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Slug Test Characterization Results for Multi-Test/Depth Intervals Conducted During the Drilling of CERCLA Operable Unit OU ZP-1 Wells 299-W10-33 and 299-W11-48

D. R. Newcomer

September 2007

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Summary

Slug-test results obtained from single and multiple, stress-level slug tests conducted during drilling and borehole advancement provide detailed hydraulic conductivity information at two Hanford Site Operable Unit (OU) ZP-1 test well locations. The individual test/depth intervals were generally sited to provide hydraulic-property information within the upper ~10 m of the unconfined aquifer (i.e., Ringold Formation, Unit 5). These characterization results complement previous and ongoing drill-and-test characterization programs at surrounding 200-West and -East Area locations (see Figure S.1).[a]

An analysis of the slug-test results indicates calculated average test-interval estimates of hydraulic conductivities ranging between 1.24 and 15.7 m/day. The ZP-1 well hydraulic-conductivity estimates were derived for test-interval sections that ranged from 1.0 to 1.6 m in length. The highest hydraulic-conductivity estimates were obtained for a single zone tested at well 299-W10-33 (i.e., range of 13.0 to 17.3 m/day), which is the southernmost ZP-1 well tested. These values bracket the reported 200-West Area geometric mean value (3.08 m/day) for recent slug tests conducted at 30 monitor-well sites completed within the upper part (i.e., upper 10 m) of the unconfined aquifer in the 200-West Area (Spane et al., 2001a, 2001b, 2002, 2003; Spane and Newcomer 2004).

References

Spane FA. Jr, PD Thorne, and DR Newcomer. 2001a. *Results of detailed hydrologic characterization tests – FY 1999*, PNNL-13378, Pacific Northwest National Laboratory, Richland, Washington.

Spane FA, Jr, PD Thorne, and DR Newcomer. 2001b. *Results of detailed hydrologic characterization tests – FY 2000*. PNNL-13514, Pacific Northwest National Laboratory, Richland, Washington.

Spane FA, Jr, PD Thorne, and DR Newcomer. 2002. *Results of detailed hydrologic characterization tests – FY 2001*. PNNL-14113, Pacific Northwest National Laboratory, Richland, Washington.

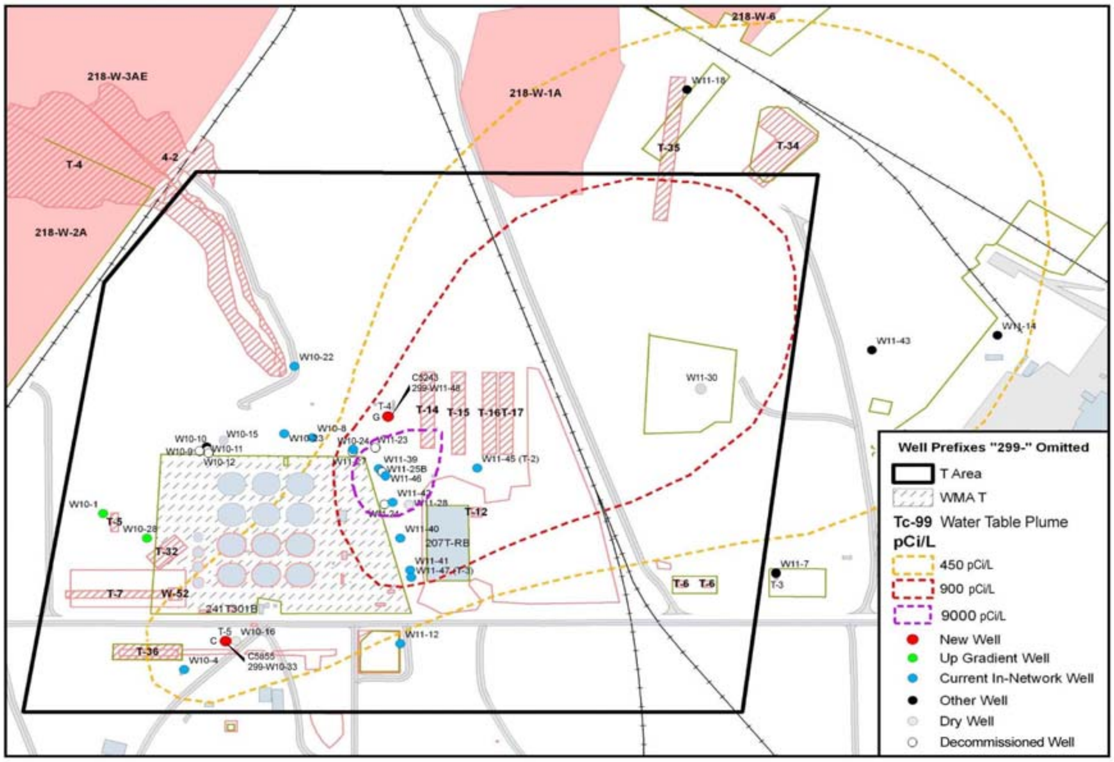
Spane FA, Jr, PD Thorne, and DR Newcomer. 2003. *Results of detailed hydrologic characterization tests – FY 2002*. PNNL-14186, Pacific Northwest National Laboratory, Richland, Washington.

(a) Spane FA. 2003. *Slug Test Characterization Results for Multi- Test/Depth Intervals Conducted During the Drilling of WMA-C Well 299-E27-22 (C4124).* Letter report to Jane Borghese (Fluor Hanford, Inc.), October 8, 2003.

Spane FA. 2005a. *Slug Test Characterization Results for Multi-Test/Depth Intervals Conducted During the Drilling of WMA-BX-BY Well 299-E33-49*. Letter report to Jane Borghese (Fluor-Hanford, ORP) January 10, 2005.

Spane FA. 2005b. *Slug Test Characterization Results for Multi-Test/Depth Intervals Conducted During the Drilling of CERCLA Operable Unit UP-1 Wells 299-W19-48, 699-30-66, and 699-36-70B.* Letter report to Mark Byrnes (Fluor-Hanford, ORP) September 13, 2005.

Spane FA. 2005c. *Slug Test Characterization Results for Multi-Test/Depth Intervals Conducted During the Drilling of CERCLA Operable Unit ZP-1 Wells 299-W11-43, 299-W15-50, and 299-W18-16*. Letter report to Mark Byrnes (Fluor-Hanford, ORP) September 13, 2005.



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1.0 General Hydrologic Test Plan Description

The following discussion of the general hydrologic test plan is taken primarily from similar slug-test characterization-program descriptions presented previously in Spane.[a] Hydrologic testing was implemented when the approximate targeted depth intervals within the unconfined aquifer were reached during drilling. To prepare the test zone for slug-test characterization, the packer/well-screen test assembly was lowered to the bottom of the borehole and the drill casing retracted, exposing an approximate 1.5-m open borehole section. The packer was then inflated to isolate the well-screened/test interval and the testing string from the inside of the drill casing.

A series of multiple, stress-level slug tests were attempted for each isolated test-interval section. The reason for using a multi-stress-level approach was to determine whether the associated slug-test responses exhibited either a variable or stress-level dependence. As noted in Butler (1998) and Spane et al. (2003b), tests exhibiting either variable or stress-level dependence can provide valuable information pertaining to the presence of a dynamic well skin or non-linear (i.e., turbulence) test-response conditions occurring within the test section. General slug-test stress levels applied during testing were designed to be within the range of ~0.3 to 0.5 m for lower stress tests and ~1.0 m for higher stress tests. The slug tests were initiated using two slugging rods of different, known displacement volumes. Unfortunately, only one of the three test zones (i.e., Zone 1 at well 299-W10-33) was tested successfully using slugging rods with different displacement volumes. The second of the three test zones (i.e., Zone 2 at well 299-W11-48) was tested successfully at a low stress, but not at a high stress, and the third zone (i.e., Zone 1 at well 299-W11-48) was tested successfully at a high stress, but not at a low stress.

For Zone 1, well 299-W10-33, three or more multi-stress slug tests were conducted successfully. Individual slug tests were fully recovered before depressing the fluid column to prepare the next slug test within the characterization sequence. A wide-range in recovery times was expected, based on an anticipated range in permeability conditions. For example, Spane et al. (2001a, 2001b, 2002, 2003a) and Spane and Newcomer (2004) report recovery times as rapid as <15 sec for high-permeability test intervals to >5 min for lower permeability test zones for 200-West Area wells. A description of the hydrologic test system used during slug-test characterization is provided in the following report section.

(a) Spane FA. 2003. *Slug Test Characterization Results for Multi- Test/Depth Intervals Conducted During the Drilling of WMA-C Well 299-E27-22 (C4124).* Letter report to Jane Borghese (Fluor Hanford, Inc.), October 8, 2003.

Spane FA. 2005a. *Slug Test Characterization Results for Multi-Test/Depth Intervals Conducted During the Drilling of WMA-BX-BY Well 299-E33-49*. Letter report to Jane Borghese (Fluor-Hanford, ORP) January 10, 2005.

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Spane FA. 2005c. *Slug Test Characterization Results for Multi-Test/Depth Intervals Conducted During the Drilling of CERCLA Operable Unit ZP-1 Wells 299-W11-43, 299-W15-50, and 299-W18-16*. Letter report to Mark Byrnes (Fluor-Hanford, ORP) September 13, 2005.

2.0 Hydrologic-Test-System Description

Figure 2.1 shows the general test-system configuration used for slug tests conducted during the drilling and testing of the ZP-1 wells with single-wall drill-casing strings. Slug tests were conducted using slugging rods for all test zones within single-wall drill casing wells 299-W10-33 and 299-W11-48. Features common to this test-system configuration include a downhole packer/well-screen test assembly and a downhole pressure transducer and surface datalogger system. The drill-casing strings used for borehole advancement during the drilling of the ZP-1 wells varied slightly for the respective well sites and had the following I.D./O.D. dimensions: well 299-W10-33: 0.248/0.273 m; and well 299-W15-48: 0.248/0.260 m).

As shown in Figure 2.1, an inflatable packer was used to seal and isolate the test interval and testing string from the encompassing drill-casing area. A 20-slot, well-screen section was attached below the packer to maintain an open section for testing after retracting the drill casing. For testing at all ZP-1 well sites, one standard packer/well-screen assembly was used: 3.05-m long, 0.1016-m I.D. well-screen (Figure 2.2). A strain-gauge pressure transducer was installed within the test-casing string to monitor downhole test-interval response before and during slug testing.

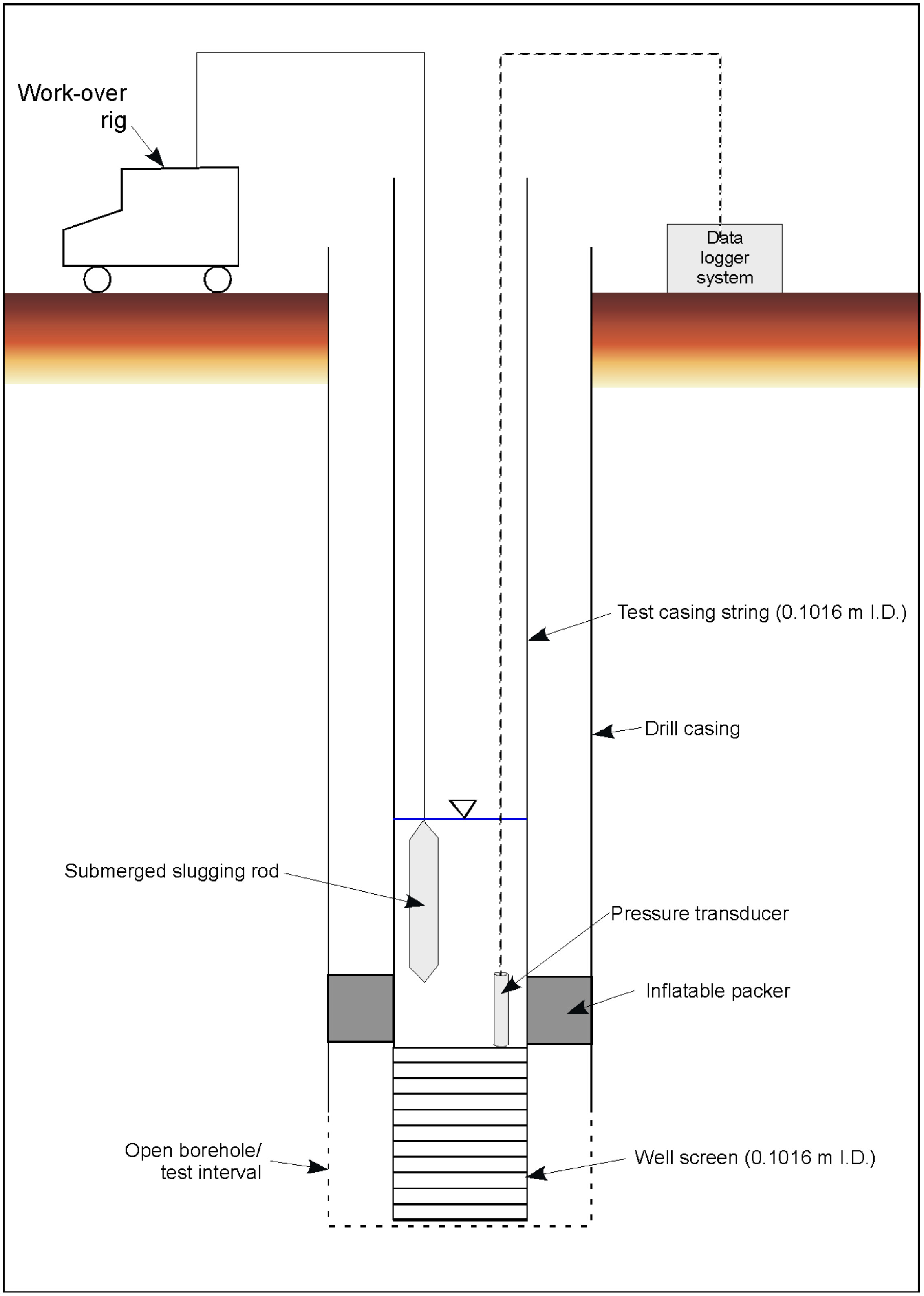


Figure 2.1. General Slug Test Configuration Using Slugging Rods

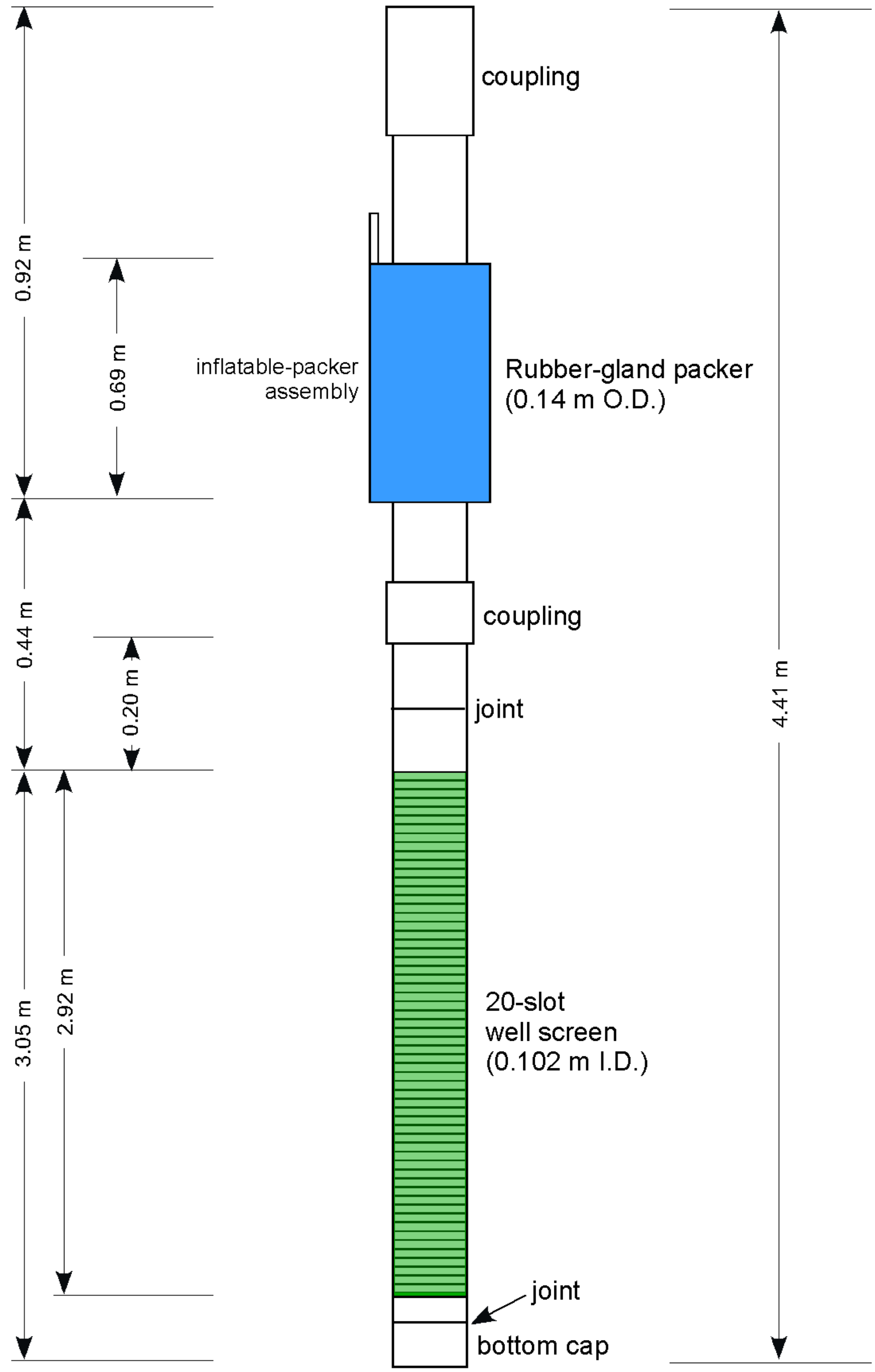


Figure 2.2. Packer/Well-Screen Assembly Dimensions

3.0 Slug Test Response/Analysis

The following discussion pertaining to slug-test response and analysis is taken primarily from Spane (see Footnote [a], p. 1.1). As shown in Figure 3.1 and discussed in Butler (1998) and Spane et al. (2003b), water levels within a test well can respond in one of three ways to the instantaneously applied stress of a slug test. These response model patterns are 1) an over-damped response, where the water levels recover in an exponentially decreasing recovery pattern, 2) an under-damped response, where the slug-test response oscillates above and below the initial static, with decreasing peak amplitudes with time, and 3) a critically damped response, where the slug test behavior exhibits characteristics that are transitional to the over- and under-damped response patterns. Factors that control the type of slug-test response model that will be exhibited within a well include a number of aquifer properties (hydraulic conductivity) and well-dimension characteristics (well-screen length, well-casing radius, well-radius, aquifer thickness, fluid-column length) and can be expressed by the response-damping parameter, C_D, which Butler (1998) reports for unconfined aquifer tests as:

$$C_D = (g/L_e)^{½} r_c^2 \ln (R_e/r_w)/(2 K L) \qquad (3.1)$$

where g = acceleration due to gravity
L_e = effective well water-column length
r_c = well casing radius; i.e., radius of well water-column that is active during testing
R_e = effective test radius parameter; as defined by Bouwer and Rice (1976)
r_w = well radius
K = hydraulic conductivity of test interval
L well-screen length.

Given the multitude of possible combinations of aquifer properties, well-casing dimensions, and test-interval lengths, no universal C_D value ranges can be provided that describe slug-test response conditions. However, for various combinations anticipated for testing at ZP-1 well sites during drilling, the following general guidelines on predicting slug-test responses are provided:

- C_D >3 = over-damped response
- C_D 1 - 3 = critically damped response
- C_D <1 = under-damped response.

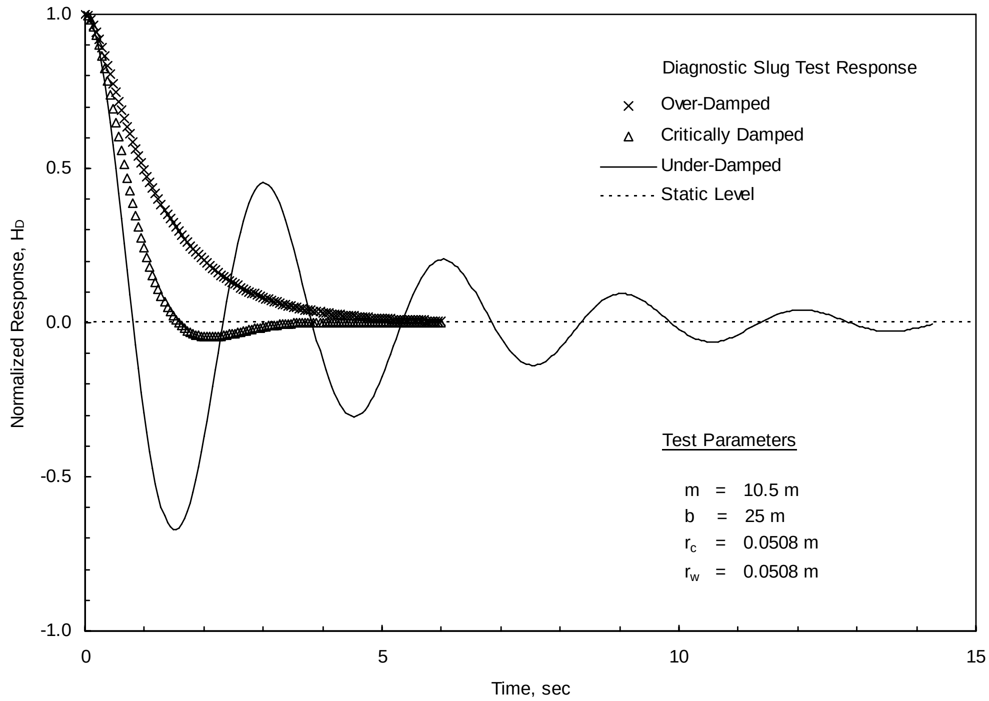


Figure 3.1. Diagnostic Slug Test Response (taken from Spane et al. (2003a)

An over-damped test response generally occurs within stress wells monitoring test formations of low to moderately high hydraulic conductivity (e.g., Ringold Formation) and are indicative of test conditions where frictional forces (i.e., resistance of groundwater flow from the test interval to the well) are predominant over test-system inertial forces. All ZP-1 well test intervals exhibited over-damped response characteristics. Figure 3.2 shows predicted slug-test recovery as a function of hydraulic conductivity (K range: 2.5 to 40 m/day; 1.5-m test interval) for test intervals exhibiting over-damped response characteristics and for general ZP-1 test well/interval conditions. The test predictions shown in the figure are based on responses occurring within a test system casing I.D. = 0.1016 m. As indicated in the figure, test intervals having hydraulic conductivity values of approximately 40 m/day or less should be readily resolved for tests exhibiting over-damped slug-test behavior. For over-damped slug tests, two different methods can be used for the slug-test analysis: the semiempirical, straight-line analysis method described in Bouwer and Rice (1976) and Bouwer (1989) and the type-curve-matching method for unconfined aquifers presented in Butler (1998). For over-damped slug tests, hydraulic-conductivity estimates obtained using the Bouwer and Rice analytical method are generally less reliable than corresponding estimates obtained using the type-curve-matching method (Hyder and Butler 1995; Butler 1998). For this reason, only the type-curve-matching analytical method was used for estimating hydraulic conductivity for zones tested at the ZP-1 wells. A detailed description of over-damped, slug-test-analysis methods is presented in Spane and Newcomer (2004).

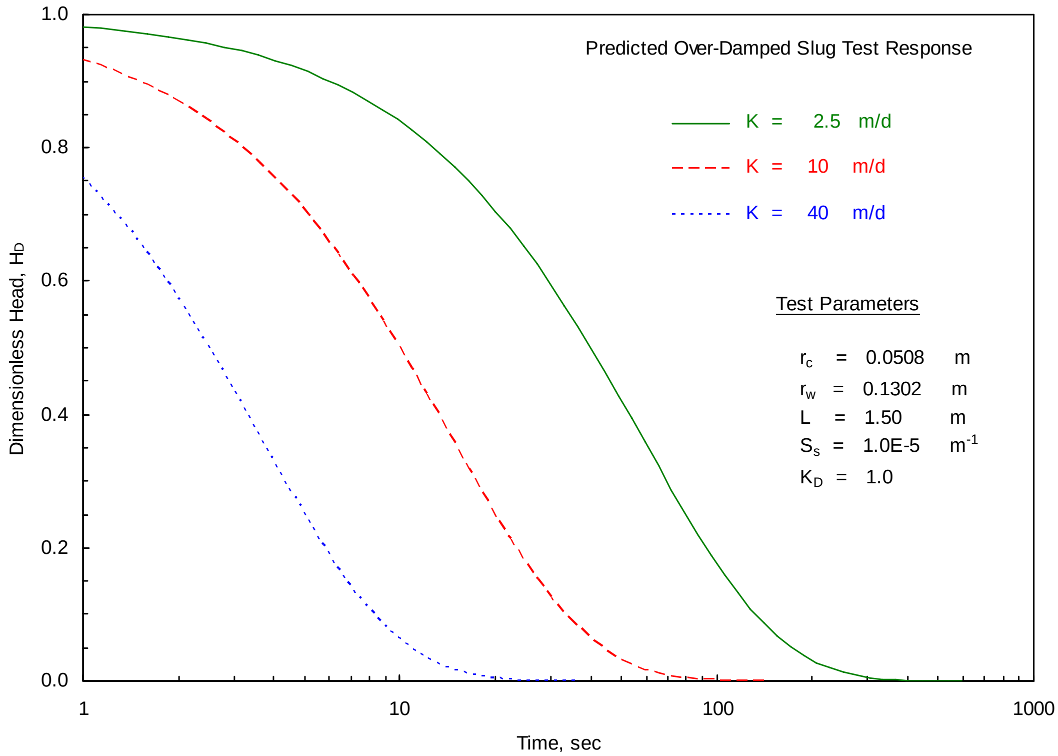


Figure 3.2. Over-Damped Slug-Test Response as a Function of Test-Interval Hydraulic Conductivity

Under-damped test-response patterns are exhibited within stress wells where inertial forces are predominant over formation frictional forces. This commonly occurs in wells with extremely long fluid columns (i.e., large water mass within the well column) and/or that penetrate highly permeable aquifers (e.g., Hanford formation). Tests exhibiting under-damped behavior should be conducted with very small stress-level applications. No ZP-1 well test intervals displayed formational test-response characteristics that were under damped.

As mentioned previously, critically damped test responses are indicated by stress well water-level responses that are transitional to the over- and under-damped test conditions, as shown in Figure 3.1. They typically occur in wells that monitor test formations exhibiting intermediate to high hydraulic conductivity. As noted in Butler (1998), distinguishing between slug-test responses that are over damped and critically damped may be difficult in some cases (i.e., due to test signal noise) when examined on arithmetic plots. Proper model identification may be enhanced when semi-log plots are used, i.e., log head versus time (e.g., Bouwer and Rice plot). Critically damped slug tests exhibit a diagnostic concave-downward pattern when plotted in this semi-log plot format. This is in contrast to over-damped response behavior, which displays either a linear or concave upward (elastic) pattern. Critically damped slug-test responses are influenced by processes (e.g., inertial) that are not accounted for in the previously discussed slug-test analytical methods (i.e., for over-damped tests). Because of this, slug tests exhibiting these response characteristics cannot be analyzed quantitatively using the Bouwer and Rice or standard type-curve methods. High-K analysis methods that can be employed for analyzing unconfined aquifer tests exhibiting response behavior that is either critically damped or under damped include those described in

Springer and Gelhar (1991), Butler (1998), McElwee and Zenner (1998), McElwee (2001), Butler and Garnett (2000), and Zurbuchen et al. (2002). Because of the ease provided by a spreadsheet-based approach, the test-analysis method presented in Butler and Garnett (2000) is preferred for analyzing tests exhibiting critically damped behavior. A detailed discussion of this analytical procedure and method is presented in Spane and Newcomer (2004). No ZP-1 well test intervals displayed formational test-response characteristics that were critically damped.

4.0 Slug-Test Results

The following discussion presents pertinent information describing slug testing activities and analysis results for the test/depth zones that were hydrologically characterized at the ZP-1 boreholes as they were advanced to their final drilling depths. Table 4.1 presents pertinent slug-test information for the respective test/depth intervals while Table 4.2 summarizes the slug-test-analysis results. Selected borehole logs are presented in Appendix B, which can be referred to for a geologic description of the respective well test zone/depth intervals.

Table 4.1. Slug-Test Characteristics for Selected Test/Depth Intervals at Operable Unit ZP-1 Test Wells 299-W10-33 and 299-W11-48

Test Well	Test Zone	Test Parameters				Diagnostic Slug Test Response Model	Hydrogeologic Unit Tested [a]
		Test Date	Number of Slug Tests	Depth to Water, m bgs	Depth/Test Interval, m bgs		
299-W10-33	Zone 1	7/6/07	5	69.98	73.2 - 74.2 (1.0)	Homogeneous Formation/ Exponential-Decay (over-damped)	Ringold Formation (Unit 5)
299-W11-48	Zone 1	4/6/07	6[b]	73.64	76.8 - 78.4 (1.6)	Heterogeneous Formation/ Exponential Decay (over-damped)	Ringold Formation (Unit 5)
	Zone 2	4/12/07	4[b]	73.79	82.8 - 84.3 (1.5)	Heterogeneous Formation/ Exponential Decay (over-damped)	Ringold Formation (Unit 5)

(a) Assumed to be uniform within the well-screen test section.
Note: For all test wells, r_c = 0.0508 meter; r_w ranged between 0.1302 and 0.1365 meters.
Unit number in parentheses indicates the relevant groundwater-flow model layer, as described in Thorne, et al. 1993.
(b) Only two of the slug tests provided analyzable results.

Table 4.2. Slug-Test-Analysis Results

Test Well	Test Zone	Type-Curve Analysis Method: Horizontal Hydraulic Conductivity, $K_{h,}$[(a)] (m/day)	Type-Curve Analysis Method: Specific Storage, S_s (m^{-1})
299-W10-33	Zone 1	13.0 – 17.3 (15.7)	1.0E-5
299-W11-48	Zone 1	1.17 - 1.30 (1.24)	5.0E-5 - 1.0E-4
	Zone 2	5.62 - 6.91 (6.27)	1.0E-5

Number in parentheses is the average value for all tests.
(a) Assumed to be uniform within the well-screen test section.

4.1 Well 299-W11-48 (C5243)

The drilling of OU ZP-1 well 299-W11-48 was initiated on November 29, 2006, and continued until reaching a final depth of 124.7-m bgs on June 4, 2007. The Lower Mud unit of the Ringold Formation was not encountered during drilling, which represents the bottom boundary of the unconfined aquifer at this location. Based on projections from neighboring well sites, however, the Lower Mud unit contact would be expected at a depth of 130 to 140-m bgs. Two test-depth intervals were tested at the borehole location: Zone 1 = 76.8 to 78.4 m bgs; and Zone 2 = 82.8 to 84.3 m bgs.

4.1.1 Zone 1

After reaching a depth of 78.4-m bgs, the packer/well-screen assembly was lowered to the bottom of the borehole and the 0.2731-m O.D. (10-$^3/_4$ inch O.D.) dual-wall, and the drill casing retracted 1.6 m, producing a test/depth interval for Zone 1 of 76.8 to 78.4-m bgs. The borehole geology log (Appendix B; Figure B.1) indicates that the test-interval section generally consists of a silty sandy gravel unit, composed of 60 to 70% gravel, 30 to 35% sand, and 10 to 20% silt.

A series of three slug injection tests (two low and one high stress test) and a series of three slug withdrawal (two low and one high stress test) were conducted between 1349 hours and 1609 hours (PST), April 6, 2007. The low-stress slug-injection and withdrawal tests were unsuccessful and yielded test data that could not be analyzed. The high-stress slug injection (SI #3) and withdrawal (SW #3) tests were marginally successful using a slugging rod with a volume of 0.011 m^3. This slug-rod volume imparted a theoretical applied stress value of 1.36 m for the high-stress tests. Downhole test-interval response pressures during testing were monitored using a 0 to 20 psig (0 to 138 kPa) pressure transducer set at a depth of ~76.7-m bgs. The static depth-to-water for the test interval during testing was 73.64-m bgs.

A diagnostic analysis of slug tests conducted for this test/depth interval indicates a heterogeneous formation/composite response condition. This composite pattern exhibits a high-permeability, fast-initial-recovery, inner-zone response, which transitions to a lower permeability response for the surrounding outer-zone formation. The presence of a high-permeability inner-zone is believed to be reflective of an artificially created condition. This artificially created high-permeability condition may be attributed to the setting of a smaller diameter packer/well-screen assembly and the retraction of the much larger diameter drill casing to expose the test/depth interval. The creation of an artificial high-permeability inner-zone (surrounding the temporary well screen) is believed to be the result of dislodged gravel and cobbles collapsing around the temporary well screen as the drill casing was retracted. An examination of the drilling log geologic description indicates the presence of a high percentage of silty, sandy gravel for this particular test/depth interval.

As discussed in Spane (see Footnote [a], p. 1.1), slug tests exhibiting linear response characteristics for heterogeneous formation tests can be analyzed quantitatively using the homogeneous-formation-analysis approaches described in Section 4. For the homogeneous-formation analysis, the type-curve method estimates for K ranged between 1.17 and 1.30 m/day (average 1.24 m/day) for the various high-stress-level tests for the formational outer-zone. Selected examples of the diagnostic and test analysis plots for this test/depth interval are shown in Figure 4.1a and b, respectively.

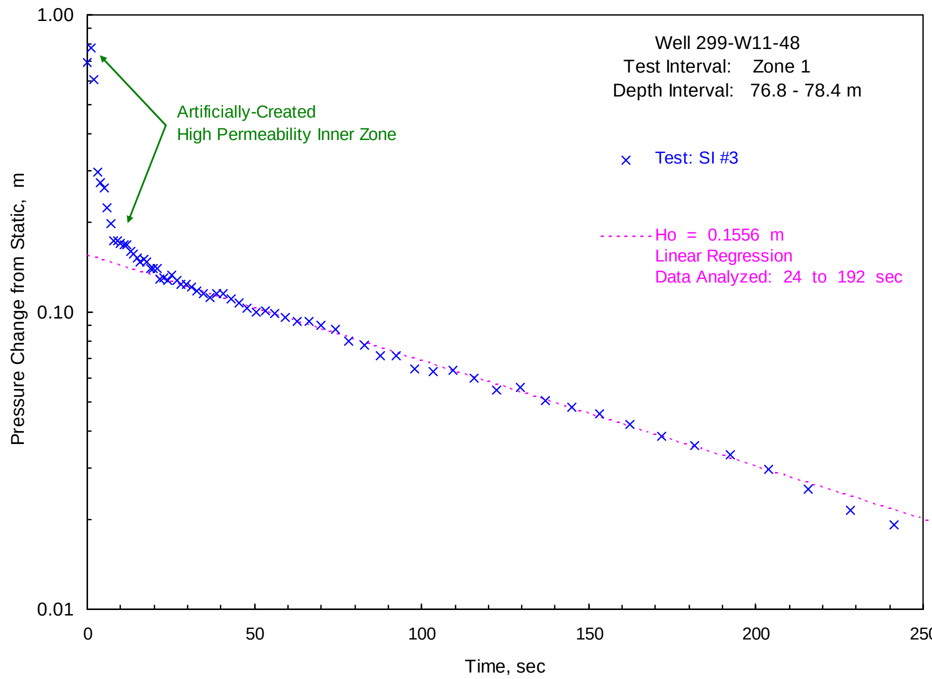
4.1.2 Zone 2

After reaching a depth of 84.3-m bgs, the packer/well-screen assembly was lowered to the bottom of the borehole, and the 0.2731-m O.D. (10-$^{3}/_{4}$-inch O.D.) dual-wall, drill casing retracted 1.5 m, producing a test/depth interval for Zone 2 of 82.8 to 84.3-m bgs. The borehole geology log (Appendix B; Figure B.1) indicates that the test interval section generally consists of a silty sandy gravel unit similar to Zone 1, composed of 60 to 70% gravel, 30 to 35% sand, and 10 to 20% silt.

A series of four slug withdrawal tests (all low stress tests) were conducted between 1029 hours and 1130 hours (PST), April 12, 2007. High-stress tests could not be performed because the larger slugging rod (i.e., volume of 0.011 m^3) would not go past the first pipe joint near the surface. Only two of the four low-stress slug tests (i.e., SW #1 and SW #3) were performed successfully, but yielded noisy data, using a slugging rod with a volume of 0.006 m^3. This slug-rod volume imparted a theoretical applied stress value of 0.68 m for the low-stress tests. It is not known what contributed to the noise in the data, but it is suspected to be vibrations associated with the drill-rig engine used to power the raising of the slugging rod. Downhole test-interval response pressures during testing were monitored using a 0 to 5 psig (0 to 35 kPa) pressure transducer set at a depth of ~76.6-m bgs. The static depth-to-water for the test interval during testing was 73.79-m bgs.

As for tests conducted for overlying Zone 1, a diagnostic analysis of slug tests conducted for this test/depth interval indicates a heterogeneous-formation/composite-response condition. This composite pattern exhibits a high permeability, fast initial recovery, and inner-zone response, which transitions to a lower permeability surrounding the outer-zone-formation response. The presence of a high permeability inner-zone is believed to be reflective of an artificially created condition. This artificially created high permeability condition may be attributed to the setting of a smaller diameter packer/well-screen assembly and retraction of the much larger diameter drill casing to expose the test/depth interval. The creation of an artificial high-permeability inner-zone (surrounding the temporary well screen) is believed to be the result of dislodged gravel and cobbles collapsing around the temporary well screen while the drill casing

(a)



(b)

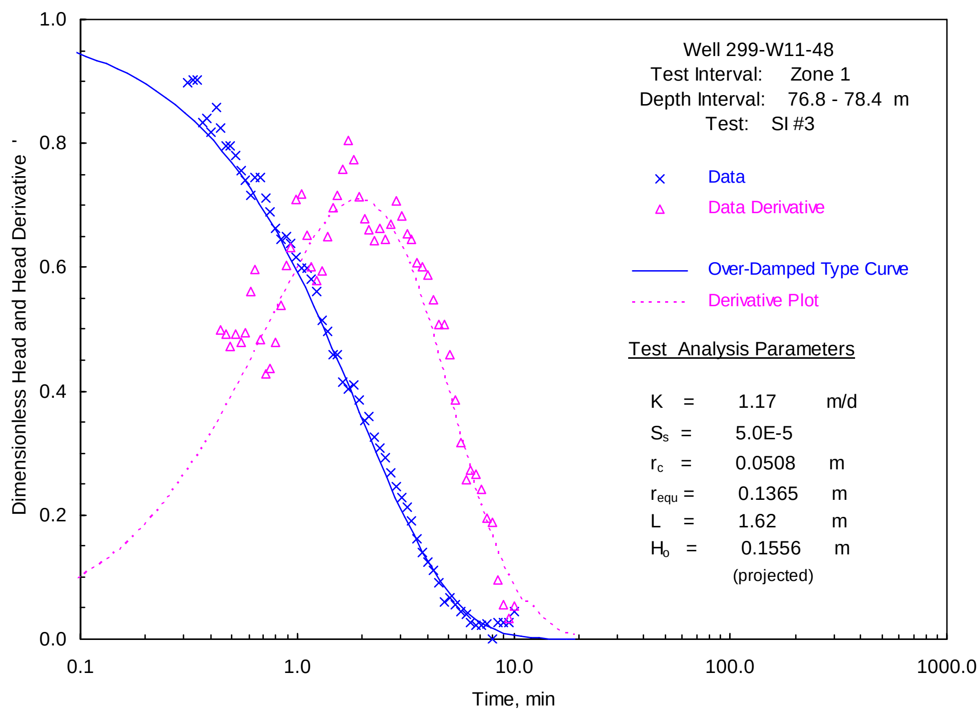


Figure 4.1. Selected Slug Test Analysis Plot for Well 299-W11-48: (a) Diagnostic(top) and (b) Type-Curve Analysis Method (bottom)

is being retracted. An examination of the drilling-log geologic description indicates the presence of a high percentage of silty, sandy gravel for this particular test/depth interval.

As discussed in Spane (see Footnote [a], p. 1.1), slug tests exhibiting linear, heterogeneous-formation, test-response characteristics can be analyzed quantitatively using the homogeneous-formation-analysis approaches described in Section 4. For the homogeneous-formation analysis, the type-curve method estimates for K ranged between 5.62 and 6.91 m/day (average 6.27 m/day) for the various low-stress-level tests for the formational outer-zone. It should be noted that the K estimates for this test interval have a higher degree of uncertainty, due to the high dissipation of low-stress slug tests by the artificially created, higher permeability, inner zone. Selected examples of the diagnostic and test analysis plots for this test/depth interval are shown in Figure 4.2a and b, respectively.

4.2 Well 299-W10-33 (C5855)

During drilling of OU ZP-1 well 299-W10-33, the Lower Mud unit of the Ringold Formation was not encountered, which represents the bottom boundary of the unconfined aquifer at this location. Based on projections from neighboring well sites, however, the Lower Mud unit contact would be expected at a depth of 130 to 140-m bgs. One test-depth interval was tested at the borehole location; Zone 1 = 73.2- to 74.2-m bgs.

4.2.1 Zone 1

After reaching a depth of 74.9-m bgs, the packer/well-screen assembly was lowered to a depth of 74.2-m bgs, and the 0.2604-m O.D. (10-$^1/_4$ inch O.D.) dual-wall drill casing retracted 1.0 m, producing a test/depth interval for Zone 1 of 73.2- to 74.2-m bgs. The borehole geology log for well 299-W10-33 was not available for this report.

A series of five slug withdrawal tests (two low-stress and three high-stress tests) were conducted between 1203 hours and 1444 hours (PST), July 6, 2007. The slug tests were initiated using slugging rods having two different displacement volumes. The calculated slugging-rod volumes impart theoretical applied stress values of 0.68 and 1.16 m for the low and high stress tests, respectively. Downhole test-interval response pressures during testing were monitored using a 0 to 5 psig (0 to 35 kPa) pressure transducer set at a depth of ~72.5-m bgs. The static depth-to-water for the test interval during testing was 69.98-m bgs.

The low-stress, slug-test responses indicate a linear, inelastic (storage), over-damped, slug-test behavior (e.g. Figure 4.3). The low-stress slug tests exhibited homogeneous-formation conditions over the entire test response. For the high-stress slug tests, a comparison of the normalized slug-test responses indicates a linear, inelastic (storage), over-damped, slug-test behavior during the early part of the test. There is some indication that test responses yield to a slightly critically damped condition during the latter part of the tests, as shown by the slightly curvi-linear semi-log plot (Figure 4.4). A comparison between normalized low and high stress tests indicates slight differences in response behavior, suggesting that the well had not been developed sufficiently to establish stable skin conditions.

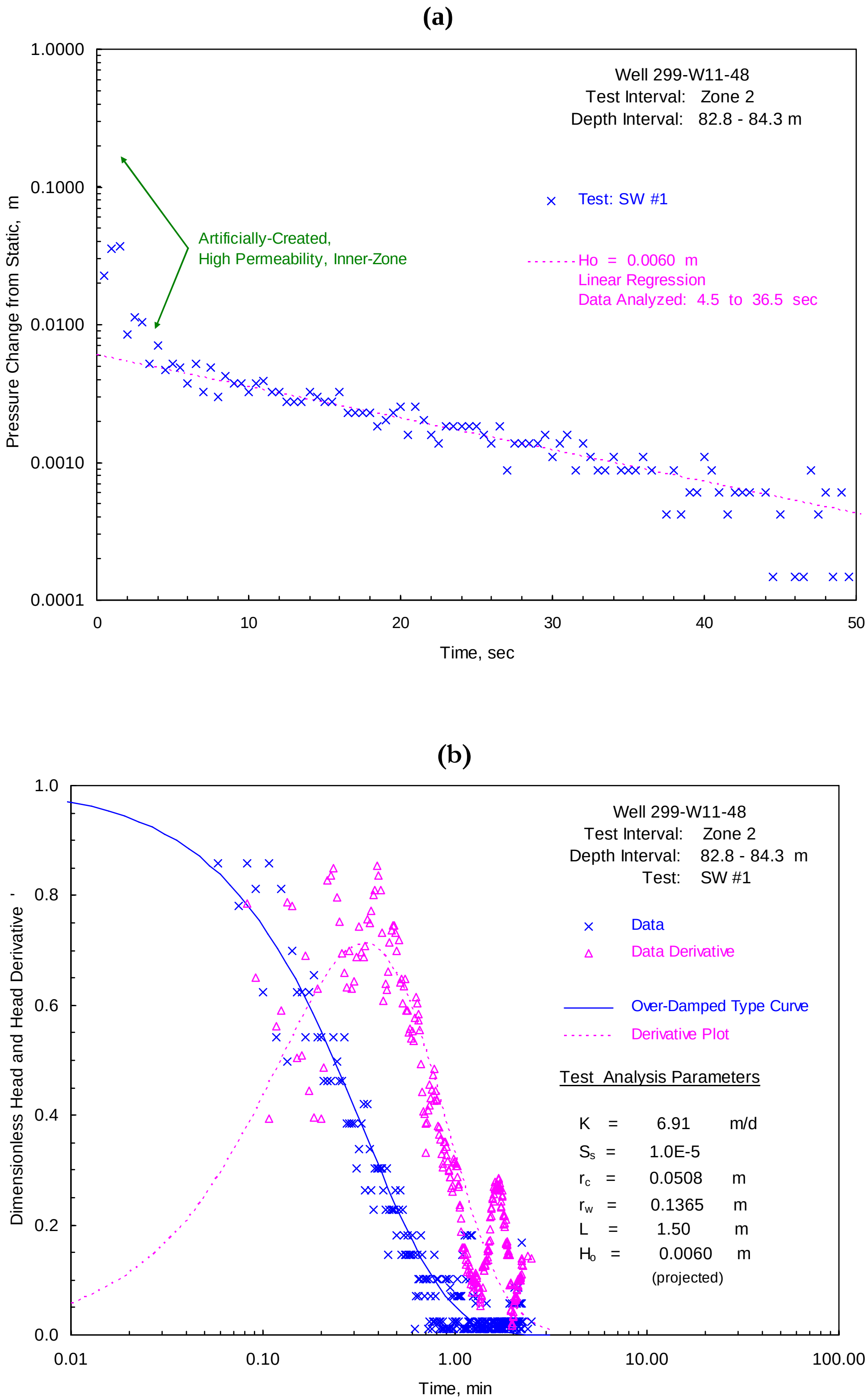


Figure 4.2. Selected Slug-Test-Analysis Plot for Well 299-W11-48: (a) Diagnostic (top) and (b) Type-Curve Analysis Method (bottom)

Slug-test results exhibiting homogeneous-formation response behavior can be analyzed quantitatively using standard, linear-response-based analytical methods (i.e., using standard type-curve methods) following procedures described in Spane and Newcomer (2004). Estimates for K using the type-curve method ranged between 13.0 and 17.3 m/day, with an average of 15.7 m/day for the five slug-withdrawal tests. Figure 4.3 shows a selected example of the analysis plots for this test interval.

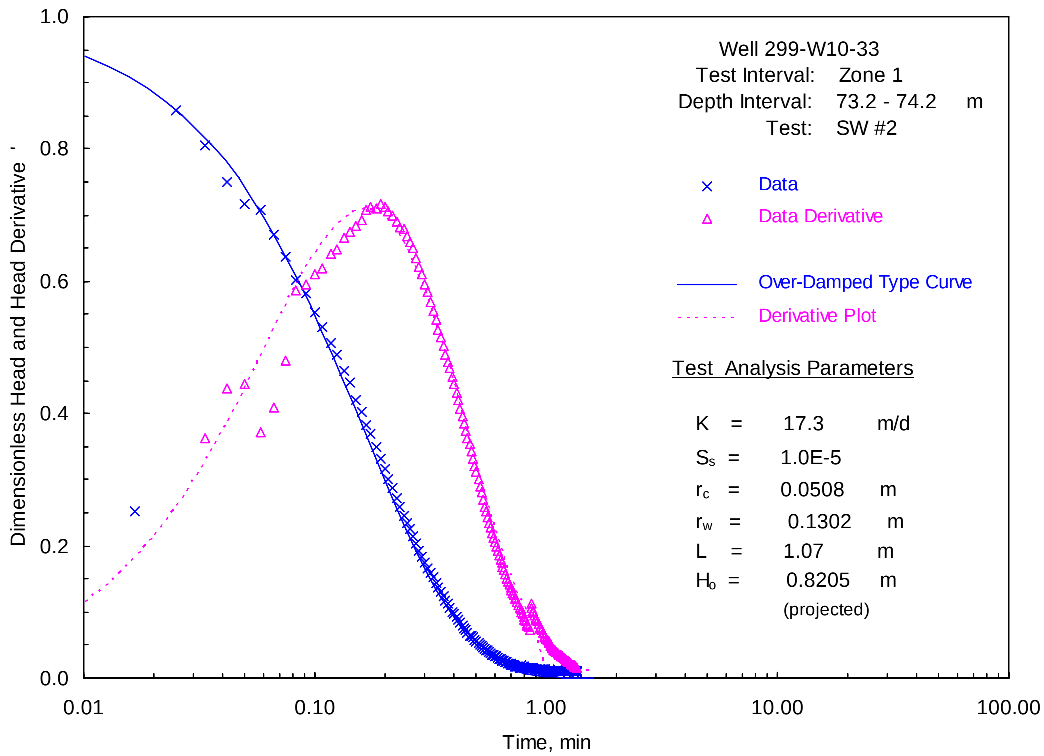


Figure 4.3. Selected Slug Test Analysis Plot for Well 299-W10-33: Test Interval Zone 1 (Type-Curve Method)

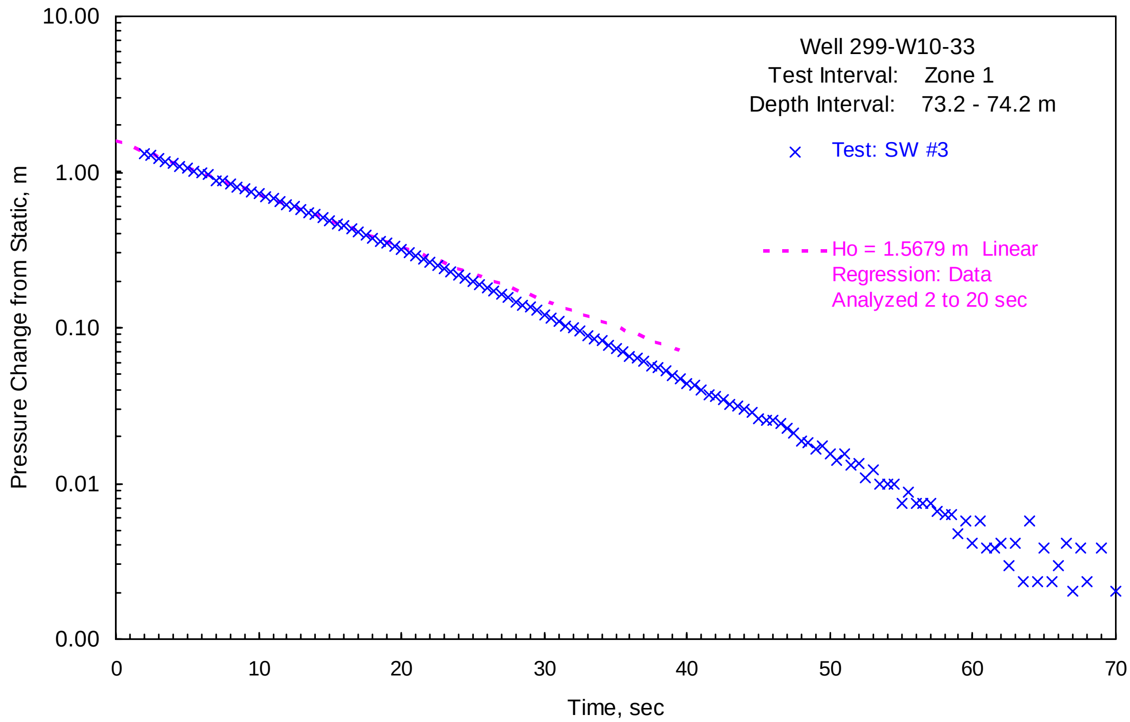


Figure 4.4. A High-Stress Slug Test Showing Slightly Critically Damped Behavior on a Semi-Log Plot for Test Interval Zone 1, Well 299-W10-33

5.0 Conclusions

Slug-test results were obtained for a total of three test/depth intervals during the drilling and borehole advancement of two OU ZP-1 wells: 299-W10-33 and 299-W11-48. The results indicate that multiple, stress-level, slug-testing methods were successful at well 299-W10-33 in providing detailed hydraulic conductivity information for two test zones. For well 299-W11-48, the slug-test results were marginally successful, and only one stress-level test for each of the two zones tested was achieved.

Results from the ZP-1 well slug tests provide hydraulic-characterization information only for the Ringold Formation (Unit 5) for individual test/depth intervals generally sited within the upper ~10 m of the unconfined aquifer. All test/depth intervals exhibit exponential-decay (over-damped) slug-test response behavior. However, the high-stress slug tests performed at well 299-W10-33 indicate slightly critically damped response behavior during the latter part the tests. Over-damped, slug-test response patterns are indicative of test intervals having low to intermediate permeability conditions, while critically damped test responses are reflective of test intervals having intermediate to high-permeability characteristics. An analysis of the slug-test results indicates calculated average test-interval estimates of hydraulic conductivities ranging between 1.24 and 15.7 m/day (Table 4.2). The ZP-1 well hydraulic-conductivity estimates were derived for test-interval sections that ranged from 1.0 to 1.6 m in length (Table 4.1).

6.0 References

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Appendix A

Slug Test Field Notes

Appendix A: Slug Test Field Notes

DRAFT

FIELD ACTIVITY REPORT - DAILY DRILLING

Page 1 of 2

Date: 4-6-07

Well ID: C5243

Well Name: 299-W11-48

Location: North of WMA-T, 200 West

Report No.: 64

Start	Finish	Total
Time 0630	Time 1615	Time 9:45
Hole Depth/Csg 257.5' / 252.0'	Hole Depth/Csg 257.5 / 252.0	Hole Depth/Csg ø / ø

Reference Measuring Point: **GROUND SURFACE**

Casing String No. 1 2 3 4 ____ See Report No. 1

Rod Size: 1 - 12 3/4" ; 2 - 10 3/4"

Time/Depth From	Time/Depth To	Description of Activities/Operations with Depth (Attach applicable drawings and document straightness test results)
0630	0715	POD meeting: Pump sample & Slug test
0715	0725	DTW = 247.5' 4" TOC - 5.7' stickup = 241.8' bgs DTB = 257.3' bgs
0715	0815	Prep time: moving generator, pump & wiring into place
0815	0900	Trip in pump with 1" riser pipe. Intake set at ~252' bgs
0900	0933	Connect hoses & wire. Tag water @ ~~247.5~~ 245.3' TOC (10 3/4") - 3.7 stickup = 241.6 bgs.
	0933[10]	Start pumping DTW = 245.3' TOC (open-hole from 252'-257.3' bgs)
	0935[30]	First water
	0940	Stabilized @ 247.5' TOC (10 3/4") pumping @ ~4 gpm
		• Est. purge time: (3 B.H. vol) = (3) x (~4 gal./ft) x (15 ft) = 180 gal.
		180 gal. ÷ ~4 gpm = 45 min.
	1005	Flow check @ 5 gpm, DTW = 247.6 TOC (10 3/4")
1030	1100	Collecting samples: B1L4P6, B1L5J4, B1L5F5 (FB), B1L4W8 & B1L5C6
	1102	Stop pumping, total high vol. est.: 5 gpm x 89 min. = 445 gal.
1102	1145	Waiting for RCT to remove pump/tremie (full time coverage)
1145	1220	RCT on site, trip out pump (all reading ≤ BKG)
1220	1230	DTW = 247.3' TOC (4"), 241.6' bgs DTB = 257.3' bgs (no silt)
1230	1308	Measuring in slug rod & setting transducer ~10' bwt
1308	1324	Waiting for water to stabilize
~~1322~~ 1324[29] (JH 4-6-07)	1342[27]	Running test #1 "Slug baseline" linear test
1342	1350	Testing packer (set @ 80 psi): Added 5 gal. water to annulus, no response in 4" indicated on logger.
	1345	EH p.m. survey, < Det., a.m. also < Det.
INJ1 1349[22]	1353[31]	Test #2 injection with 0.195 ft^3 rod. Removed rod too soon, miscommunication with driller. Decided to scratch test #3.

Reported By: J. Horner		Reviewed By:
Title: Geologist	Date: 4-6-07	Title: / Date:
Signature: John Horner		Signature:

A-6003-651 (04/03)

FIELD ACTIVITY REPORT - DAILY DRILLING

Continuation Page

Page 2 of 3

Date: 4-6-07

Well Name: 299-W11-48		Well ID: C5243	
Location: North of WMA-T, 200 west		Continuation of Report No.: 64	

	Time/Depth From	Time/Depth To	Description of Activities/Operations with Depth
	1353	1416	Set rod in place above water & wait for stabilization
INJ 2	1416^{07}	1432^{27}	Test #4 (skipped #3): injection with 0.195 ft^3 rod "Slug 2"
			• Start reading @ 10.13' bwt End @ 10.12' bwt
WITH 2	1436^{20}	1452^{52}	Test #5 "withdrawal #2" remove 0.195 ft^3 slug rod
			• start reading @ 10.12' bwt End @ 10.0' bwt
	1455	1506	Decided to make up for test #3, inject rod & wait for rec.
WITH 1	1506^{53}	1529^{48}	Test #3 "withdrawal #1" remove 0.195 ft^3 slug rod
			• start reading @ 9.98' bwt End @ 9.65' bwt
			• Note: Data logger start time on test #5 was a little late,
			test #3 should be perfect timing.
	1529	→	Decided to try larger slug rod (not much room for cable)
	→	1534	Driller changing to 0.390 ft^3 slug rod. Same length, 7 ft.
INJ 3	1536^{47}	1555^{24}	Injection with 0.390 ft^3 rod, test #9 "3F9WD"
			• Start reading @ 9.42' bwt End @ 9.29
WITH 3	1556^{08}	1609^{12}	Test #10 withdrawal test "Spring Fever 10" 0.390 ft^3 rod
			• Start @ 9.29 End @ 9.15
	1609	→	Drillers remove H.T. bit to take to town for hardfacing.
		1615	Geologist leaves site
			*Note: Excel files for tests #9 & #10
			were renamed to:
			3F9WD → Injection #3
			SpringFever10 → Withdrawal #3
			JH 4-9-07
			not used JH 4-6-07

Reported By: J. Horner		Reviewed By:	
Title: Geologist	Date: 4-6-07	Title:	Date:
Signature: John Horner		Signature:	

A-6003-652 (04/03)

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: 4-12-07

Test/Depth Interval: ~~279.1 - 284.1~~ 271.5 - 276.5 ft bgs DRN

Pre-Test Depth-to-Water: 249.7 ft btoc

Post-Test Depth-to-Water: 249.6 ft btoc

Well ID: ~~C5243~~ DRN 299-W11-48

Borehole ID: C5243

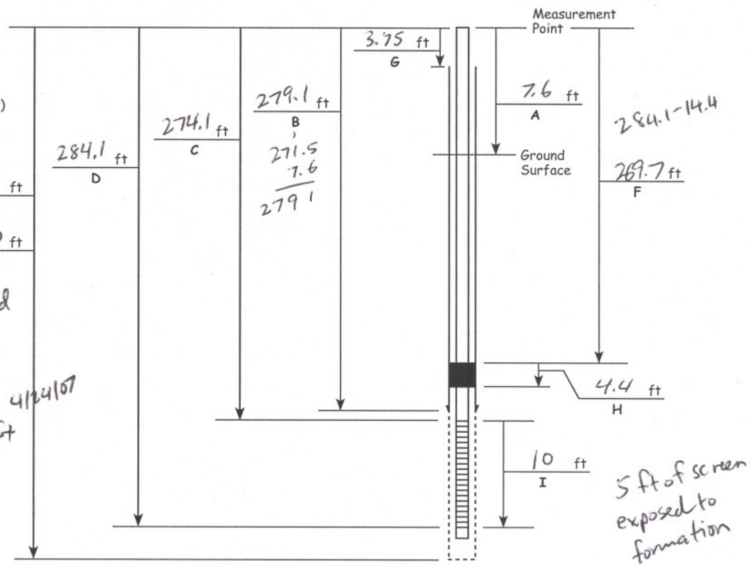
Transducer S/N: ~~488532~~ DRN 2162639 (5psig)

Multiplier: ~~H.539~~ DRN 2.3400 ft/(mV/V)

Logger S/N: SN X 46933

Measured Test Lengths

A = Measurement Pt (MP) to Ground Surface
B = MP to Bottom of Outer Casing
C = MP to Top of Screen
D = MP to Bottom of Screen
E = MP to Bottom of Borehole (Pre- & Post-Test)
F = MP to Top of Packer
G = MP to Top of Outer Casing
H = Packer Length
I = Screen Length



Test Stress Information

Test #	Stress Applied
1	2" rod fully submerged
2	" "
3	" "
4	" "

DRN 4/24/07

Stress applied = ~~0.451~~ ft 2.217

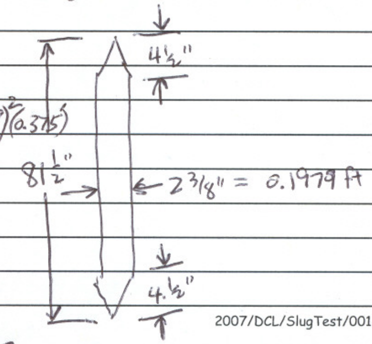
Prepared by: NRN (sign)	Darrell Newcomer (print) Date: 4-12-07
Reviewed by: (sign)	(print) Date:

Time: **Field Notes:**

See notebook, pages 30-32

$$\begin{array}{r} 284.1 \\ -14.4 \\ \hline 269.7 \end{array}$$

Slug Rod dimensions for 2" rod:



$$\text{Slug Volume} = \pi r^2 h_1 + 2\left(\tfrac{1}{3}\pi r^2 h_2\right)$$

$$= \pi\left(\frac{0.1979\,ft}{2}\right)^2 (6.042\,ft) + \frac{2}{3}\pi\left(\frac{0.1979}{2}\right)^2 (0.375)$$

$= \cancel{1.8773 +}$ DRN

$= 0.1858 + 0.00769$

$= 0.1935\ ft^3$

$$h_o = \frac{1}{\frac{\pi(2/12)^2}{0.1935\,ft^3}} = 1/0.451\ ft$$

DRN 4/24/07

$h_o = 2.217\ ft$

2007/DCL/SlugTest/001 (04/04)

Slug Testing at T Tank Farm well 4-12-07
(North of T Tank Farm) 299-W11-48 (C5243)

D/W = 242.1 ft bgs (measured by Geologist)
D/W ~~Stickup~~ = 249.7' ft btoc (4") Stickup = 7.6 ft
D/ Bottom screen = 276.5' bgs
Bottom of packer = 266.5' bgs
10 ft screen; 5 ft screen exposed
screen = 271.5 - 276.5 exposed screen interval

0900 Attached etape to top of small-dia. slug rod and run it down inside 4" ID casing. Driller ran slug rod past transducer probe. When rod was raised up, it got stuck in hole at ~42m btoc. They are running a camera down hole now.

0945 Transducer SN 488532 (50 psig) and E-tape was removed, but they are destroyed.
Lowered 2" OD rod to bottom of well at 284.1' btoc.
Raised rod up 42' so it is out of water column. Make mark on cable. Now lower rod 7' (submerged level) and make another mark on cable (end of rod is 35' off bottom.

Now use SN 2162639 Druck transducer (5 psig) Set to 259' btoc.
1019 Packer inflated to 70 psi
1020 Reading is 9.6895'

Well 299-W11-48 (C5243) 4-12-07

1029 Initiate Test #1, but little or no response.

1055 Large slug rod will not go past 1st joint at 5' btoc, because 4" ID casing is not straight. We'll repeat tests with small slug rod.

During sampling, Q was ~15 gpm and there was no measurable drawdown, according to Geologist. They got very little test response in last set of slug tests 10ft higher

1106 Initiate Slug withdrawal test #2. 2" OD rod 1-2 sec to completely withdraw slug ~~a~~ rod. $\Delta t = 0.5$ sec.

1108 Transducer readings changed abruptly for no apparent reason.

1111 Lower rod into water column

1120 Change Δt to 0.25 sec

1120:30 Test #3 (slug withdrawal test with 2" OD rod)

1122:40 Lower rod back down into water column

1130 Test #4; Slug withdrawal with 2" OD rod

There is a much slower test response now.

1136 Packer pressure still at 70 psi

1138:50 Conduct packer integrity test - pour 5 gal of clean water down ~~a~~ annulus between 4" ~~and~~ DRN inner casing and outer casing.

1139:40 Finished pouring 5 gal.

1141 Appears to be no response, so packer is ~~holding~~ DRN sealing fine (cont.) Slug Testing at well 299-W11-48 4-12-07

Save data to file W11485I-4.dat and back it up on a jump drive

1150 D/Bottom = 284.0' btoc (4")

1153 D/W = 249.6' btoc (4")

David P Newcomer
4-12-07

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: 7/6/07 1100

Test/Depth Interval: 233.5 - 243.5 ft

Pre-Test Depth-to-Water: 229.59 ft

Post-Test Depth-to-Water: 229.65 ft ← done by driller

Well ID: T5 Borehole

Borehole ID: C5855

Transducer S/N: 2162639 Druck 5PSIG

Multiplier: 2.34 ft/mv/v

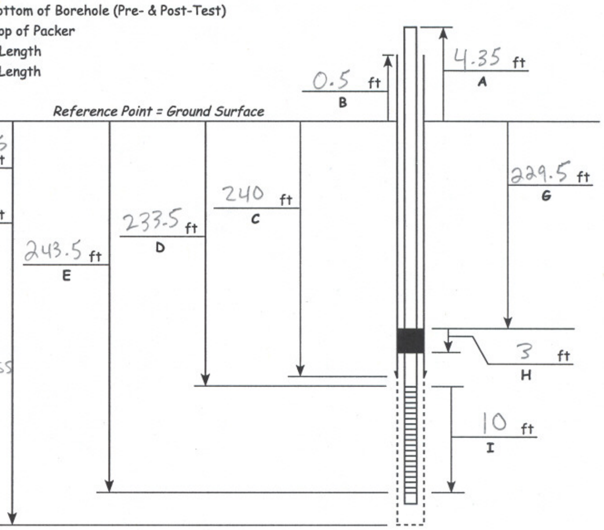
Logger S/N: X14158

Measured Test Lengths

A = Reference Pt (RP) to Top of Inner Casing
B = RP to Top of Outer Casing
C = RP to Bottom of Outer Casing
D = RP to Top of Screen
E = RP to Bottom of Screen
F = RP to Bottom of Borehole (Pre- & Post-Test)
G = RP to Top of Packer
H = Packer Length
I = Screen Length

Pre-Test 245.65 ft F (1)

Post-Test 245.65 ft F (2)



Test Stress Information

Test #	Stress Applied
1	Small rod
2	Small rod
3	Larger rod
4	Larger rod
5	Larger rod

Inner Diameter (inch)

well-screen/ testing string	4" Stainless
drill casing	9.75
borehole	10.25

Prepared by: Rob D. Mackley (sign)	[illegible] (print)	Date: 7/6/07
Reviewed by: (sign)	(print)	Date:

Time:	Field Notes:
1120	Geolgist (Jess Hawkins) has notes stating D/W (BGS) of 229.6' @ 0721 7/6/07.
↓	"Small" Slugging rod is 2 5/16" OD x 81" long w/ tapers at Both ends. 0.195 stamp.
↓	"Larger" Slugging rod is ~3" OD x 81" long w/ tapers at Both ends. No stamp.
1125	D/B = 245.65 BGS D/W = 229.59
1130	Made marks on cable-tool rig cable w/ chalk @ submerged and unsubmerged depths; Rod submerged ~1' Below water table, Rod suspended ~1' above water table.
1137	Xducer Set at 238' BGS (~8.38' pressure).
1145	Pour 5 gallon clean H_2O down annulus to verify packer seal; passed - no pressure response.
1151	Lowered small slug rod into water (1.74' increase initially - then stablized)

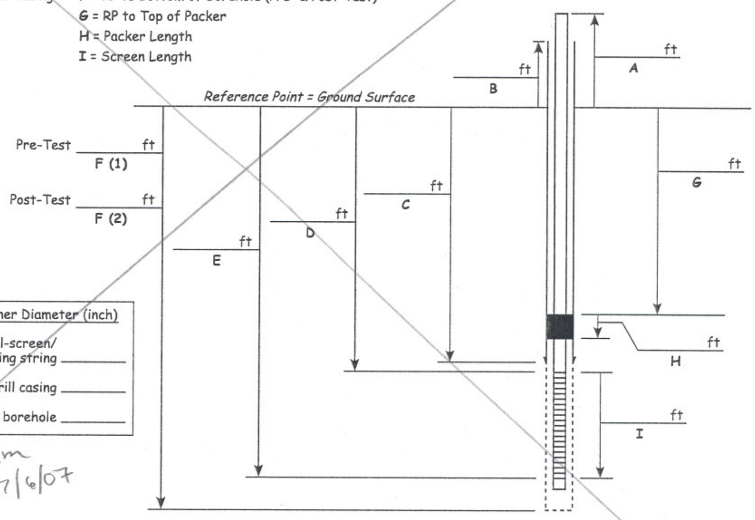
2007/DCL/SlugTest/001 (05/04)

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: ____________ | Well ID: ____________
Test/Depth Interval: ____________ ft | Borehole ID: ____________
Pre-Test Depth-to-Water: ____________ ft | Transducer S/N: ____________
Post-Test Depth-to-Water: ____________ ft | Multiplier: ____________
Logger S/N: ____________

Measured Test Lengths

A = Reference Pt (RP) to Top of Inner Casing
B = RP to Top of Outer Casing
C = RP to Bottom of Outer Casing
D = RP to Top of Screen
E = RP to Bottom of Screen
F = RP to Bottom of Borehole (Pre- & Post-Test)
G = RP to Top of Packer
H = Packer Length
I = Screen Length



Test Stress Information

Test #	Stress Applied

Inner Diameter (inch)

well-screen/testing string ________
drill casing ________
borehole ________

rdm
7/6/07

Prepared by: ____________ (sign) ____________ (print) Date: ____________

Reviewed by: ____________ (sign) ____________ (print) Date: ____________

Time:	Field Notes:
1203	Test #1 - slugging w/ small rod w/ withrawl test. 1.92' stress w/
↓	exp. decay curve recovery (overdamped).
1212	Good recovery back to stable pressure, but 0.02' lower pressure.
1216	Lowered small slug rod into water for next withdrawl.
1223	Starting cable-tool rig. Small increase in background noise in signal.
1230	Test #2 - slugging w/ small rod w/ withdrawl test. 2.17' stress with
↓	exp. decay (over damped) response.
1241	Tripping out X-ducer to clear way for removal of slug rod.
1249	Tripping in X-ducer. Re-installed @ 238' BGS.
1301	Stable pressure. Fixed short in cable in Campbell Box.
1330	Stable pressure but 0.1' offset from previous install - I think

2007/DCL/SlugTest/001 (05/04)

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: ______________

Test/Depth Interval: ______________ ft

Pre-Test Depth-to-Water: ______________ ft

Post-Test Depth-to-Water: ______________ ft

Well ID: ______________

Borehole ID: ______________

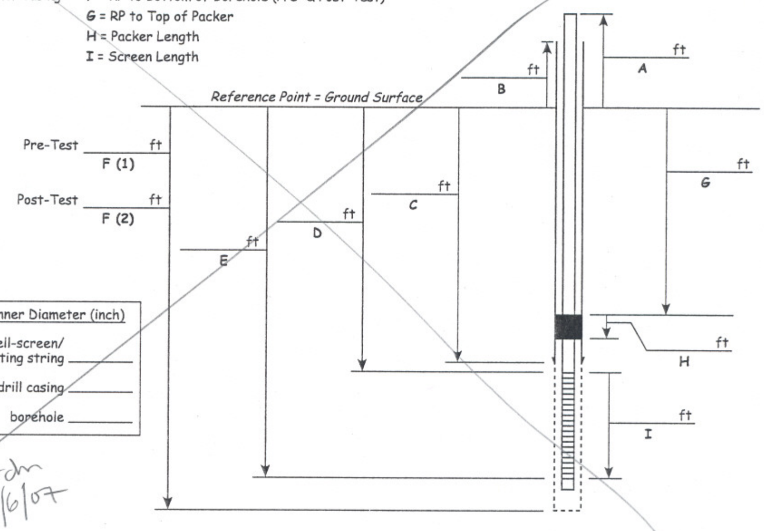
Transducer S/N: ______________

Multiplier: ______________

Logger S/N: ______________

Measured Test Lengths

A = Reference Pt (RP) to Top of Inner Casing
B = RP to Top of Outer Casing
C = RP to Bottom of Outer Casing
D = RP to Top of Screen
E = RP to Bottom of Screen
F = RP to Bottom of Borehole (Pre- & Post-Test)
G = RP to Top of Packer
H = Packer Length
I = Screen Length



Test Stress Information

Test #	Stress Applied

Inner Diameter (inch)	
well-screen/ testing string	
drill casing	
borehole	

vdm 7/6/07

Prepared by: ______________ (sign) ______________ (print) Date: ______________

Reviewed by: ______________ (sign) ______________ (print) Date: ______________

Time:	Field Notes:
1330	cont... the cables (sensor & drill string) ARE twisted. Yes, sensor
↓	Cable was wrapped around slug-rod / rig cable connection. Fixed
↓	it And re-installed X-ducer several feet lower (~240' BGS).
1340	double-checked possible twisting of cables by raising/lowering drill rig
↓	cable slowly - no apparent twisting. GOOD!
1400	Test #3 - slugging w/ larger rod w/ withdrawl test (rising head). 5.53'
↓	Stress w/ exp. decay (overdamped) recovery. Good Clean Curve.
1410	Lowered large slug rod into water. 0.02' higher pressure. Checked
↓	for twisted cable. Maybe slug rod took slack out of sensor cable.
1420	Test #4 - Slugging w/ larger rod w/ rising head test. 5.2' stress with
↓	exp. decay curve (overdamped).

2007/DCL/SlugTest/001 (05/04)

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: ____________ **Well ID:** ____________

Test/Depth Interval: ____________ ft Borehole ID: ____________

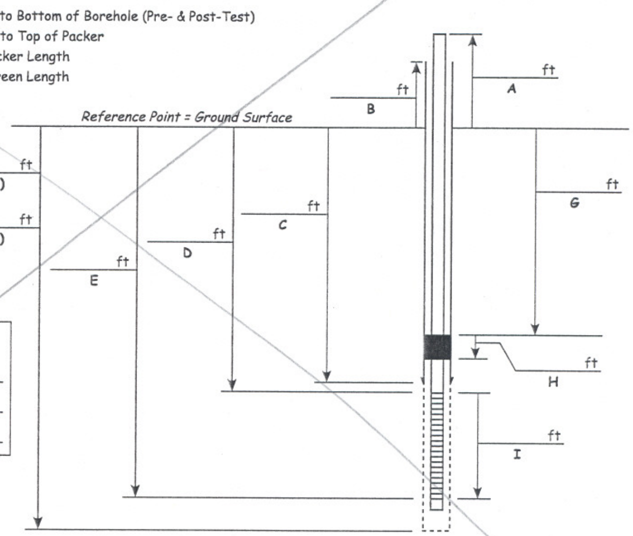
Pre-Test Depth-to-Water: ____________ ft Transducer S/N: ____________

Post-Test Depth-to-Water: ____________ ft Multiplier: ____________

Logger S/N: ____________

Measured Test Lengths

A = Reference Pt (RP) to Top of Inner Casing
B = RP to Top of Outer Casing
C = RP to Bottom of Outer Casing
D = RP to Top of Screen
E = RP to Bottom of Screen
F = RP to Bottom of Borehole (Pre- & Post-Test)
G = RP to Top of Packer
H = Packer Length
I = Screen Length



Test Stress Information

Pre-Test ____ ft F (1)

Post-Test ____ ft F (2)

Test #	Stress Applied

Inner Diameter (inch)

well-screen/testing string ____
drill casing ____
borehole ____

RDM 7/6/07

Prepared by: ____ sign ____ print Date: ____

Reviewed by: ____ sign ____ print Date: ____

Time:	Field Notes:
1428	Tripping out larger slug rod - finished using larger rod.
1437	Tripping in (lowering) smaller slug rod. Left X-ducer installed @ ~240' BGS.
1444	Test #5 - slugging with smaller slugging rod with withdrawl test. 2.15' stress with overdamped response.
1451	Tripping out slug rod. Re-checked packer for leaks using 5 gallons of clean H_2O down annulus. No change in pressure - looks like A good seal still. Had driller take D/W & D/B again. D/W = 229.65' BGS D/B = 245.65'.
1510	Leaving Site; HPT cleared equipment.

2007/DCL/SlugTest/001 (05/04)

Appendix B

Selected Borehole Logs

Appendix B: Selected Borehole Logs

Figure B.1 Well 299-W11-48

Borehole Log for Well 299-W10-33 not available.

BOREHOLE LOG

Page 1 of 11
Date: 11-29-06

Well ID: C5243	Well Name: 299-W11-48	Location: North of T-Farm, 200 W
Project: T4/T5 Monitoring Wells		Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
0				0-0.5': gravel pad (crushed rock)	ODEX drilling with
					12 3/4" (O.D.) threaded
				0.5'-4.0: Sl. Silty Sand (m)S	carbon steel casing
				well-sort. vf-m dk. grayish brown	
				(2.5Y, 4/2) sand (60-70% felsic).	
5	Grab			With 5-10% silt. Mod-strong HCl rxn	NCO collecting grab samples
					every 5 ft. & geologist
				4.0'-22': Silty Sandy gravel	collecting archives every
				Poorly sorted w/ >70% vf-vc pebbles	5 ft. G.S. = Grab sample.
				(>60% basalt) w/ ~15-20% vf-vc	Grab Sample @ 5-ft bgs
10	Grab			Sand & 10-15% silt (2.5Y, 5/2) lt.	•BIL494, BIL452, BIL452 @ 11-30-06
				brownish gray.	G.S. @ 10 ft bgs HEIS #s
				• Silt & sand fraction decrease	•BIL495, BIL462, BIL460
				at ~15'	
				22'-27': Sandy Gravel	G.S. @ 15' bgs 12-1-06
15	Grab			Poorly sort. w/ 50-60% ang.-sub-rnd.	#s: BIL496, BIL463 & BIL461
				vf-vc pebbles (>70% basalt) with	
				45-55% f-vc (>50% crs.) ang. Sand	G.S @ 20' bgs 12-1-06
				(>70% basalt) sl. moist with <5% silt.	#s: BIL497, BIL464 & BIL462
				moist sand is v. dk brown to black	
20	Grab			(2.5Y, 2.5/1), possibly wk. soil development.	G.S. @ 25' bgs 12-4-06
				• 1"-2" gravel fragments indicates	#s: ~~BIL884, BIL869 & BIL~~ 12-4-06
				small-med cobbles are present	BIL498, BIL465 & BIL463
					G.S. @ 30' bgs 12-4-06
					#s: BIL499, BIL466 & BIL464
25	Grab			27'-32': Sand	
				Mod. sort. with >80% f-vc ang (70% c)	
				olive brown (2.5Y, 4/3) sand (~50%	G.S. @ 35' bgs 12-4-06
				felsic, 50% mafic), ~5-15% vf-f pebbles	#s: BIL4B1, BIL468 & BIL466
				& 5-10% brown silt. No HCl rxn. max	
30	Grab			particle = 8 mm	Split Spoon @ 33'-35' bgs
				• 32' color lightens up to light	12-4-06, HEIS# = BIL8P5
				brownish gray (2.5Y, 6/2), very minor	
				silt, f-m pebble fraction increases	
	Split-Spoon			32'-38': Gravelly Sand	Split Spoon @ 35.5'-37.5' bgs
35		G.S.		Mod-poorly sorted with 70% m-vc ang.	12-4-06, HEIS# BIL896
	Split-Spoon			Sand (50-60% felsic), >25% vf-f ang	
				pebbles (>70% basalt) with <5% silt.	
				lt. brownish gray to grayish brown (2.5Y, 5.5/2)	
				No HCl rxn, Max particle = 2 cm. Mod oxid. & weathered grains.	

Reported By: J. Horner	Reviewed By: L.D. Walker	
Title: Geologist	Title: Geologist	
Signature: John Horner — Date: 12-5-06	Signature: LD Walker	Date: 4/27/07

A-6003-642 (03/03)

BOREHOLE LOG

Date: 12-4-06

Well ID: C5243 | Well Name: 299-W11-48 | Location: N of T-farm, 200 W

Project: T4/T5 Monitoring Wells | Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample: Type No.	Sample: Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
40	Grab			38'-56.5': Sand	ODEX drilling
				Mod. sorted with >90% m-vc angular	G.S. @ 40' bgs 12-4-06
				olive brown (2.5Y, 4/4) sand (60% felsic,	#s: B1L4B2, B1L4L9, B1L467
				40% basalt), 5-10% vf pebbles & <5% M.	
				No HCl rxn, max particle = 1cm	
45	Grab			Moisture increased slightly from gS above.	
				• 42' pebble fraction increases to ~25%	G.S. @ 45' bgs 12-5-06
				pebbles are 70-80% basalt	#s: B1L4B3, B1L4M0, B1L468
				• 55.5' pebble fraction decreases	
				to <5%, Sand is vf-m &	G.S. @ 50' bgs 12-5-06
50	Grab			~80% felsic	#s: B1L4B4, B1L4M1, B1L469
	@55-[illegible]				Split spoon @ 53.5-55.5'
					12-5-06, HEIS# B1LEP7
					~~55.5~~ 55.0' @ 12-5-06
55	Split-spoon	G.S.			G.S. @ 55' bgs 12-5-06
					#s: B1L4B5, B1L4M2, B1L470
				56.5'-84.5': Sandy Gravel	
				Poorly sorted with 60% vf-vc ang	
				Sand (~70% felsic), 35-40% vf-f	
60	Grab			sub-ang. to ang. pebbles (>70% basalt)	G.S. @ 60' bgs 12-5-06
				vc-c sand is also basalt-dominated.	#s: B1L4B6, B1L4M3, B1L471
				with 0-5% silt. sand is mostly	w/ Duplicates: ~~B1L4R0~~ B1L5R0
				dry compared to sand above. Wk rxn	@ 12-5-06 & B1L4K9
				with HCl, max grain = 2cm. Bulk	65' G.S. 12-5-06
65	Grab			color is grayish brown - lt. brownish gray	#s: B1L4B7, B1L4M4, B1L472
				(2.5Y, 5.5/2).	
				• 64' sl. increase in moisture &	
				vf sand - silt fraction (lt. ol. brn. 2.5Y,	
				5/3)	
				• 66' silt fraction is <5%, ~50% ca. &	G.S. @ 70' bgs 12-5-06
70	Grab			50% sand, moisture decreases.	#s: B1L4B8, B1L4M5, B1L473
				• 69'-70' ~85% vf-m sand, 10%, 5% M	
				• 70'-84.5' Sandy Gravel as above,	
				with up to 10% silt, strong HCl rxn.	75' ~~70'~~ @ 12-5-06
75	Grab			• 72' silt decreases, ~5%	G.S. @ ~~80'~~ 75' bgs 12-5-06
					#s: ~~B1L4F9, B1L4M7, B1L4~~
					B1L4F7, B1L4M6, B1L474
					@ 12-5-06

Reported By: J. Horner		Reviewed By: L.D. Walker	
Title: Geologist		Title: Geologist	
Signature: John Horner	Date: 12-5-06	Signature: [signature]	Date: 4/27/07

A-6003-642 (03/03)

BOREHOLE LOG	Page 3 of 11
	Date: 12-5-06

Well ID: C5243	Well Name: 299-W11-48	Location: N of T-Farm, 200W
Project: T4/T5 Monitoring Wells		Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
80	Grab				
					G.S. @ 80' bgs, 12-5-06
					#s, BIL4F8, BIL4A7, BIL475
				84.5'-96': Silt (Upper Cold Crk. Unit)	Split spoon @ 84'-86' bgs
85	Split spoon	100% rec.		Well-sorted light olive brown (2.5y, 5/3)	12-6-06, HEIS# BIL8P8
				silt & v. fine sand (>80% M)	
	Split spoon	G.S. 100% rec.		Strong HCl rxn.	G.S. @ 86' bgs 12-6-06
				•90' vf sand fraction decreases, almost	#s, BIL4F9, BIL4M8 & BIL476
				100% silt.	
90	Grab				Split spoon @ 86'-88' bgs
					12-6-06, HEIS# BIL8P9
					G.S. @ 90' bgs 12-6-06
					#s BIL4H0, BIL4M9 & BIL477
95	Grab	vapor sample 94.5-97'		96'-106': Sandy Silt (sM)	
				Well-sorted & light olive brown (2.5y, 5/2)	G.S. @ 95' bgs 12-6-06
				with ~60% silt & 40% vf-c ang.	#s BIL4H1, BIL4N0 & BIL478
				sand. Coarse sand is basalt dominated,	
				but sparse vf-m sand is felsic-dom.	G.S. @ 100' bgs 12-7-06
100	Grab			•103' moisture decreases (sl. moist to	#s BIL4H2, BIL4N1, & BIL479
				almost dry). lt. brownish gray (2.5y 6/2)	
					Vapor sample @ 94.5'-97' bgs
				106'-109': Silty Sandy Gravel (caliche)	(drilled to 100', cased to 97'
				Poorly sorted cuttings with 40-50%	while backpulling to 94.5')
105	Grab			vf-m ang. $CaCO_3$ cemented pebbles	HEIS# BIL4R4, BIL5N9
				& $CaCO_3$ coated basalt pebbles. ~25%	& Duplicate BIL5P0
				felsic vf-vc sand & ~25% lt. gray	
				silt. Max cutting is ~2cm, very	G.S. @ 105' bgs 12-11-06
				strong HCl rxn. Well cemented caliche	#s BIL4H3, BIL4N2, BIL480
110	Grab			nodules are present.	Duplicates: BIL5K1 & BIL4L0
				109'-113': Silt (M)	G.S. @ 110' bgs 12-11-06
				well-sorted light olive brown (2.5y, 5/4)	#s: BIL4H4, BIL4N3, BIL481
				silt with minor vf sand & v. sparse	
				pebbles	G.S. @ 115' bgs 12-11-06
115	Grab			113'-119': Gravelly sandy Silt (gsM)	#s: BIL4H5, BIL4N4, BIL482
				Poorly sort. with >50% pale yellow	~~G.S. @~~ @12-11-06
				(2.5, 7/4) silt, ~40% vf-vc ang. sand	
				fine sand is felsic c-vc sand >70% mafic	Split Spoon - 118'-120'
	Split spoon			& 10-15% vf-m ang. mafic pebbles.	12-11-06, HEIS# BILBD3

Reported By: J. Horner		Reviewed By: L.D. Walker	
Title: Geologist		Title: Geologist	
Signature: Jake Horner	Date: 12-11-06	Signature: LD Walker	Date: 4/27/07

A-6003-642 (03/03)

BOREHOLE LOG

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Date: 12-11-06

Well ID: C5243 | Well Name: 299-W11-48 | Location: North of T-Farm, 200W

Project: T4/T5 Monitoring Wells | Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample: Type No.	Sample: Blows Recovery	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
120	Split Spoon	100% rec ← G.S.	119'–128': Silt (M)	Split spoon @ 118'-120'
			very well-sorted olive brown silt	12-11-06, HEIS # B1LBD3
			(2.5Y, 5/4). Silt is moist with	
			a very weak – no HCl rxn.	120' G.S. 12-11-06
				#s B1L4H6, B1L4N5 & B1L483
125	Grab			
			128'–145': Silty Sandy Gravel (msG)	G.S. @ 125' bgs, 12-11-06
			Poorly sorted with > 70% sub-angular	#s B1L4H7, B1L4N6 & B1L484
	@12-11-06		mafic-dominated pebbles & small cobbles	
			(>75% basalt), ~15% vf-vc felsic sand	G.S. @ 130' bgs, 12-11-06
130	Grab		(c-vc fraction is angular & basalt-dom)	#s B1L4H8, B1L4N7 & B1L485
			with ~15% lt. brownish gray (2.5Y, 6/2)	
			silt. Max cutting = 5 cm, Mod.-Strong	*Attempted vapor sample from
	Vapor sample		rxn with HCl. Silt is dry.	124'-130' bgs, could not
			• ~~silt~~ @ 12-12-06	retract drill bit in silt
135	Grab		• 140' silt fraction increases to > 15%	& had to drill deeper to
			& moisture content increases to very	enable bit removal.
			slightly moist. Silt is lt. ol. brown	
			(2.5Y, 5/3).	Vapor sample @ 132'-133' bgs
			• 145' silt fraction decreases to ~5%,	12-12-06, HEIS# B1L5P1
140	Grab		sand fraction is ~30%, G = 65%	& Duplicate B1L5P2
			145'–174': Sandy Gravel (sG)	G.S. @ 135' bgs, 12-12-06
			Poorly sorted with ~65% mafic-dom.	#s B1L4H9, B1L4N8 & B1L486
			angular pebbles & small cobbles, 30%	
145	Grab		vf – vc sub-angular sand (>70% coarse [illegible]; 50%	G.S. @ 140' bgs, 12-12-06
			felsic) & < 5% silt. Max = 4-5 cm	#s B1L450, B1L4N9 & B1L487
			• 150' sand fraction is 60-70% felsic	
			• 162' sand fraction increases (40-50%)	~~G.S. @ 140' bgs, 12-12-06~~
			& grain size is dominantly medium	~~#s~~ @ 12-12-06
150	Grab			
				G.S. @ 145' bgs, 12-12-06
				#s B1L451, B1L4P0 & B1L488
				G.S. @ 150' bgs 12-14-06
155	Grab			#s B1L452, B1L4P1 & B1L489
				G.S. @ 155' bgs 12-14-06
				#s B1L453, B1L4P2 & B1L490

Reported By: J. Horner | Reviewed By: L. D. Walker

Title: Geologist | Title: Geologist

Signature: [signature] | Date: 12-15-06 | Signature: [signature] | Date: 7/23/07

A-6003-642 (03/03)

Date: 12-15-06

BOREHOLE LOG

Well ID: C5243 | Well Name: 299-W11-48 | Location: North of T-Farm, 200W

Project: T4/T5 Monitoring Wells | Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
				Sandy Gravel continued from page 4	
160	Grab			145'-174': Sandy Gravel (sG)	G.S. @ 160' bgs, 12-15-06
				•162' sand fraction increases to 40%-	#s BIL454, ~~BIL493~~ BIL491 12-15-06, & BIL491
				50% & dominate grain size is medium	BIL493
				*slow drilling in sG interval @	
165	Grab			~1.5' per hour. Driller suggest that	G.S. @ 165' bgs, 12-15-06
				the borehole keeps caving in.	#s BIL455, BIL494 & BIL492
170	Grab				G.S. @ 170' bgs,
					#s BIL456, BIL495 & BIL493
					(last G.S. collected by NCOs)
				174'-184': Silty Sandy Gravel (msG)	G.S. @ 175' bgs
175	Grab			Mod sorted with >75% sub-well rounded	#s: BIM9N5, BIM9V6 & BIMB08
				pebbles (60-70% basalt), 10-15%	w/ duplicates BIM9V7 &
				vf-m felsic sand (~70% felsic) &	BIMB09
				>10% lt. yellowish brown (2.5Y, 6/3) silt.	
				No HCl rxn, max particle = 5cm.	G.S. @ 180' bgs
180	Grab			*Drilling rate increased to 4-5'	#s: BIM9N6, BIM9V8 & BIMB10
				per half hour.	
				184'-186': Sandy Gravel (sG)	
185	Grab			Mod-poorly sorted & matrix supported	G.S. @ 185' bgs
				with 50-70% vf-vc (80% m) sub-	#s: BIM9N7, BIM9V9 & BIMB11
				angular sand (60-70% felsic), 30-	
				50% sub-rnd. to sub-ang. pebbles	
				& small cobbles (heterolithic with	
190	Grab			~30% basalt); <5% silt; no	G.S. @ 190' bgs
				HCl rxn; Sand is pale olive	#s: ~~BIM9N8~~ BIM9N8, BIM9W0
				(5Y, 6/3); Max cutting ≈ 6cm	& BIMB12 @ 12-19-06
				186'-198': Gravel (G)	
195	Grab			Well-sorted & clast supported with	G.S. @ 195' bgs
	Grab			up to 90% sub-rnd to sub-ang	G.S. @ 197' bgs
				pebbles & cobbles with <10% vf-c	#s BIM9N9, BIM9W1, BIMB13
				(>80 m) sand (>90% felsic). Minor lt.	Cable tool drilling
				gray silt, no HCl rxn.	from 197' bgs down.

Reported By: J. Horner	Reviewed By: L.D. Walker
Title: Geologist	Title: Geologist
Signature: John Horner — Date: 3-16-07	Signature: L.D. Walker — Date: 7/23/07

A-6003-642 (03/03)

BOREHOLE LOG

Date: 3-16-07

Well ID: C5243 | Well Name: 299-W11-48 | Location: North of WMA-T, 200 West

Project: T4/T5 Monitoring Wells | Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description (Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl)	Comments (Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level)
200	G.S.			198'-230: Silty Sandy Gravel	Cable tool drilling
				Poorly sort, moist, consolidated &	w/ drive barrel &
				clast supported w/ ~75% sub to well	$10^{3}/_{4}$" temp. casing.
				rounded f-c heterolithic pebbles &	
				small to med cobbles (max = 15cm) >20%	G.S. @ 200' bgs
205				ang. med. felsic sand (>85% quartz)	#s: B1M9P0, B1M9W2 & B1MB14
	G.S.			slightly oxidized (ol. yellow, 2.5Y, 6/6)	@ 3-18-07
				& <5% ~~st~~ @3-16-07 dark grayish brn (2.5Y, 4/2)	G.S. @ ~~205~~ 206' bgs
				silt present in small concentrated pockets	#s: B1M9P1, B1M9W3 & B1MB15
				in contrast with zones of clean sand	
210	G.S.			described above.	G.S. @ 210' bgs
				• 204' dark grayish brn silt fraction	#s: B1M9P2, B1M9W4 & B1MB16
				increases up to 30% in some intv.'	
				• 220' yellowish oxidation decreases,	
	G.S.			cuttings are unconsolidated. silt	G.S. @ 214' bgs
215	archive			fraction increases (G 60-70%, S&M 15-20%)	#s: B1M9P3, B1M9W5 & B1MB17
				Silt is dry & light brownish gray (2.5Y, 6/2)	(Geologist archive @ 215' bgs)
				• 225' silt fraction decreases (5-10%)	& duplicates B1M9W6 &
					B1MB18 @ 214' bgs.
220	G.S.				G.S. @ 220' bgs
					#s: B1M9P4, B1M9W7 & B1MB19
	Split-Spoon B1LBD3	100% rec.			split-spoon on 3-22-07 from
					221.8' to 223.5' bgs 100% rec.
					HEIS#: B1LBD3
225	G.S.				
	Vapor Sample				G.S. @ 225' bgs
					#s: B1M9P5, B1M9W8 & B1MB20
				230'-235.5': Sandy Gravel	Vapor Sample w/ open-
230	G.S.			Poorly sorted, slightly moist, unconsolidated	hole from 225.5' (casing
				w/ 60-70% sub-rnd. heterolithic pebbles	shoe) to 227.5' (DTB) bgs
				& small cobbles, 30-35% med. (>75%) ang.	#s: B1L5P3 & B1L5P4
				sand (>85% felsic) with <5% silt.	
				Very similar to mstl above. Max cobble	G.S. @ 230' bgs
235	G.S.			is >10cm. Light brownish gray to yellowish	#s: B1M9P6, B1M9W9 & B1MB21
				brown (2.5Y, 6/2.5).	
				• 231' slight increase in moisture	G.S. @ 235' bgs
				• 235.5' Increase in silt fraction (10-30%)	#s: B1M9P7, ~~B1M9X1~~ @ 3-28-07 B1M9X0 & B1MB22

Reported By: J. Horner | Reviewed By: L.D. Walker

Title: Geologist | Title: Geologist

Signature: [signature] Date: 3-30-07 | Signature: [signature] Date: 7/23/07

A-6003-642 (03/03)

BOREHOLE LOG

Page 7 of 11
Date: 3-30-07

Well ID: C5243	Well Name: 299-W11-48	Location: North of WMA-T, 200 W
Project: T-4 Monitoring Well		Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample Type No.	Sample ~~Blows~~ ~~Recovery~~	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
240				235.5' - 277' : Silty Sandy Gravel	Started hard tool
				Same as sG described on pg. 6,	drilling @ 239' bgs
	G.S.	▽		but with an increase in silt (10-20%)	
					G.S. from 239'-242.5'
					mixed hard tool (H.T.) cuttings.
245	G.S.				#s: B1M9P8, B1M9X1 & B1MB23
					DTW = 242.0' bgs on 4-4-07.
					G.S. @ 245' (239'-245')
					#s: B1M9P9, B1M9X2 & B1MB24
	G.S.				
250					G.S. @ 249.5' (245'-249.5')
					#s: B1M9R0, B1M9X3 & B1MB25
		Pumped W.S. & Sl'ing Test			G.S. @ 256' (249.5'-256')
					#s: B1M9R1, B1M9X4 & B1MB26
255	G.S.				
					Pumped W.S. 252'-257.3' bgs
					#s: B1L4P6, B1L5J4, B1L5F5
					B1L4W8 & B1L5C6
260				• 260 drilling mud much thinner,	G.S. @ 262' bgs
				may be less silt.	#s: B1M9R2, B1M9X5 & B1MB27
	G.S.				
					G.S. @ 265' bgs
		Pumped W.S.			#s: B1M9R3, B1M9X6 & B1MB28
265	G.S.				w/ duplicates B1M9X7 & B1MB29
					Pumped W.S. 262'-267' bgs
					#s: B1L4P7, B1L5J4, B1L5F6 (FB)
					B1L4W9 & B1L5C7
270					G.S. @ 272' bgs
					#s: B1M9R4, B1M9X8 & B1MB30
	G.S.				
		Pumped W.S.			Pumped W.S. 271.5'-276.5' bgs
					#s B1L4P8, P1L5J6 (FB)
275				• 275 Same desc. as Above	B1L5F7, B1L4X0, B1L5C8
	G.S.				G.S. @ 277' bgs
					B1M9R5, B1M9X9, B1MB31

Reported By: J. Horner		Reviewed By: L. D. Walker	
Title: Geologist		Title: Geologist	
Signature: Julie Horner	Date: 4/12/07	Signature: LD Walker	Date: 7/23/07

A-6003-642 (03/03)

BOREHOLE LOG

Page 8 of 11
Date: 4-12-07

Well ID: C5243 | Well Name: 299-W11-48 | Location: North of WMA-T, 200W

Project: T-4 Monitoring Well | Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description (Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl)	Comments (Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level)	
280	G.S.			277 - 280 : Silty Sandy Gravel poorly sorted	G.S. from 280 - 281.0	Hard tooling
				Hard tool drilling mud Brownish gray increase	mixed (H.T.) cuttings	
		KABIS		in silt 10-20%	#'s B1M9R6, B1M940,	
		Sample +			B1MB32	
		Slug Test		280-285' : Silt % went up	Kabis Sample taken 282.0	
285	G.S.			grayish Brown Hard tool slurry	#'s - B1L4P9, B1L5J7, B1L890	
				282.5 - 289.0 Sand (S) Mod well sorted	B1L5F8, B1L4X1	
				sub-rounded, med. silica sand (30% mafic)		
				little silt No pebbles	G.S. taken 285-286	4/16/07
					#'s B1M9R8 B1M9X1 B1MB33	
290	G.S.			289 - 310' Sandy Gravel (SG)	+ B1M9R8, B1M9Y2, B1MB34	
		Pumped W.S.		Pebble/Cobble fraction increases to		
				60%. very little silt sand med. to fine	G.S. taken @ 291.0-292.0	4/16/07
				Cobbles poorly sort subangular to	#'s B1M9R9, B1M9Y3, B1MB35	
				subrounded		
295					Pump Sample Intake 290.5' bgs	4/17/07
	G.S.			296' bgs Pebble Cobble fraction	#'s B1L4R0, B1L5J8, B1L5F9	
				drops to 50% same desc.	B1L4X2, B1L500	
				as above	G.S. @ 296.0' #'s B1M9T0,	4/17/07
					B1M9Y4, B1MB36	
300				301.5' bgs Gravel % goes up		
	G.S			still very little silt content	G.S. taken @ 301.5'	4/24/07
				Hard tool slurry:	#'s B1M9T1, B1M9Y5, B1MB37	
		Pumped W.S.			Chip + Archive jars Taken	
				310.0' bgs Sandy Gravel (SG)		
305				same desc. as above	Pump sample Intake @ 312.0' bgs	
	G.S.				#'s B1L4R1, B1L5J9, B1L5H0	4/25/07
					B1L5H1, B1L4X3, B1L4X4,	
				310 - 320 Sandy Gravel (SG)	B1L5D1, B1L5D2	
				75% Basalt (Drilling Mud)		
310	G.S.			very little silt fine grained sand	G.S. @ 306.0' bgs 4/25/07	
					#'s B1M9T2, B1M9Y6, B1MB38	
		Kabis Sample			G.S. @ 310.0 bgs 5/15/07	
					#'s B1M9T3, B1M9Y7, B1MB39	
					Kabis Sample Taken @ 312.0' bgs	5/16/07
315	G.S.				#'s B1L4R2, B1L5K0, B1L5H2,	
					B1L4X5, B1L5D3	
					G.S. @ 315.0' bgs #'s	
					B1M9T4, B1M9Y8 B1MB40	

Reported By: J. Meheer | Reviewed By: L.D. Walker

Title: Scientist | Title: Geologist

Signature: [signature] Date: 4-16-07 | Signature: [signature] Date: 7/23/07

A-6003-642 (03/03)

BOREHOLE LOG

Page 9 of 11
Date: 5-16-07

Well ID: C5243 | Well Name: 299-W11-48 | Location: North of T-Farm, 200W

Project: T-4 Monitoring Well | Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample Type No.	Sample ~~Blows~~ J.M. 5-17-07 Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
320	G.S.			320' - Same desc. as above	Cable Tool drilling
					Hard Tool method
				325' - Same desc. as above	Grab Sample Taken @ 320 5-16-07
	Pump Sample				#'s B1M9T5, B1M949, B1MB41
				330' - Ringold E still	
325	G.S			hard tool slurry same desc. as above (msG)	Grab Sample @ 325 5-17-07 J.M.
					#'s B1M9T6, ~~B1M~~
					B1MB00, B1MB42
				340' - Hard tool slurry (msG)	
				Sand + silt fraction have increased (60% sand 35% pebbles/cobbles + 5% silt)	Pump Sample: Intake @ 321' bgs
330	G.S				HEIS#: B1L5K1, B1L5D4,
					B1L5H3, B1L4X6, B1L4R3
	Kabis				Grab Sample @ 330'
					Heis#'s B1M9T7, B1MB01, B1MB43
335	G.S				Kabis Sample; 332'-333'
					HEIS#'s B1L4R3, B1L5K2(FB)
					B1L491(TB), B1L5H4, B1L4X7
					B1L5D5 | Grab @ 335' #'s
340	G.S.				B1M9T8, B1MB02, B1MB44
					Grab Sample @ 340' #'s B1M9T9
	342			345' - Hard tool Slurry (mgS)	B1MB03 B1MB45 5-22-07
				silty gravelly sand. Sand fraction continues	
				to rise (70% sand 25% gravel 5% silt	Grab Sample @ 345' #'s B1M9V0
345	G.S.			Pebble cuttings are ~1cm Sand is a med silicic rich	B1MB04, B1MB46 5-22-07
					Grab Sample @ 350' #'s
	344.9			350' - Same desc. as above	B1M9V1, B1MB05, B1MB47
					5-22-07 342'-344.9'
350	G.S.				Pump Sample @ 347' #'s
				355 - Same description	B1L4R5, B1L5K3(FB), B1L5H5
					B1L4X8, B1L5D6 5-22-07
	Kabis				
					Grab Sample @ 355
355	G.S.				#'s B1M9V2, B1MB06
					B1MB48 5-24-07
					Kabis 352-353' bgs

Reported By: J. Mehrer | Reviewed By: L.D. Walker

Title: Env. Scientist | Title: Geologist

Signature: [signature] | Date: 5-16-07 | Signature: [signature] | Date: 7/23/07

A-6003-642 (03/03)

BOREHOLE LOG

Page 10 of 11
Date: 5-25-07

Well ID: C5243 | Well Name: 299-W11-48 | Location: North of T-Farm, 200W

Project: T-4 Project | Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
360	G.S.			360 - Hard tool slurry (mgS)	Cable Tool drilling
				silty gravelly Sand. Sand fraction	*Hard Tool Method
				levels off (70% Sand, 25% gravel 5% silt	
	PUMP	Sample		Pebble cuttings are ~1cm Sand's	360-Grab Sample 5-24-07
				a med Silica Rich.	#'s BIM9V3, BIMD07 BIMB??
365	G.S.			~~365~~ JM	
				365-375 Hard tool Slurry	365-Grab Sample (5-25-07)
				Gravelly Sand (g.S.) Sand	# = BINP77
				Fraction increases (70% Sand 25%	
				gravel V. little silty Sand is medium	370-Grab Sample (5-25-07)
370	G.S.			to fine V. Silica Rich	#= BINP78
					375-Grab Sample (5-25-07)
	KAB	IS Sample		375 - Gravel % increases	# = BINP79
				slightly 65% Sand 30% -	(5-25-07)
375	G.S.			35% ~~silt~~ JM Gravel little to no	372-373 Kabis Sample
				silt	#'s BIL4R8, BIL5K6 (FB)
					BIL5H9, BIL4Y2, BIL5F0
				380 - Same desc. As Above	
					380 - Grab Sample (5-29-07)
380	G.S.			385 - Same desc. As Above	#'s BINP80 IGS-80
				Gravel % increasing maybe a	
	PUMP	SAMPLE		Sandy Gravel hard to tell cause	385-GRAB Sample (5-29-07)
				of slurry and poor retrieval of	IGS-81 #'s BINP81
				cuttings	
385	G.S.				~~#~~ 382 - Pump Sample
				390 - Hard Tool Slurry = Sandy Gravel	#'s BIL4R9, BIL5K7, BIL5R0
				No Rxn HCl 10YR 7/3 See desc. above	BIL4Y3, BIL5F1
					Switched to Drive barrel
390	G.S.				@ 385 ft bgs RA
					Switched Back To Hard Tool
	KABIS	~~Pump~~ JM			
		Sample			390 - Grab Sample Taken 5-30-07
					#'s BINP82
395	G.S.			395 - Hard Tool Slurry = Sandy Gravel -	
				Silty Sandy Gravel; 10YR 5/2 grayish brown;	395- Grab sample Taken 5-31-07
				Hard description due to state of cuttings.	#'s BINP83
				HEIS #'s For Kabis = BIL4T0, BIL5K8(FB) BIL5R1	392 - KABIS ~~Pump~~ JM Sample : BIL4Y4 BIL5F2

Reported By: J. Mehrer / Jim Horsburg | Reviewed By: L.D. Walker

Title: Env. Scientist / Geologist | Title: Geologist

Signature: [signature] | Date: 5-25-07 | Signature: [signature] | Date: 7/23/07

A-6003-642 (03/03)

BOREHOLE LOG

Page 11 of 11

Date: 6-4-07

Well ID: C5243 | Well Name: 299-W11-48 | Location: North of WMA-T, 200 W

Project: T-4 Monitoring Well | Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
400	G.S.	Pumped water sample		401.5 - bailed hard tool cuttings contain a few peices of lt. olive brn. (2.5Y, 5/3) clay. largest fragment was ~1/2". Clay fragment was well sorted & contained no s&G.	Cobb tool drilling with hard tool bit. G.S. @ 401' bgs HEIS#: ~~B1M9V3, B1M807~~ ~~#B1M849~~ JH 6-18-07 I-84 HEIS# B1NP84
405	G.S.			407' - Abundant clay fragments present, up to 1".	G.S. @ 407' bgs HEIS#: B1NP85
	Split Spoon				
410				407.5 - 409: Sand (split-spoon) well sorted & well consolidated with >90% v. fine lt. ol. brn. (2.5Y, 5.5/3.5) felsic sand (>95% felsic) & < 10% felsic silt	Split spoon sample collected from 407.5-409 ft. bgs, for geologic observation.
415				not used JH 6-5-07	W.S. from 399'-409' bgs (pumped). Borehole open 399'-404' bgs, slough/hard tool cuttings present from 404'-409' bgs. Itv. #54 HEIS #s: B1L4T1, B1L5K9, B1L5R2, B1L4Y5, B1L5F3 TD = 409' bgs

Reported By: J. Horner | Reviewed By: L.D. Walker

Title: Geologist | Title: Geologist

Signature: [signature] Date: 6-5-07 | Signature: [signature] Date: 7/23/07

A-6003-642 (03/03)

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