Hydraulic Pulse Interference Tests for Integrity Testing of Containment and Reactive Barrier Systems

by

Grant Hocking
Golder Sierra LLC
Atlanta, GA

(submitted to 2001 International Containment & Remediation Technology Conference, to be held June 10-13 at Orlando, FL)

ABSTRACT: Hydraulic pulse interference tests involve a cyclic injection of fluid into the source well, and by high precision measurement of the pressure pulse in a neighboring well, detailed hydraulic characterization between wells can be made. The pulse interference test is highly sensitive to hydrogeological properties between the pulse source and receiver wells. The transient nature of the test, involving the time delay and attenuation of the hydraulic pulse, enables the formation's complete hydraulic properties to be computed. The advantages of the pulse interference test are the short duration of the test, the high resolution and directional characterization data obtained, and the lack of any generated contaminated groundwater. To maximize the pulse test's resolution, a small section of the injector well is isolated by packers, the flow rate into the source injector well is rate controlled and set at a constant flow rate depending on the site hydraulic conditions. High precision pressure transducers are located in receiver wells and isolated from receiver borehole storage effects by straddle packers. Thus the pulse is basically a point source, and borehole storage effects are eliminated from both the injector and receiver wells. The injector well is pulsed for a set time, shut in for the same time period, and the cycle repeated. The pulse source and receivers can be located at differing depth locations in their respective wells and a detailed image of the site's hydraulic conditions can be determined. The hydraulic pulse interference test is ideal to test the integrity of a hydraulic containment system or to determine whether a permeable reactive barrier (PRB) impacts groundwater flow. Pulse interference tests are presented pre and post PRB installation for integrity testing of an iron PRB constructed in a confined aquifer from a depth of 45 feet down to a total depth of 110 feet.

INTRODUCTION

Hydraulic pulse interference tests have been utilized in the petroleum industry since the mid sixities, Johnson et. al. (1966) and Horne (1995), primarily as full penetrating aquifer tests, but in some cases as vertical pulse interference tests, Burns (1969) and Hirasaki (1974). Type curves are available for interpreting pulse interference tests, either as a fully penetrating wellbore, with and without borehole storage effects, or partially penetrating wellbore system. Pulse interference testing has not been used extensively in the groundwater or environmental fields. However, considering the advantages of the test; namely, it's short duration, high resolution and directional characterization data obtained, and the lack of any generated contaminated groundwater, the test has considerable merit for both groundwater and environmental applications. To obtain maximum hydraulic property resolution (Hocking and Wells, 1997), the pulse interference test can be constructed as a point source utilizing straddle packers in the injector well.

PULSE TESTS AND INTERPRETATION

A series of hydraulic pulse interference tests were conducted in a confined aquifer overlain by an upper confining layer from ground surface down to 35 feet below ground surface (bgs) and underlain by a lower confining layer at a depth of 110 feet bgs. Both the source and receiver wells were straddled packed in a screened well section of 2" diameter from a depth of 100 feet down to 105 feet bgs.

The interpretation of the point source hydraulic pulse interference test follows similar procedures to line source interpretation procedures such as type curves and non-linear regression analysis. The type curve for the confined aquifer test described above was generated by the method of images to incorporate the periodic nature of the injections and also the confined nature and finite thickness of the aquifer system. The receiver well response for the interpreted values of hydraulic conductivity and a specific storage generated for the confined aquifer geometry is shown as predicted on Figure 1 along with the measured receiver well response.

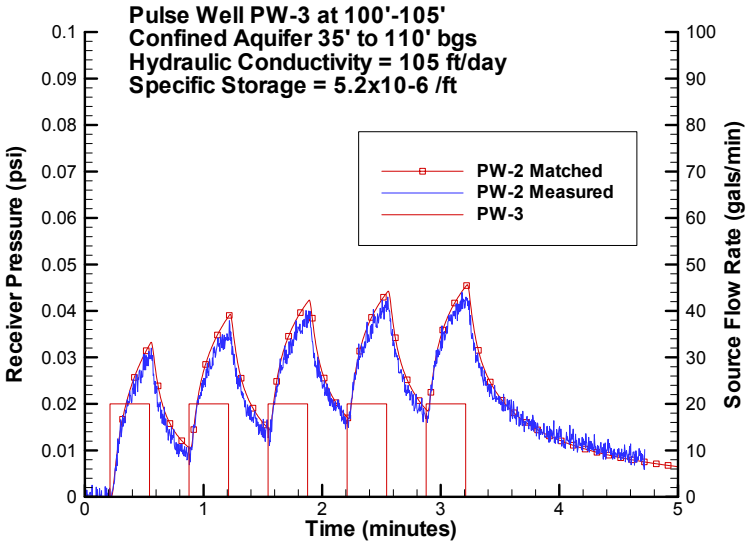

FIGURE 1. Predicted/Matched and Measured Receiver Well Response.

PULSE INTERFERENCE INTEGRITY TESTS

The hydraulic pulse interference test is an ideal test for the integrity testing of hydraulic containment systems such as cut off or slurry walls and for permeable reactive barrier (PRB) systems. The most significant difference between a permeable reactive barrier and a containment system is the need to ensure the barrier's permeability does not impede or modify the groundwater flow regimes. An iron PRB was constructed within the confined aquifer system described earlier, from a depth of approximately 45 feet bgs down to a total depth of 110 feet bgs. The PRB was installed by the azimuth controlled vertical hydraulic fracturing technology (Hocking and Wells, 1997). Pre and post construction pulse interference tests were conducted across the PRB alignment from pulse wells located 25 feet up and down gradient from the PRB, and the test results are shown on Figure 2. The receiver well pressure response, amplitude, signature and time delay, shows no attenuation when comparing pre- and post- construction tests. These tests confirm that the PRB has an in placed hydraulic conductivity of at least that of the formation's highest conductive horizon.

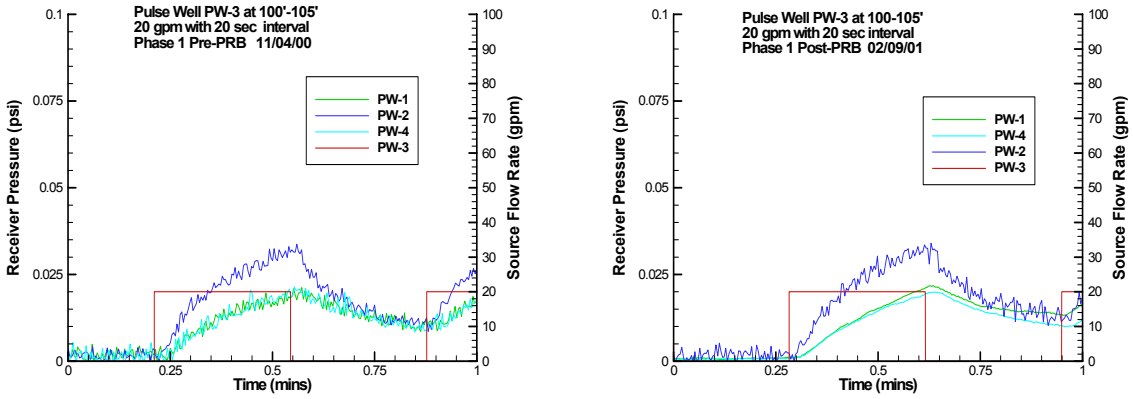

FIGURE 2. Pre and Post PRB Construction Pulse Interference Tests.

CONCLUSIONS

The hydraulic pulse interference test is an ideal test for the quantification of a site's hydrogeological properties. The transient nature of the test, involving the time delay and attenuation of the hydraulic pulse, enables the formation's complete hydraulic properties to be computed. The method is equally applicable to porous media and fractured bedrock systems. The advantages of the pulse interference test are the short duration of the test, the high resolution and directional characterization data obtained, and the lack of any generated contaminated groundwater during the test. Pre and post PRB construction pulse interference tests quantified that the azimuth controlled vertical hydraulic fracturing technology installed the PRB with an in placed permeability equivalent to or greater than the formation's highest hydraulic conductive horizon.

References:

Burns, W. A. Jr. (1969). New Single-Well Test for Determining Vertical Permeability, JPT, Vol. 243, pp743-752, Trans., AIME.

Hirasaki, G. J. (1974). Pulse Tests and Other Early Transient Pressure Analyses for In-Situ Estimation of Vertical Permeability, Soc. Pet. Eng. J., Vol. 257, pp75-90, Trans., AIME.

Hocking, G., and S. L. Wells. (1997). "Orientated Vertical Hydraulic Fracture Iron Reactive Walls", presented at the ASCE Environmental Group Meeting, Atlanta, GA, March.

Horne, R. N. (1995). Modern Well Test Analysis - A Computer-Aided Approach, Petroway, Palo Alto, 2nd. Ed.

Johnson, C. R., R. A. Greenhorn and E. G. Woods (1966). Pulse-Testing: A New Method for Describing Reservoir Flow Properties Between Wells. *JPT*, Vol. 237, pp1599-1604, Trans., AIME.