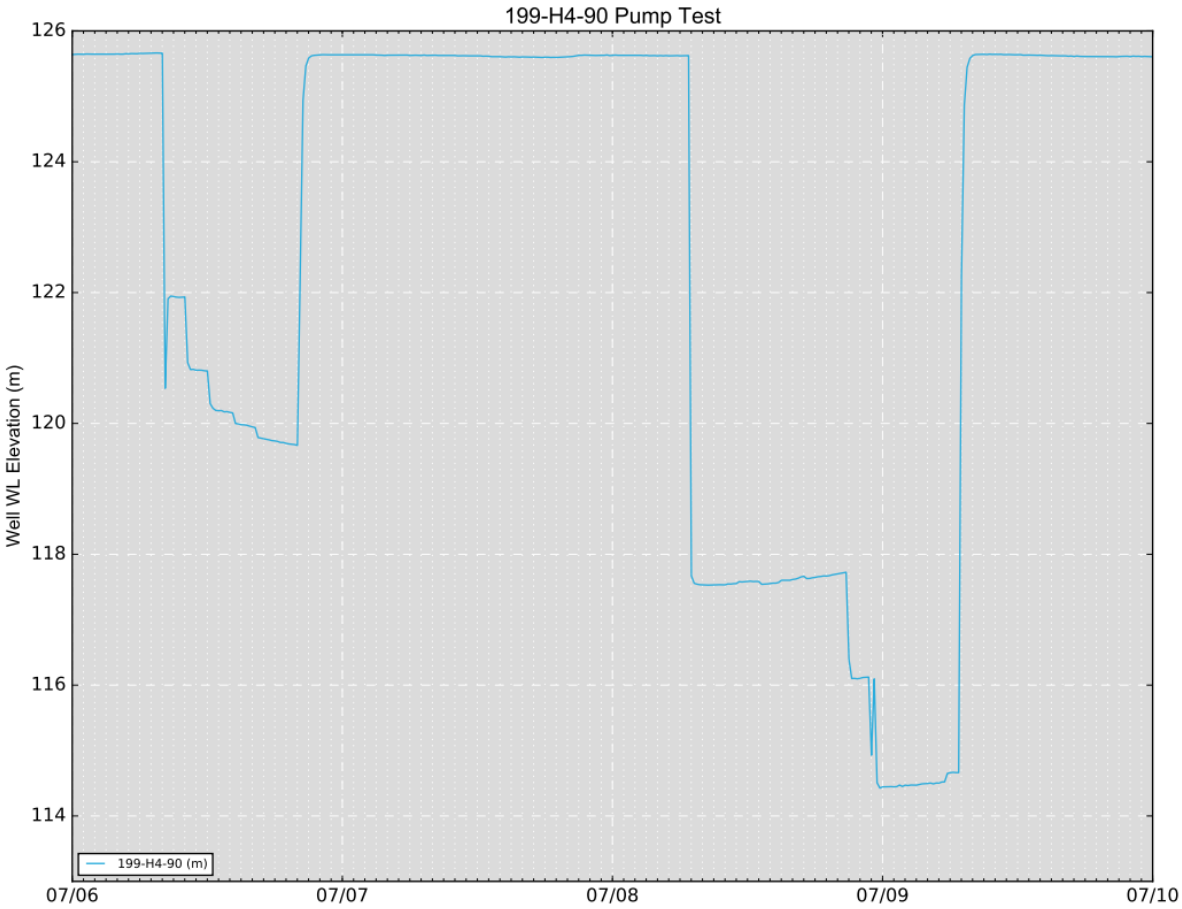
Note: Water level data were recorded by hand as the water level was drawn down below the transducer.

Figure 4. Water Elevation during 199-H3-10 Step and Constant Rate Pumping Tests and Response in Nearby Well 199-H3-2C

3.2 Zone 2

Zone 2 is located at the southeastern portion of the study area. It had a single test well (199-H4-90) and one other RUM well (199-H4-91) in the vicinity (215 m away). To date, the test in this section has provided limited data. Water levels in well 199-H4-90 during pumping are shown in Figure 5. The lower pump rate of 8 gpm during the constant rate test did not produce a measureable response in any surrounding RUM or unconfined aquifer well. It is not yet determined if this lack of response is due to an insufficient pump rate, difference in stratigraphy, or limitations from distance to the nearest observation well. Neither RUM well in zone 2 exhibits a discernable river influence. This lack of response may be due to their inland distance or lack of hydraulic communication between the river and the RUM aquifer, even though well 199-H4-91 is located only ~100 m from the river.

Unconfined aquifer wells in Zone 2 show responses to river level and barometric pressure similar to the unconfined wells in the other two zones. Wells completed in this unit within ~100 m of the river typically show connectivity being muted the farther inland the well is located. As discussed, there was no response in the unconfined aquifer to pumping in the RUM well (199-H4-90).



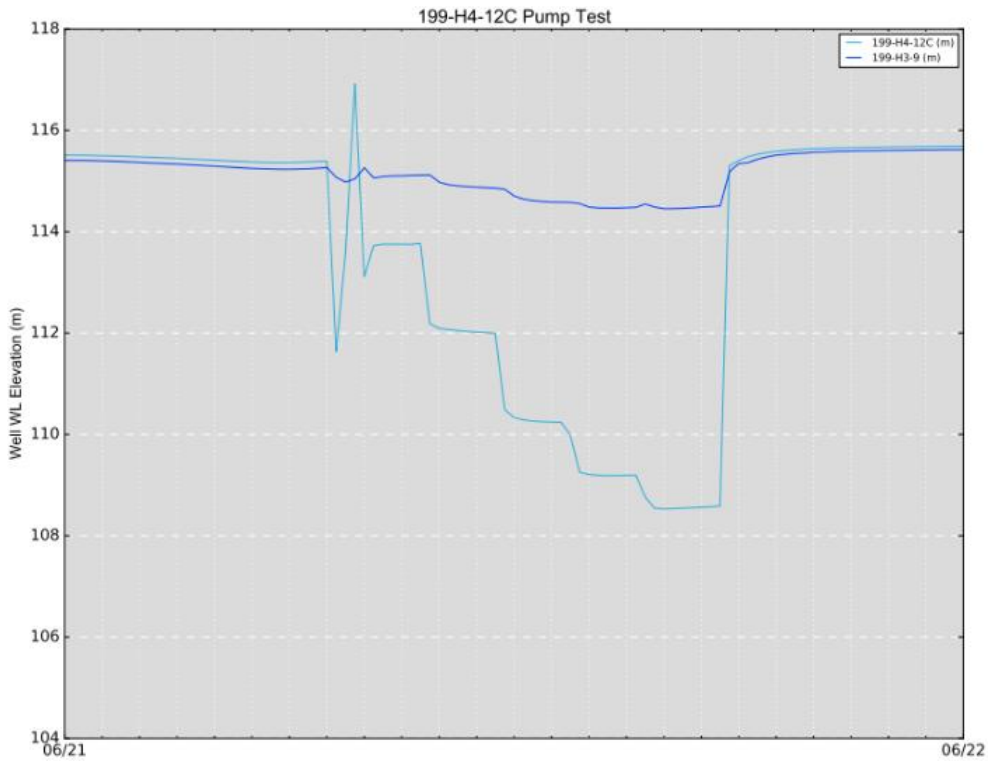
Note: The initial spike at the beginning of the step test is due to nonideal test conditions.

Figure 5. Water Level Elevation during 199-H4-90 Step and Constant Rate Pumping Tests

3.3 Zone 3

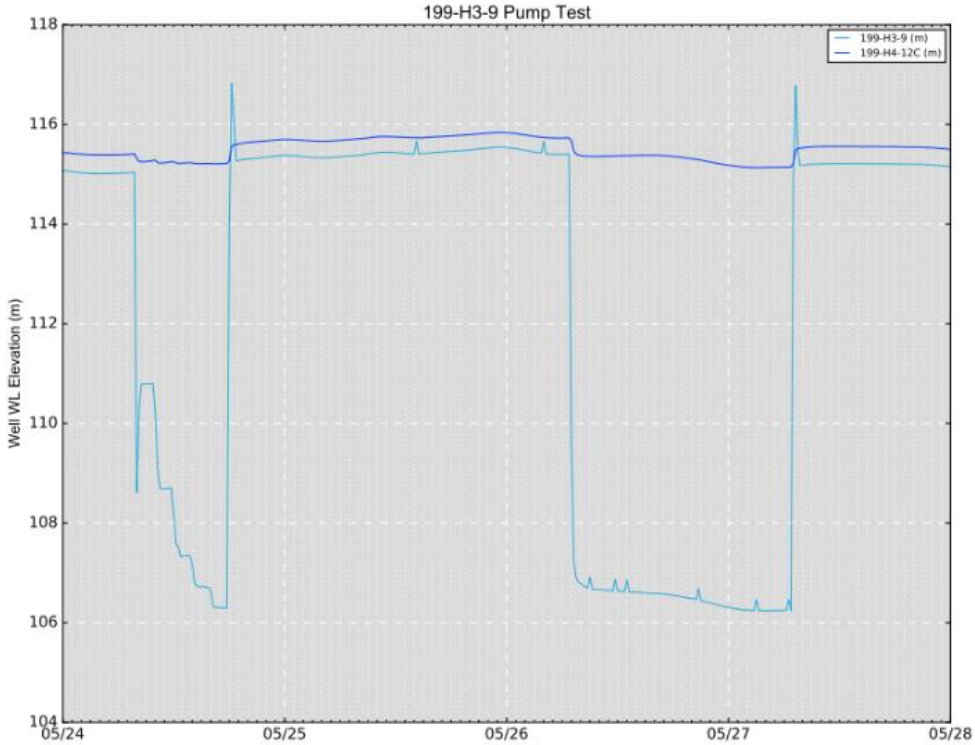
Zone 3 is located near the Columbia River in the northeastern part of the test area. Two RUM wells were tested in this area (199-H4-12C and 199-H3-9); two additional RUM observation wells (199-H4-15CS and 199-H2-1) and numerous wells in the unconfined aquifer were used as observation points. Well pumping tests in Zone 3 provided indications of a pressure and possible hydraulic connection between at least some of the RUM wells and the river. No response was observed between the RUM and unconfined aquifers in this zone.

The test of well 199-H4-12C shows a similar response pattern, as do the wells in Zone 1, with a strong response from a nearby RUM well, in this case 199-H3-9 (Figure 6). The pumping test at 199-H3-9 shows a very similar response (Figure 7), with the two wells in clear and immediate communication at a close proximity of ~25 m.



Note: The initial spike at the beginning of the step test is due to nonideal test conditions.

Figure 6. 199-H4-12C Step Drawdown Pumping Test Response and Response of Nearby Well 199-H3-9



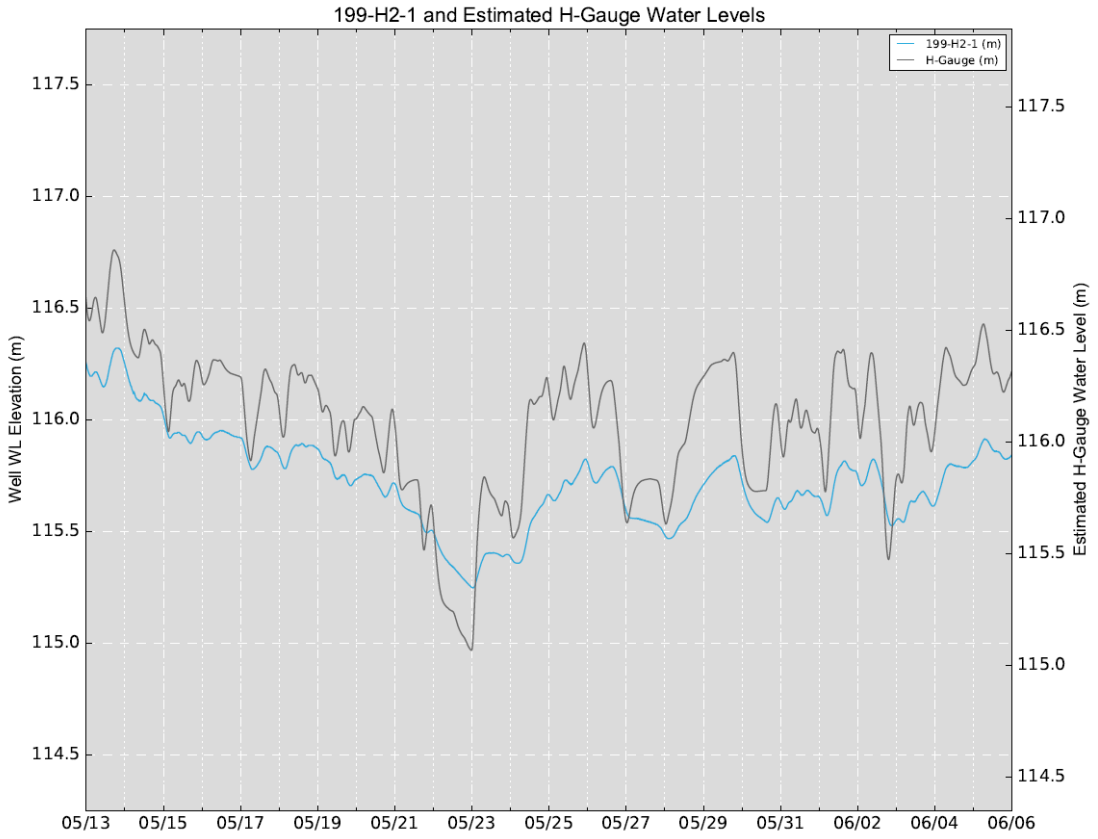
Note: The initial spike at the beginning of the step test is due to nonideal test conditions.

Figure 7. 199-H3-9 Well Pumping Test Showing Response in Nearby Well 199-H4-12C and Slight River Stage Effects during Nonpumping Periods

No response to pumping at either well (199-H4-12C or 199-H3-9) was identified in the other RUM wells in zone 3. Well 199-H4-15CS, roughly 150 m from the test wells, and well 199-H2-1 at 300 m are presumed to be located close enough to the pumping wells that a response would be expected. The lack of any observable pressure response in these two wells is due to their larger radial distance or possible lack of hydraulic connection. Additional evaluation will be conducted to determine if a response would have been expected, based on the RUM aquifer properties.

There appears to be no pressure response in any of the unconfined aquifer wells during the RUM aquifer pumping tests, although this may be obscured by fluctuations in pressure caused by stage changes in the Columbia River. This apparent lack of hydraulic connection to the unconfined aquifer is consistent with Cr(VI) concentrations observed in the RUM wells, where 199-H4-12C and 199-H3-9 have very similar and high concentrations (~120 µg/L and 80 µg/L at the time of testing, respectively). Well 199-H4-15CS has a much lower concentration (~37 µg/L), and Cr(VI) concentrations in well 199-H2-1 are ~20 µg/L.

All wells in this zone react to changes in river water elevation to some extent, including the RUM wells (Figure 8). This connection with the river boundary may be masking the signal of leaks that may occur elsewhere between the aquifers, making it indistinguishable in the data. Further complicating the interpretation of data to determine a hydraulic connection, unconfined aquifer wells (199-H1-7 and 199-H4-5) have more attenuated and delayed responses to river stage changes, despite being a similar distance to the river as other wells. This suggests that even the unconfined aquifer in this small zone is not homogenous and may be influenced by older river channels and various erosional features on the surface of the RUM and/or the presence of pockets of Ringold Formation unit E in this area.



Note: Elevation scales for the well and gauge are not identical.

Figure 8. Comparison of Temporal Response in Groundwater Elevation in RUM Well 199-H2-1 during a Period of No Pumping and the Estimated River Stage at 100-H from Priest Rapids Dam Data

3.4 Summary of Preliminary Results

The RUM well pumping test was successful in qualitatively answering a number of the objectives put forth in the test plan, and the results appear to be very encouraging. Based upon an initial review of the results, a preliminary radius of influence of each test well and spatially variable hydraulic connections in the RUM aquifer across the test area have been identified. The magnitude of these findings and ultimate effects on the transport and concentrations of Cr(VI) in the RUM aquifer still need to be determined.

3.5 Next Steps

The following subsequent quantitative analyses and interpretations will help accomplish the remainder of the test objectives and maximize information from the RUM testing (subject to revision as necessary):

- Identify and remove possible well water level responses to river stage effects in observation wells for better evaluation of pressure response to pumping in RUM test wells. Multiple regression deconvolution methods will be used.
- Assess changes in groundwater temperature and specific conductance during and following pumping tests for indications of captured mixed groundwater-river water (typically lower specific conductance in river and near shore zone).
- Estimate aquifer hydraulic properties (e.g., transmissivity, hydraulic conductivity, and storativity), using straight line and type curve analysis methods. Drawdown derivative analysis may help identify boundary head conditions and/or heterogeneities. Hydraulic property estimates from single well responses will be compared to composite responses from one or more observation wells (where analyzable responses are observed) in order to indicate heterogeneity and/or well inefficiency (i.e., skin effects).
- Summarize well performance information such as specific drawdown and yield, linear and nonlinear well losses, and degree of well skin.
- Review and compare previously published hydraulic property estimates for the RUM aquifer with results from this study.

4 References

ECF-Hanford-13-0028, 2016, *Columbia River Stage Correlation for the Hanford Area*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

HW-77170, 1963 (unclassified 1997), *Status of the Ground Water Beneath Hanford Reactor Areas January, 1962 to January, 1963*, General Electric Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0084838.

SGW-59756, 2016, *100-H Area RUM Aquifer Pump Test Plan*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0075565H.