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MEMORANDUM

To:	Dana Bayuk, Oregon, Department of Environmental Quality	**Date:**	June 17, 2015
From:	John J. Renda, R.G., Anchor QEA	**Project:**	000029-02.34
Cc:	Bob Wyatt, Northwest Natural; Patty Dost, Pearl Legal Group; Ben Hung, John Edwards, and Carl Stivers, Anchor QEA		
Re:	Aqua Gard CO_2 Injections		

OVERVIEW

In an email dated June 12, 2015, DEQ requested that NW Natural provide documentation of the extraction well development work completed prior to the initiation of the interim Phase 2 hydraulic control and containment (HC&C) system test. DEQ stated that documentation should include, but is not necessarily limited to, the list of wells developed, representative photos of development methods and equipment, downhole video(s), the duration of development work, flow rates and water level measurements made during development, and the specific capacity of each extraction well before and after development.

This memo discusses the Aqua Gard CO_2 injections completed prior to initiation of the interim Phase 2 HC&C system test. The Aqua Gard CO_2 injections are an operations and maintenance (O&M) technology to prevent fouling of the extraction well screen and surrounding annular sand pack. Discussion of liquid CO_2 injections for routine maintenance can be found in section 3.2.2.4 of the Construction Design Report (Anchor QEA 2012). The Aqua Gard injections were scheduled prior to the interim Phase 2 HC&C system test because of a loss of specific capacity in PW-1U after completion of the Phase 1 Step 6 HC&C system test. Table 1 shows the specific capacities of each of the extraction wells before and after the Aqua Gard injections.

AQUA GARD CO_2 INJECTION PROCEDURES

In April 2015, Aqua Gard CO_2 injections were completed in 15 extraction wells, including PW-1U, PW-1L, PW-2U, PW2-L, PW-3U, PW-4U, PW-5U, PW-6U, PW-6L, PW-7-93, PW-8-39, PW-8-68, PW-11U, PW-12U, and PW-13U. In May 2015, Aqua Gard CO_2 injections were

repeated in PW-1U and three additional extraction wells, including PW-1U, PW-3-118, PW-4L, and PW-5L.

The Aqua Gard CO_2 injections were conducted by Water Recovery Services (WRS) of Spokane, Washington. WRS is the Pacific Northwest licensed contractor for Aqua Gard technology. Injection procedures were similar at each extraction well. The well to be treated was shut down, all valves were closed, the pressure transducer was removed, a CO_2 injection manifold (Photo 1) was attached to the well, and all openings at the wellhead were sealed. The well was pressurized with CO_2 gas at the manifold shown on Photo 1. The manifold connects to the drop pipe, which extends down the well to the screen zone. Once pressurized, the injection switched from gaseous to liquid CO_2. The amount of gas and liquid CO_2 used at each well was selected by the contractor, who considered the variables of well depth, screen length, formation conductivity, and how aggressive a treatment was needed. Photo 2 shows the liquid and gas CO_2 tanks. At the completion of the CO_2 injection, a pressure relief valve was opened to vent CO_2 gas, and the manifold was removed. The pressure transducer was then reinstalled into the drop pipe, and the valves were opened. The extraction well remained off, typically overnight, to allow the carbonic acid in the well to dissolve any remaining deposits.

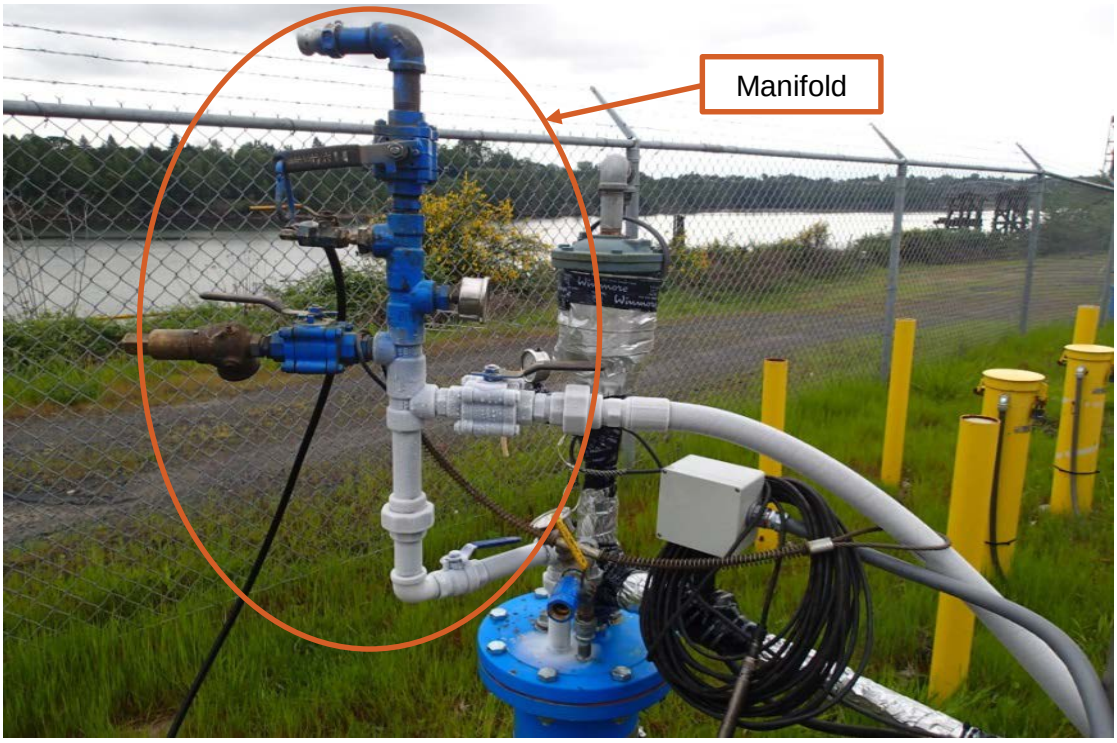

Photo 1
CO_2 injection manifold

Photo 2
CO_2 tanks: gas-phase CO_2 on the left, and liquid-phase CO_2 on the right

Table 1 shows that improvements in specific capacity were observed at PW-1U, PW-1L, PW-3U, PW-4U, PW-8-68, PW-11U, PW-12U, and PW-13U. Improvements in specific capacity were not observed in PW-2U, PW-2L, PW-3-118, PW-4L, PW-5U, PW-5L, PW-6U, PW-6L, PW-7-93, or PW-8-39. However, the specific capacity data shown in Table 1 have not been corrected for drawdown effects from neighboring wells. As explained below, additional analysis of the data would have to be done to determine the actual change in specific capacity that resulted from the Aqua Gard treatment.

Specific capacity of an extraction well is calculated by dividing the well discharge rate by the drawdown that is measured in the extraction well. For example, a well that is pumping 100 gallons per minute (gpm) with 10 feet of drawdown has a specific capacity of 10 gpm/foot. However, this calculation assumes that no other wells are affecting the water level at the

pumping well that is under consideration. If nearby wells are pumping at the same time, the overlapping drawdown from those wells will cause the water level to drop in the well being considered. This additional drawdown results in a calculated reduction in specific capacity, but it is only an apparent reduction. The overlapping drawdown from neighboring extraction wells causes a false reduction in the calculated specific capacity. The specific capacity of the extraction well will be affected by the number of nearby wells that are pumping and their pumping rates. Because the pumping rates of the extraction wells at this site change frequently in response to river tidal fluctuations, the specific capacities listed in Table 1 are likely misleading for the purpose of evaluating the effectiveness of the Aqua Gard treatment. Therefore, additional methods for evaluating the effectiveness of the Aqua Gard treatment are being considered.

As previously discussed, the Aqua Gard injections were scheduled before the start of the Phase 2 interim test, to potentially increase specific capacity in PW-1U. A downhole video was taken at PW-1U on January 28, 2014, to determine if there was evidence of iron slime or other precipitate plugging the screen. The screen appeared clear. The downhole video is in Attachment A (CD). As shown in Table 1, the Aqua Gard injections were completed three times in PW-1U. At the remaining wells, the CO_2 injections were performed as a routine O&M measure to prevent fouling of the extraction well screens. Aqua Gard injections are planned to be performed at least annually in the extraction wells.

REFERENCES

Anchor QEA, 2012. *Revised Groundwater Source Control Construction Design Report.* NW Natural Gasco Site. Prepared for NW Natural. In Association with Sevenson Environmental Services, Inc., and Advanced Remediation Technologies, Inc. January 2012.

ATTACHMENTS

Table 1 Specific Capacity Calculations

Attachment A – PW-1U Downhole Video

Table 1
Specific Capacity Calculations

Well ID	Date	Specific Capacity (gallons per minute/foot)	Comment
PW-1U	4/28/2015	0.30	
	4/29/2015	-	Aqua Gard
	5/5/2015	0.55	
	5/26/2015	-	Aqua Gard
	5/27/2015	0.55	
	5/27/2015	-	Aqua Gard
	5/28/2015	0.64	
PW-1L	4/24/2015	5.50	
	4/29/2015	-	Aqua Gard
	5/4/2015	9.00	
PW-2U	4/26/2015	1.80	
	4/29/2015	-	Aqua Gard
	5/4/2015	1.80	
PW-2L	4/24/2015	0.75	
	4/29/2015	-	Aqua Gard
	4/30/2015	0.65	
PW-3U	4/28/2015	0.30	
	4/28/2015	-	Aqua Gard
	5/4/2015	0.35	
PW-3-118	4/25/2015	6.00	
	5/27/2015	-	Aqua Gard
	5/28/2015	5.43	
PW-4U	4/24/2015	0.40	
	4/28/2015	-	Aqua Gard
	5/4/2015	0.55	
PW-4L	4/24/2015	9.00	
	5/28/2015	-	Aqua Gard
	5/29/2015	8.85	
PW-5U	4/24/2015	0.65	
	4/27/2015	-	Aqua Gard
	5/4/2015	0.50	
PW-5L	5/4/2015	3.00	
	5/27/2015	-	Aqua Gard
	5/28/2015	1.93	
PW-6U	4/24/2015	0.70	
	4/28/2015	-	Aqua Gard
	5/4/2015	0.65	
PW-6L	4/24/2015	2.00	
	4/28/2015	-	Aqua Gard
	5/4/2015	1.50	

Table 1
Specific Capacity Calculations

Well ID	Date	Specific Capacity (gallons per minute/foot)	Comment
PW-7-93	4/24/2015	1.80	
	4/28/2015	-	Aqua Gard
	5/4/2015	1.20	
PW-8-39	4/24/2015	0.50	
	4/27/2015	-	Aqua Gard
	5/4/2015	0.40	
PW-8-68	4/24/2015	1.00	
	4/27/2015	-	Aqua Gard
	5/4/2015	2.00	
PW-11U	4/24/2015	0.35	
	4/28/2015	-	Aqua Gard
	5/2/2014	0.40	
PW-12U	4/24/2015	0.55	
	4/28/2015	-	Aqua Gard
	5/4/2015	0.60	
PW-13U	4/25/2015	0.20	
	4/28/2015	-	Aqua Gard
	5/4/2015	0.35	