Achieving Regulatory Closure of a PCE Groundwater Plume Using a Hybrid P&T and ISCO Approach at a State Superfund Site in Quartzsite, Arizona

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ABSTRACT: The objective of this project was to expedite site closure at a lower cost than the implemented pump-and-treat (P&T) system, which was anticipated to operate through 2032. A shallow perched aquifer used as a private drinking water supply in Quartzsite, Arizona was contaminated with tetrachloroethene (PCE). In 2005, the extent of the PCE plume exceeding the Drinking Water Maximum Contaminant Level (MCL) for PCE (i.e., 5 micrograms per liter [µg/L]) covered an area of approximately 8.2 acres (3 hectares). The remedial objectives (ROs) were to control downgradient migration of the plume, achieve the MCL for PCE in impacted groundwater, and close the site without use restrictions. Achievement of the ROs was performed in three phases: Phase 1 – P&T, Phase 2 – P&T combined with in situ chemical oxidation (ISCO), and Phase 3 – manual ISCO polish treatments. Phase 1 was implemented in 2005 and by 2012 was successfully containing the plume; however, it was estimated that another 20 years of operation was required. Therefore, Phase 2 was implemented in 2014 to accelerate cleanup. By April 2016, the size of the plume had been decreased to the areas of two monitoring wells. Phase 3 was implemented in July 2016 and consisted of three manual polish ISCO treatments. The MCL of 5.0 µg/L was achieved by May 2017 and the Arizona Department of Environmental Quality (ADEQ) closed the site. Phases 2 and 3 decreased the estimated time to closure by 15 years and saved ADEQ $1.2MM in future O&M costs.

INTRODUCTION

The Site is known as the Tyson Wash Water Quality Assurance Revolving Fund (WQARF) Registry Site located in Quartzsite, Arizona. The WQARF program is the Arizona equivalent of the Federal Superfund Program and is administered by ADEQ. In August 1995, ADEQ collected a water sample containing 200 µg/L of PCE from a private drinking water well in Quartzsite, Arizona. The source of the PCE contamination was suspected to be a former dry-cleaning shop. The PCE contaminated groundwater originated from a shallow low yield and fine-grained perched aquifer with depth-to-water approximately 60 feet (ft) (18 meters [m]) deep. The lower confining layer is present at 75 ft (23 m). The perched aquifer was used as a drinking water supply by residents and businesses in the area. Remedial Investigation identified that the extent of the PCE plume exceeding the Drinking Water Maximum Contaminant Level (MCL) for

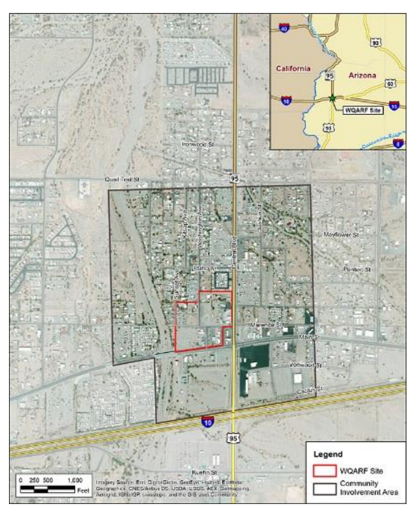


Figure 1 – Site Location

PCE (i.e., 5 µg/L) covered an area of approximately 8.2 acres (3 hectares) (Figure 2). Bottled water was supplied to affected residents and businesses until they were connected to the municipal water supply in 2002. Therefore, the ROs were to control downgradient migration of the plume, achieve the MCL for PCE in impacted groundwater, and close the site without use restrictions. A responsible party could not be identified for cost recovery; therefore, the project was totally funded by WQARF as an orphan site.

Figure 2 – 2005 PCE Plume

MATERIALS AND METHODS

Achievement of the ROs was performed in three phases: Phase 1 – P&T, Phase 2 – P&T combined with ISCO, and Phase 3 – manual ISCO polish treatments.

Phase 1 – P&T System. A pilot-scale P&T system consisting of two extraction wells (EW-1 and EW-2) and an injection well (INJ-1) was installed as an Early Response Action (ERA) during August 2002 in the area of the highest PCE concentrations. The treatment system consisted of granular activated carbon (GAC). The treated water would then be gravity injected to INJ-1 through a 500-gallon (GAL) (1,893 liter [L]) equalization tank. The P&T system was started in March 2003. Based on the results of the P&T system operation, maintenance, and monitoring (OM&M), ADEQ requested that the P&T system be expanded. Therefore, in 2005 the P&T system was expanded to three additional extraction wells (EW-3 through EW-5) and an additional injection well (INJ-2). Groundwater data obtained during the pilot test were modeled and the results indicated that the designed system would effectively control migration of the plume and remove PCE mass. However, the model predicted more than 25 years of operation would be required to achieve the MCL for PCE of 5.0 µg/L in samples collected from the monitoring wells. Based on the cost analysis, this was acceptable to ADEQ. Therefore, in 2007 ADEQ selected P&T as the remedy for the Site because it met the following criteria:

- Adequately assures the protection of public health and welfare and the environment;
- To the extent practicable, provides for the control, management and cleanup of the PCE and TCE contamination, maximizing beneficial use of the groundwater; and
- Is reasonable, necessary, cost-effective and technically feasible.

Due to slow injection rates, the P&T system was limited to a pumping rate of 8 gallons per minute (GPM) (30 LPM) and approximately 9 hours per day. Groundwater monitoring was performed quarterly to bi-annually to monitor changes in PCE concentrations, plume containment, and PCE mass removal.

Phase 2 – P&T combined with ISCO. In 2012, ADEQ identified sites with approved long-term remedies as candidates for expedited remediation/closure. The site was selected as the "test" site under this program. On this basis, the P&T system was modified in June 2014 to include insitu chemical oxidation (ISCO) using the EN Rx reagent (catalyzed hydrogen peroxide) and the Smart Feedback Optimized Continuous Injection System (SmartFOCIS), which pulse injects the EN Rx reagent to the aquifer. The HP is catalyzed by a sodium-based compound called Synergist-D and enhanced by a proprietary compound called SSO. The reaction creates the strong hydroxyl radical that is required to oxidize chlorinated volatile organic compounds (VOCs) to water, carbon dioxide, and free chlorine. The HP was diluted to 4% strength prior to injection. The process regarding production of long-lasting hydroxyl radicals with the above formula is proprietary information.

In March 2013, a pilot test was implemented using two injection wells (ISCO-1 and ISCO-2). Based on the results, the full-scale system was started in June 2014 and operated for 18 months until April 2016. EW-5 continued to be pumped at 1 GPM (3.8 LPM) through December 2015 to maintain plume containment, with the water mixed with the EN Rx reagent and gravity injected to two injection wells. Phase 2 also included manual injections to four monitoring wells and to EW-5 after December 2015. Groundwater monitoring was performed quarterly to evaluate system effectiveness and dissolved oxygen (DO) and oxidation-reduction potential (ORP) were measured to evaluate oxidant distribution. During ISCO system operation, approximately 76,000 pounds (lbs) (34,500 kilograms [kg]) of 35% strength EN Rx was injected to the aquifer.

Phase 3 – Manual ISCO Treatments. Post-FOCIS rebound monitoring commenced in May 2016. Minor rebounding of PCE concentrations had occurred between 5 and 10 µg/L in five monitoring wells between May 2016 and November 2016. Therefore, manual polish treatments were applied to these wells on July 11, 2016, January 9-10, 2017, and April 4, 2017. A total of 1,500 lbs (680 kg) of 35% EN Rx reagent was diluted to 4% strength and gravity injected to these wells over the three events. Quarterly groundwater sampling was performed during May 2016, August 2016, November 2016, February 2017, and May 2017 to evaluate treatment effectiveness.

RESULTS AND DISCUSSION

Phase 1 – P&T System. The PCE plume at the start of P&T system operation is shown on Figure 2. Sixteen wells were impacted with PCE concentrations above 5.0 µg/L, ranging from 11 µg/L to 200 µg/L. The P&T system operated through 2014, pumping and treating 10,510,000 GALS (39,800,000 L) of water and removed 2.48 pounds (LBS) (1.12 kilograms [KG] of dissolved PCE. Figure 3 shows the PCE plume in April 2014 and Figure 4 provides PCE concentration versus time graphs for the impacted wells.

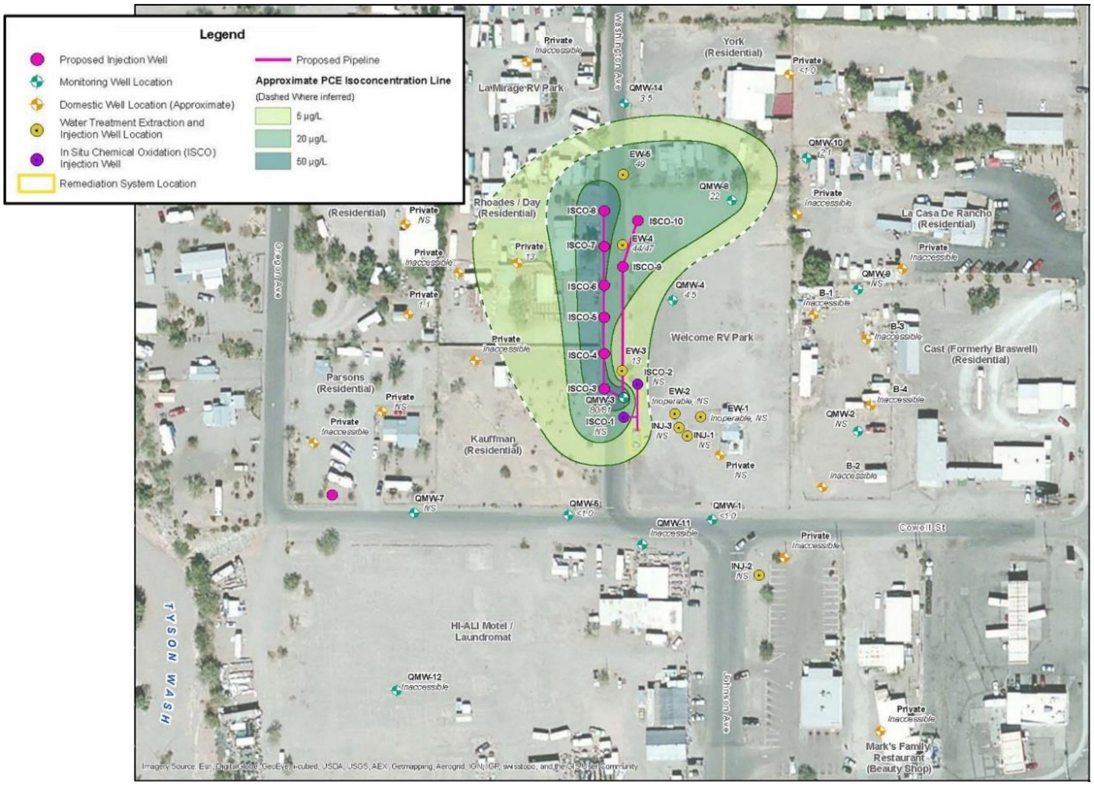


Figure 3 – 2014 PCE Distribution

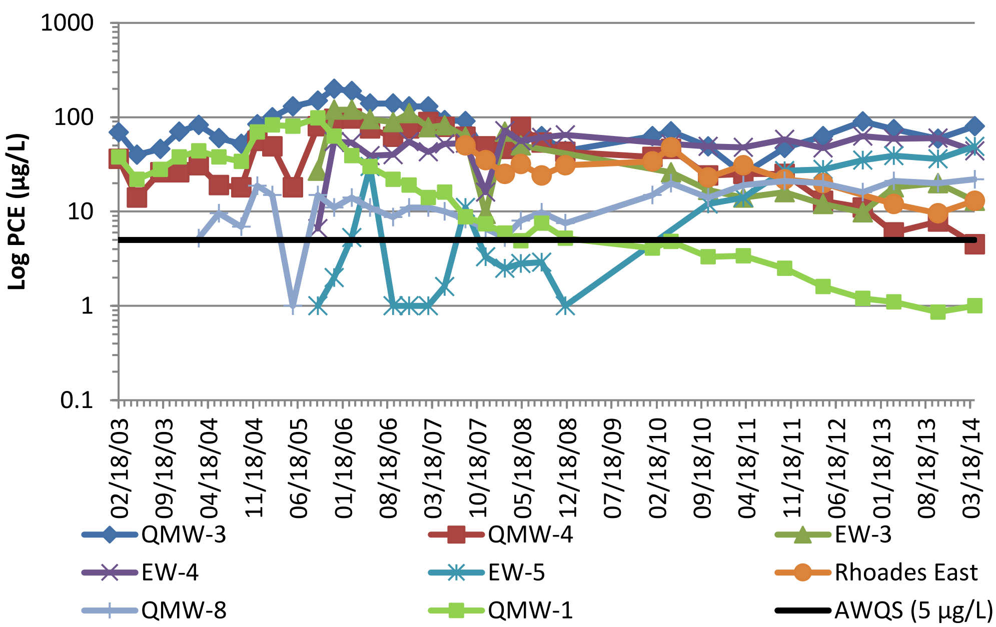


Figure 4 - PCE Concentrations vs. Time (2003-2014)
Wells QMW-1, QMW-3, QMW-4, EW-3, EW-4, EW-5, Rhoades East and QMW-8

By April 2014, the size of the PCE plume had been decreased to approximately 2.4 acres (0.97 hectares) and the maximum PCE concentration had been decreased from 200 µg/L to 80 µg/L at well QMW-3. PCE concentration had also increased at EW-5 from <2.0 µg/L to 49 µg/L as the plume was shifted to the north. Therefore, the P&T system operated as designed, decreasing dissolved PCE and controlling the plume migration. However, PCE still exceeded 5.0 µg/L at seven wells and an additional 18 years of operation was projected at an estimated cost of $1.8MM to achieve the MCL of 5.0 µg/L.

Phase 2 – P&T Combined with ISCO. The P&T system was modified in June 2014 to include ISCO. Figure 3 shows the locations of the 12 ISCO wells that included ISCO-1 through ISCO-10 and EW-3 and EW-4. As shown in Figure 5, by May 2016 the PCE plume above 5.0 µg/L had been decreased to two separate areas surrounding wells QMW-3 and EW-5. Figure 6 provides PCE concentration versus time graphs from March 2013 (pre-ISCO) to May 2017. Between April 2014 and May 2016, PCE concentrations at QMW-3 had been decreased from 49 µg/L to 29 µg/L and at EW-5 from 38 µg/L to 11 µg/L.

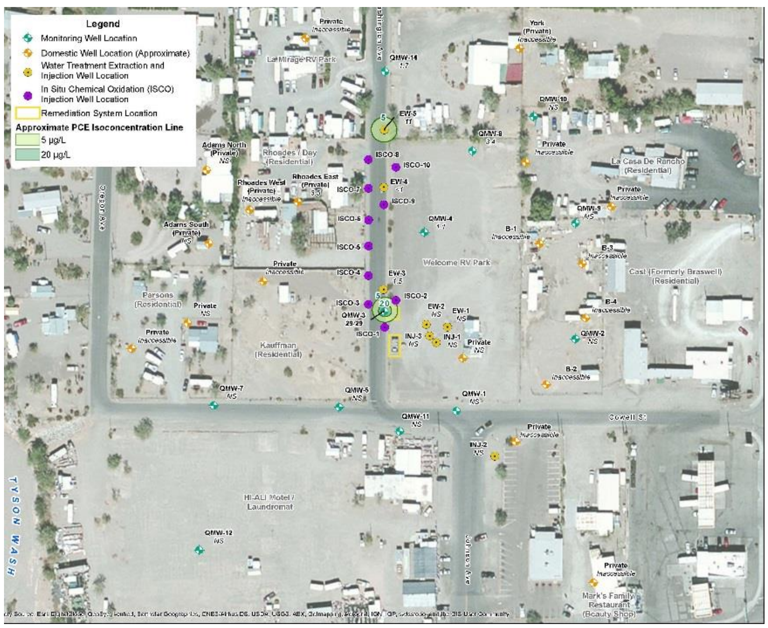
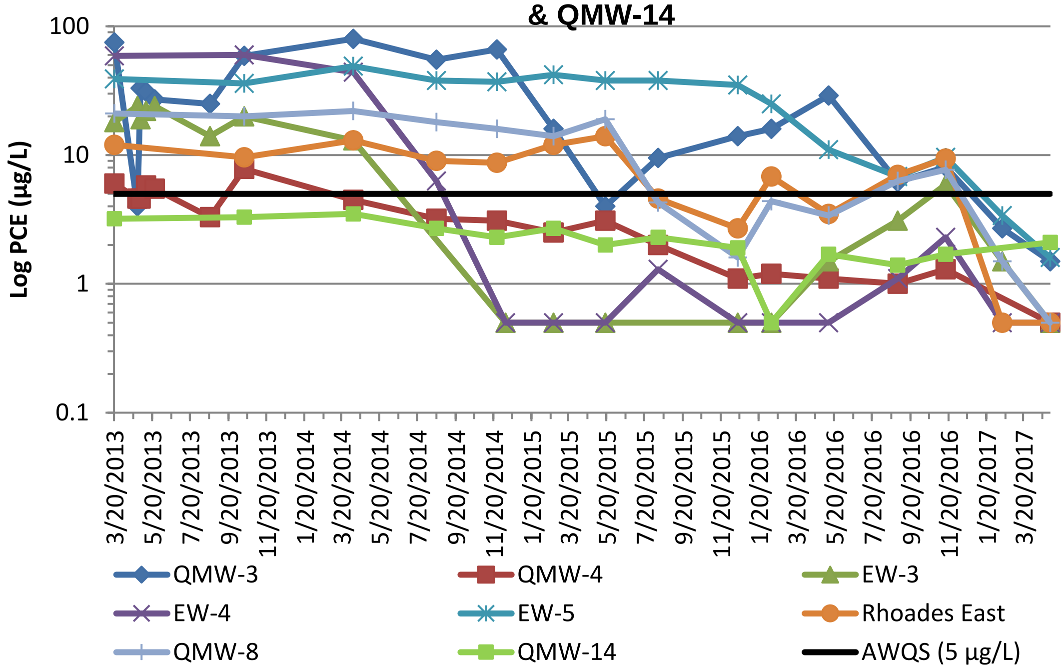


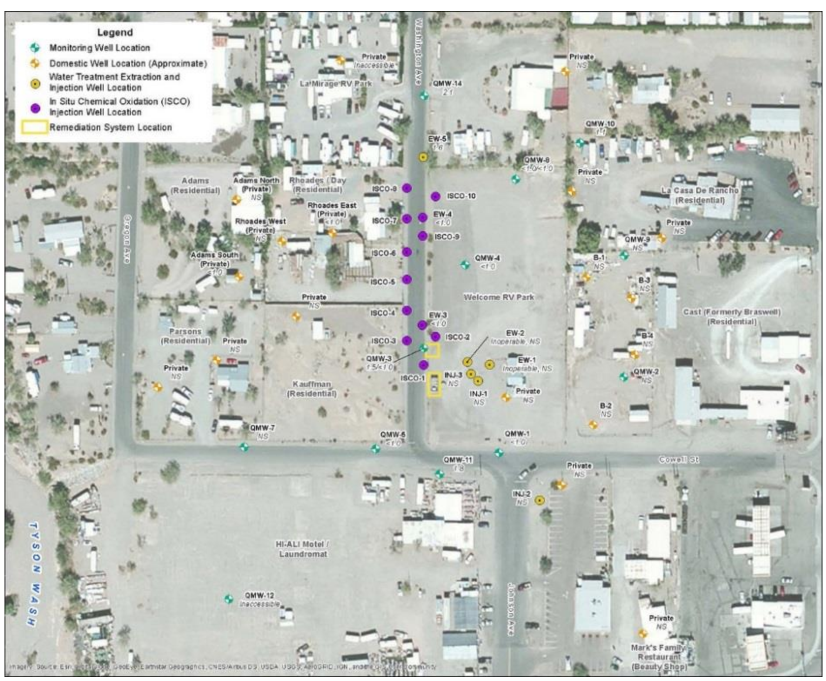
Figure 5 – May 2016 PCE Distribution

Phase 3 – Manual ISCO Treatments. Based on the May 2016 analytical results, EN Rx reagent was manually injected to QMW-3 and EW-5 on July 11, 2016. Groundwater samples were then collected on August 30, 2106. As shown in Figure 6, PCE concentrations decreased in samples collected from QMW-3 (6.2 µg/L) and EW-5 (6.8 µg/L); however, they rebounded above 5.0 µg/L in the samples collected from QMW-8 (6.8 µg/L) and Rhoades East (7.0 µg/L). A second confirmatory sampling event was performed on November 15, 2016. PCE concentrations remained above 5.0 µg/L in the samples collected from QMW-3 (8.1 µg/L), QMW-8 (7.7 µg/L), EW-3 (5.9 µg/L), EW-5 (9.6 µg/L), and Rhoades East (9.4 µg/L). Though below 5.0 µg/L, the PCE concentration in the sample collected from EW-4 had increased to 2.3 µg/L. Therefore, on January 9-11, 2017, the EN Rx reagent was manually injected to QMW-3, QMW-8, EW-3, EW-4, EW-5, and Rhoades East. PCE concentrations reported in confirmatory samples collected on

February 14, 2017 were below 5.0 µg/L, ranging from <1.0 µg/L (EW-4 and Rhoades East) to 3.4 µg/L (EW-5). On April 4, 2017, the EN Rx reagent was manually injected to QMW-3, QMW-8, EW-3, EW-5, and Rhoades East as a polish treatment. PCE concentrations reported in confirmation samples collected on May 2, 2017 were below 5.0 µg/L, ranging from <1.0 µg/L (QMW-8, EW-3, EW-4, EW-5, and Rhoades East) to 1.6 µg/L (EW-5). The May 2017 PCE distribution is shown on Figure 7.

Figure 6 - PCE Concentrations vs. Time (March 2013-May 2017)
Wells QMW-3, QMW-4, EW-3, EW-4, EW-5, Rhoades East, QMW-8 & QMW-14

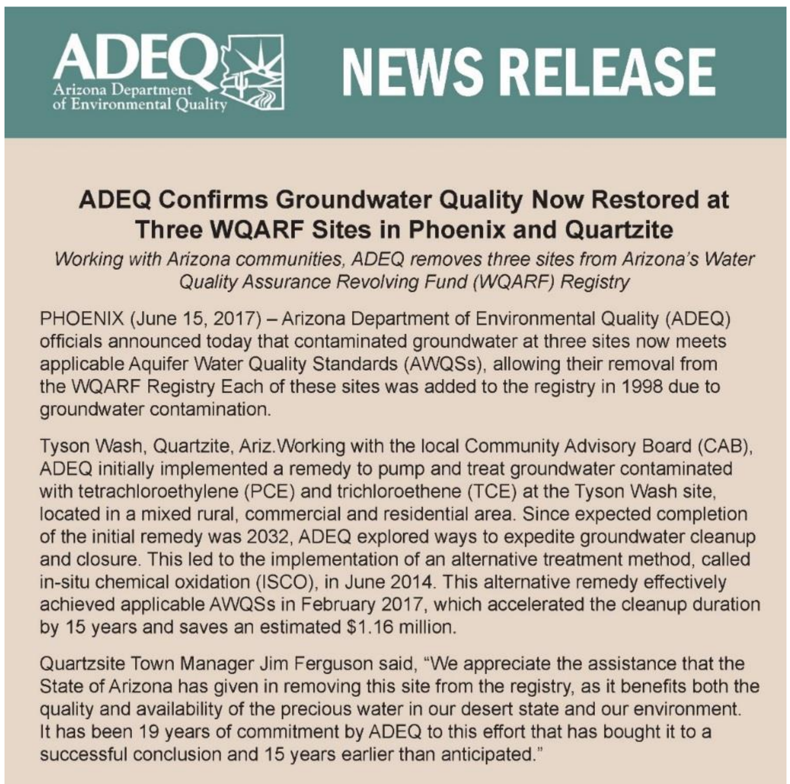




Based on these results, ADEQ determined that the ROs had been achieved and closed the Site in June 2017. This was the first Arizona WQARF site closed using active remediation. Total cost for the ISCO system was $614,000 and achieved closure in four years from the pilot test, decreasing estimated time to closure by 15 years and saving ADEQ $1.2MM in future O&M costs.

CONCLUSIONS AND LESSONS LEARNED

Though longer-term remedies such as pump-and-treat and monitored natural attenuation spread out costs over a longer period, thus meeting fiscal year budgets, a more aggressive shorter-term remedy can result in achievement of cleanup goals and site closure at overall lower life-cycle remediation costs. This provides benefits to stakeholders and the public.



ADEQ Arizona Department of Environmental Quality NEWS RELEASE

ADEQ Confirms Groundwater Quality Now Restored at Three WQARF Sites in Phoenix and Quartzite

Working with Arizona communities, ADEQ removes three sites from Arizona's Water Quality Assurance Revolving Fund (WQARF) Registry

PHOENIX (June 15, 2017) – Arizona Department of Environmental Quality (ADEQ) officials announced today that contaminated groundwater at three sites now meets applicable Aquifer Water Quality Standards (AWQSs), allowing their removal from the WQARF Registry Each of these sites was added to the registry in 1998 due to groundwater contamination.

Tyson Wash, Quartzite, Ariz.Working with the local Community Advisory Board (CAB), ADEQ initially implemented a remedy to pump and treat groundwater contaminated with tetrachloroethylene (PCE) and trichloroethene (TCE) at the Tyson Wash site, located in a mixed rural, commercial and residential area. Since expected completion of the initial remedy was 2032, ADEQ explored ways to expedite groundwater cleanup and closure. This led to the implementation of an alternative treatment method, called in-situ chemical oxidation (ISCO), in June 2014. This alternative remedy effectively achieved applicable AWQSs in February 2017, which accelerated the cleanup duration by 15 years and saves an estimated $1.16 million.

Quartzsite Town Manager Jim Ferguson said, "We appreciate the assistance that the State of Arizona has given in removing this site from the registry, as it benefits both the quality and availability of the precious water in our desert state and our environment. It has been 19 years of commitment by ADEQ to this effort that has bought it to a successful conclusion and 15 years earlier than anticipated."

Figure 7 – May 2017 PCE Distribution