Benefits of Using Down Well, Real-time, Telemetric Water Quality Meters to Monitor the Effects of a Chemical Injection

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Background

The Project Site in Wichita, Kansas was historically used as a chemical storage and distribution facility. The Project Site consists of a 0.7 acre parcel (**Figure 1**). A single building is present at the Project Site, which includes office, warehouse, and loading dock and occupies approximately one-quarter of the site. A concrete paved material storage yard comprises the area south of the building and is the location of the injection remediation.

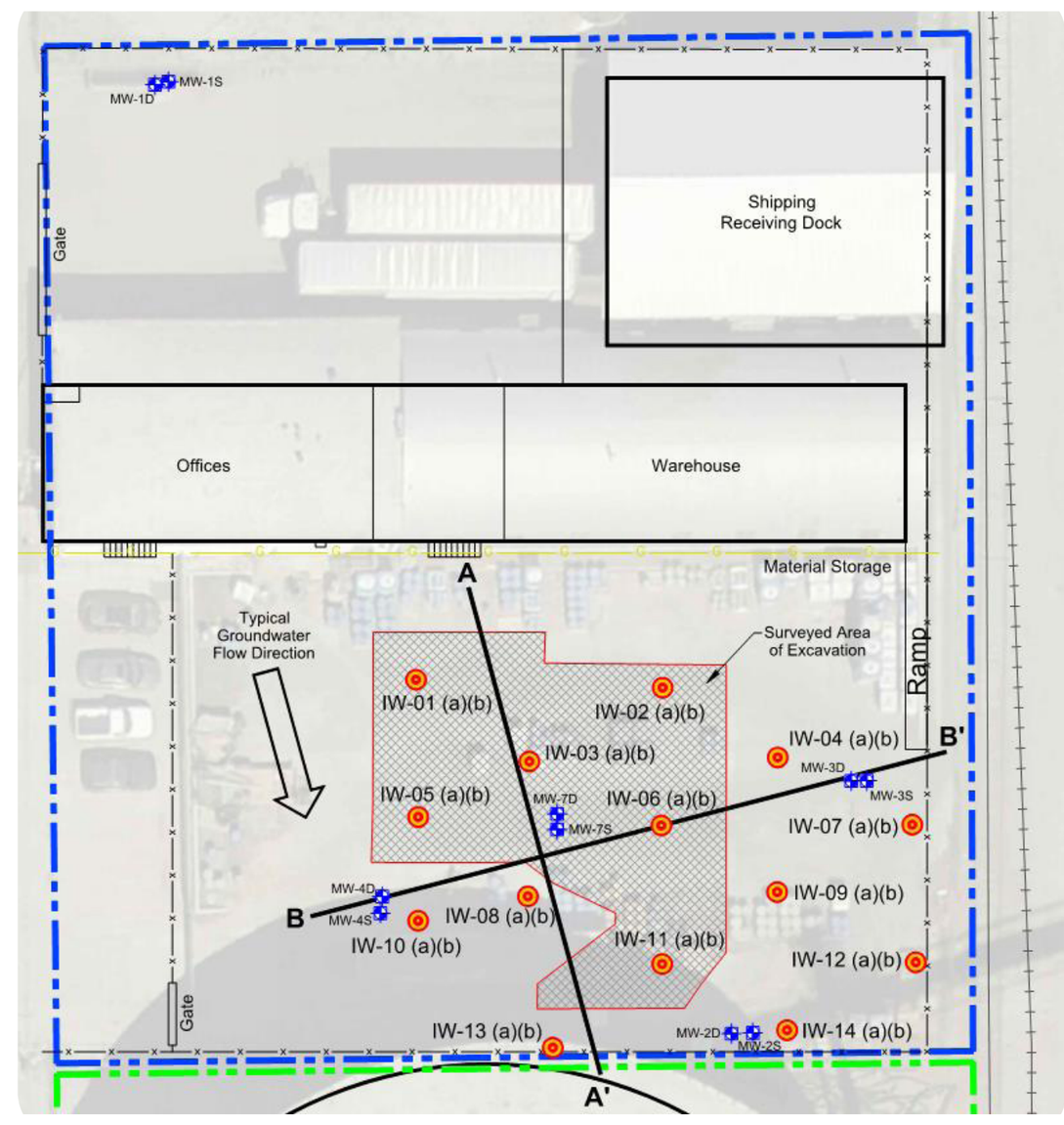

Figure 1. *Site Layout*

Groundwater flow is generally to the south-southeast. The vertical groundwater gradients on-Site are very low with limited downward gradient indicated at the MW-7s/d well nest. Figures 2 and 3 illustrate the elevation of the observed water table (~13 ft below ground surface (bgs) in relation to various sand strata. The site is generally underlain by a series of upward fining layers ranging from coarse to fine sand and capped by silt and clay. As shown on the figures, near surface silt and clay deposits were the focus of earlier remedial excavations (now replaced by fill), which were generally within 6 to 7 feet of the ground surface. Fine sands generally occupy the unsaturated zone beneath these shallow silty/clayey layers with thickness of 5 to 7 feet. The shallow saturated zone is generally comprised of medium and coarse sand, with some interbedded fine to medium sand.

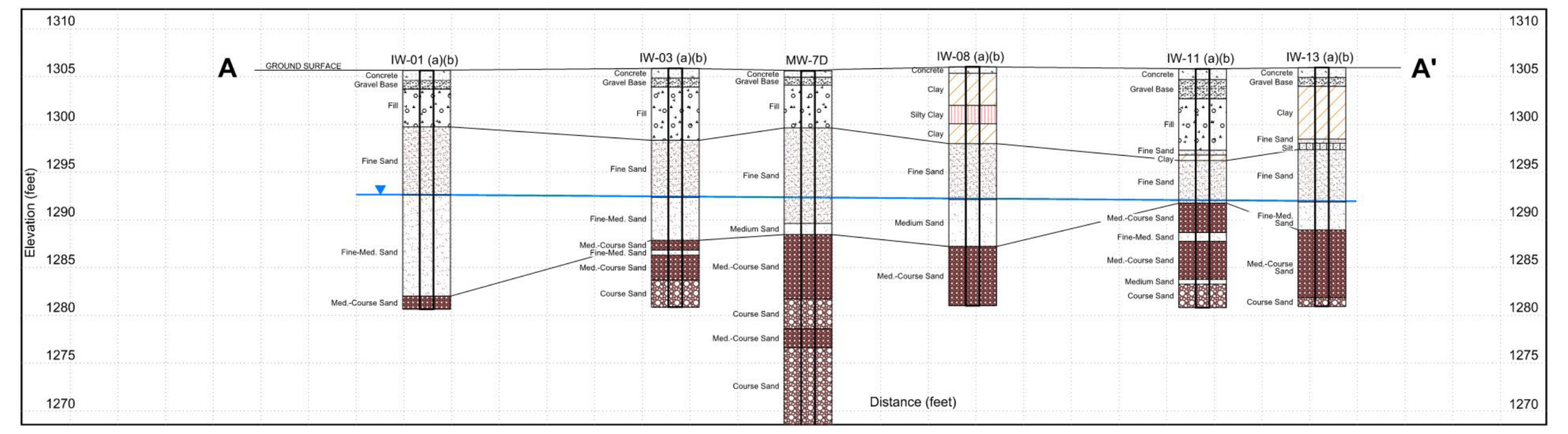

Figure 2. *Cross-Section A-A'*

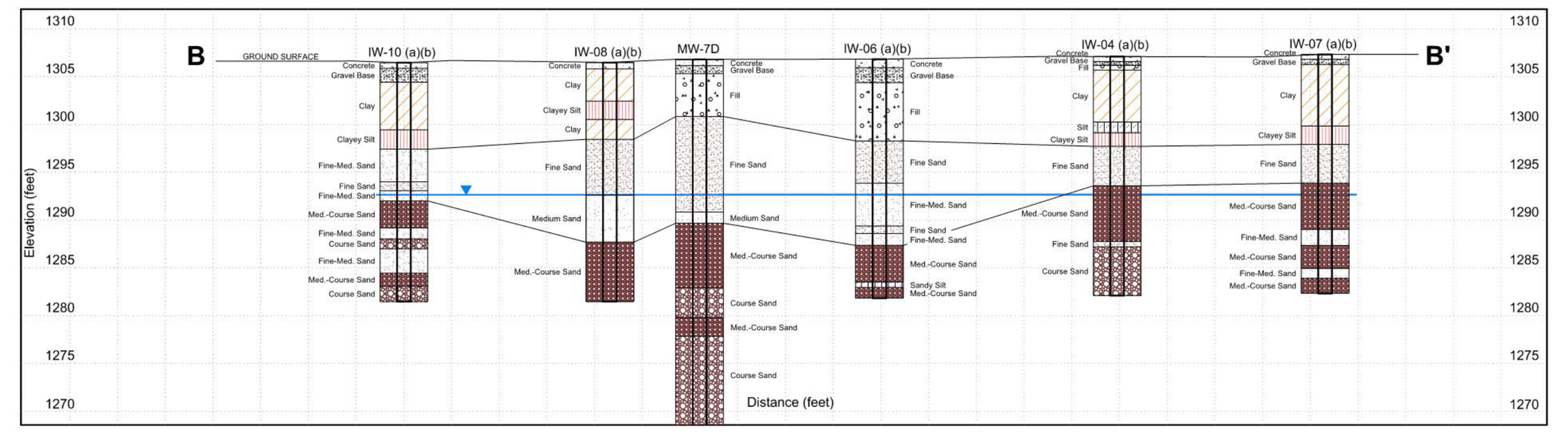

Figure 3. *Cross-Section B-B'*

Previous investigations of the Site revealed that shallow groundwater at the Site exceeded maximum contaminant levels (MCLs) for drinking water for trichloroethylene (TCE), perchloroethylene (PCE), and vinyl chloride (VC). Upgradient Site wells also showed detections, though below MCLs. Thus both on-Site and upgradient sources were indicated. An area of on-Site impacted soil in the material storage yard was discovered.

Remedial efforts have been coordinated through a Kansas Department of Health and Environment (KDHE) Bureau of Environmental Remediation. An Interim Remedial Measure (IRM) for soil was previously conducted in the material storage yard. In 2007, 683 cubic yards of soil and concrete was excavated to a depth of six to eight feet bgs and disposed off-site. The excavation was backfilled with clean fill and paved with concrete.

Objectives

The following remedial action objectives (RAOs) were developed for the Project Site:

- Reduce mass of VOCs in the source area to the extent practicable;
- Reduce concentrations of chemicals of potential concern (COPCs) in groundwater in order to restore the aquifer to its most beneficial reuse; and
- Prevent exposure to impacted groundwater.

The work described herein was implemented to address these RAOs and success was determined through periodic monitoring and evaluation. The work included:

- Enhance the well network with one additional well pair.
- Collect soil samples from below the former excavation to evaluate residual impacts
- Install injection well network
- Install real-time monitoring equipment
- Inject a potassium permanganate solution
- Evaluate the remedial effectiveness using real-time monitoring and the groundwater sampling results.

Methods

Injection Well Installation

- Continuous soil cores were collected, described, and sampled for VOCs from two depths within the unsaturated zone based on photoionization detector (PID) readings and visual observation.
- Fourteen pairs of injection wells were installed (**Figure 1**).
  - Paired 1-inch wells
  - Screens at 2 depths: 13 to 18 feet; and 20 to 25 feet.
- All injection wells were developed and surveyed.

Potassium Permanganate Injection Process

- Procure 4,629 pounds of potassium permanganate
- Construct injection equipment (**Figures 4** and **5**).
  - two 550-gallon poly tanks, one for water storage and one for mixing the injection solution
  - transfer hose, pumps, manifold, and gauges
- Prepare solution
  - Mixed 330 pounds potassium permanganate with 1,600 gallons water
- Inject solution
  - Simultaneous injection to a co-located deep and shallow injection well pair
  - Sustained pressures: 0 to 30 psig
  - Maximum pressure of 50 psig was not exceeded
  - Flow rates: between 3 and 10 gallons per minute (gpm).
  - 600 to 1,000 gallons injected per well; 1600 gallons per paired well location
  - No surfacing of injected material

Figure 4. *Injection Tank, Pump, and Piping*

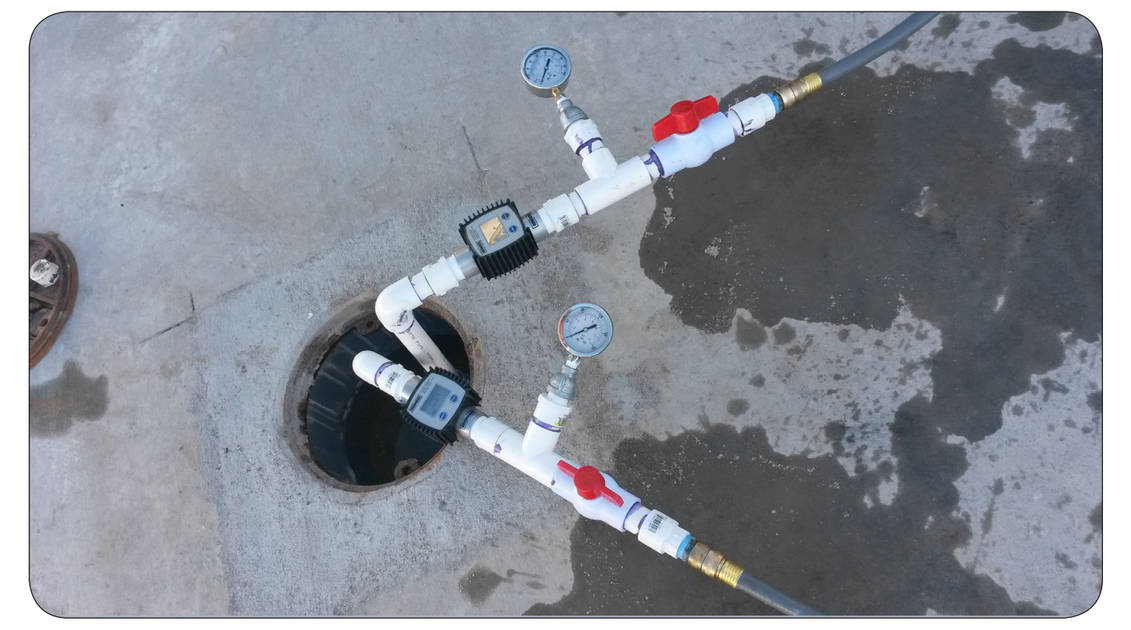

Figure 5. *Injection Well*

Preliminary Soil Data Evaluation

Soil samples were collected from the vadose zone from each well location including new wells MW-7S, MW-7D and each pair of injection wells. Typically two samples were collected, one from the 7-to-10-foot bgs zone and the other from within the 10-to-14-foot bgs zone. PID screening of the soil cores was performed to evaluate potential impacts that might change the injection plan; however no significant PID readings were observed and no changes to the injection plan were made.

The order of injection into each injection well was determined based upon the PID readings and soil analytical results. Initial chemical injections were focused on the area near MW-7s.

All soil sampling analytical results were below the RSK values for the leaching to groundwater pathway suggesting the **source area soil had been adequately remediated.**

Groundwater Monitoring

The Site groundwater network included, among others, on-site wells MW-2s, MW-4s, MW-7s, all screened from 15 to 25 feet bgs.

Baseline groundwater monitoring

November 3-4, 2016

Injections

November 10-18, 2016

Quarterly groundwater monitoring

January 25-26, 2017

April 10-12; 2017

July 17-18; 2017

October 11-12, 2017

January 31-February 1, 2018

Real-time Groundwater Monitoring Probes

Real-time In-Situ Inc. AquaTROLL 600 Multiparameter Sondes and TubeR Telemetry Systems were suspended in monitoring wells MW-02S, MW-04S and MW-07S shortly before the oxidant injection.

Figure 6. *AquaTROLL 600 and TubeR Telemetry System*

Data readings pH, dissolved oxygen (DO), conductivity, oxidation reduction potential (ORP), temperature, water level, and barometric pressure were collected every 15 minutes and uploaded to HydroVu Web site daily. **Data were reviewed remotely each day** to verify site aquifer conditions. The real-time monitoring probes remained in monitoring wells MW-02s, MW-04s and MW-07s after injection and continued to collect hourly. Automated upload of the data was programmed for once per day. Data were evaluated weekly using HydroVu software graphics to observe trends.

Results and Discussion

- The injection event was successful at delivering the planned volume and mass of oxidant to the target depth below the water table to a depth of 25 feet bgs. Variability in pressures and volumes were within expected tolerances and no surfacing of injection solution or groundwater was observed.
- During the October 2017 sampling event, groundwater analytical results did not exceed the Residential RSK values for groundwater in any on-site wells, including: MW-2s; MW-4s; MW-7s.
- In shallow groundwater at MW-2s and MW-3s, PCE, TCE and DCE generally trend together and overall have generally declined through time. TCE declined after implementation of the corrective action and both TCE and DCE remain below the residential RSK level.

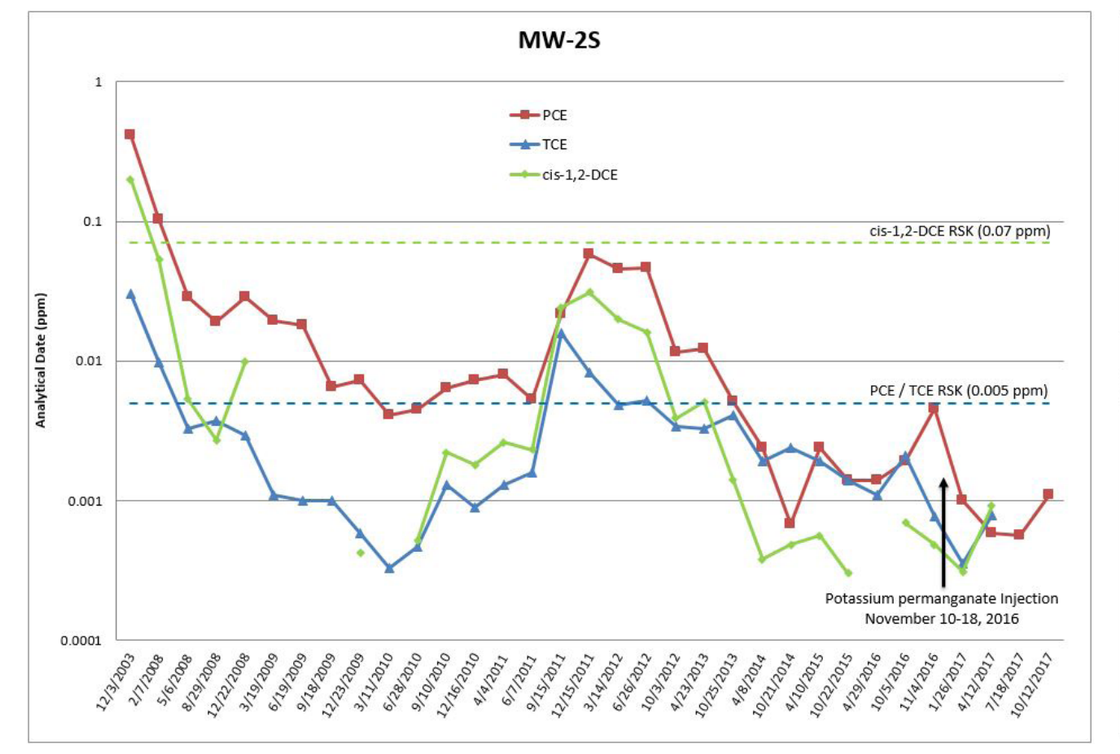

Figure 7a. *PCE, TCE, and DCE at MW-2S*

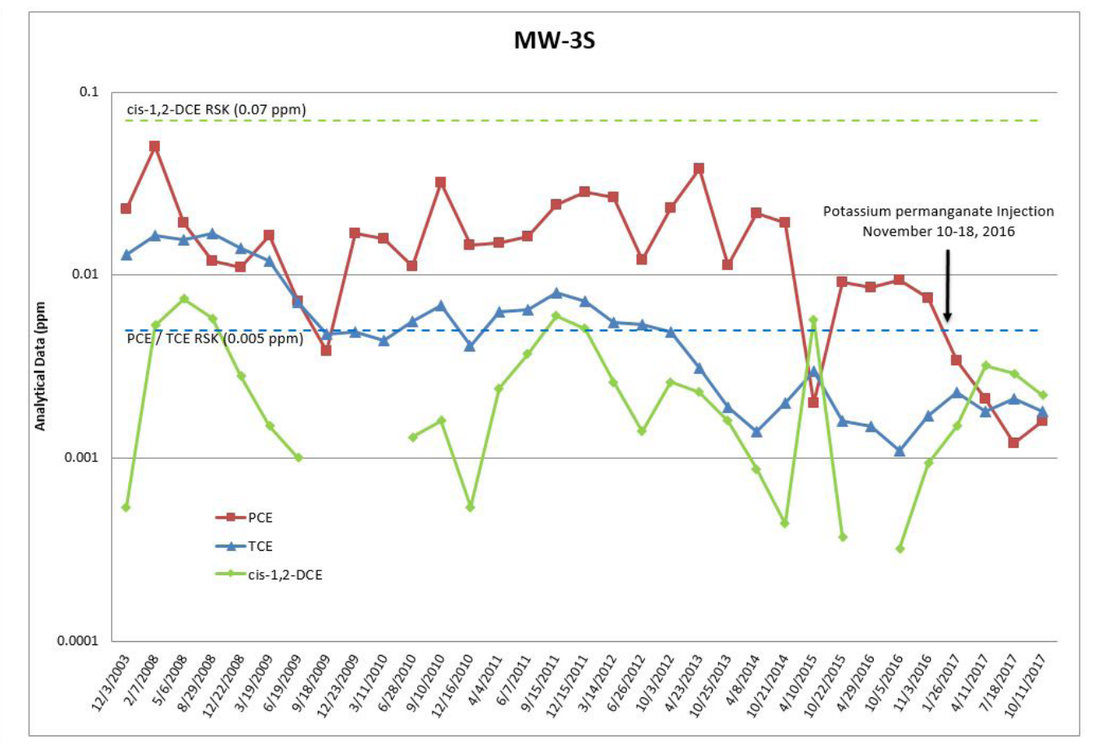

Figure 7b. *PCE, TCE, and DCE at MW-3s*

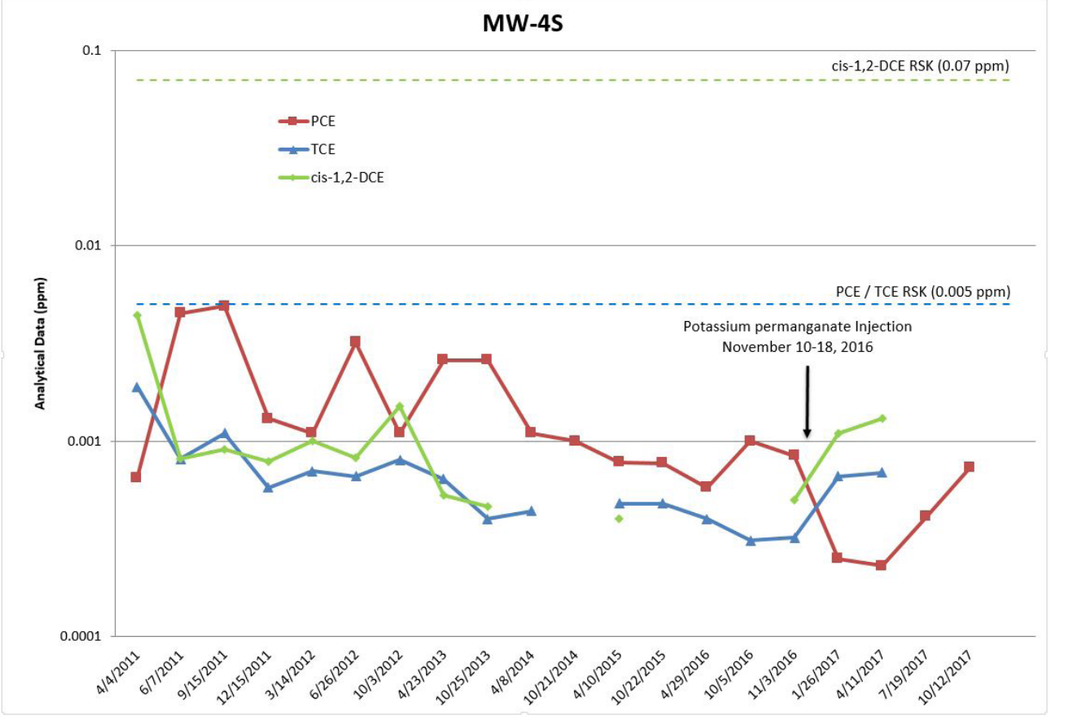

Figure 7c. *PCE, TCE, and DCE at MW-4S*

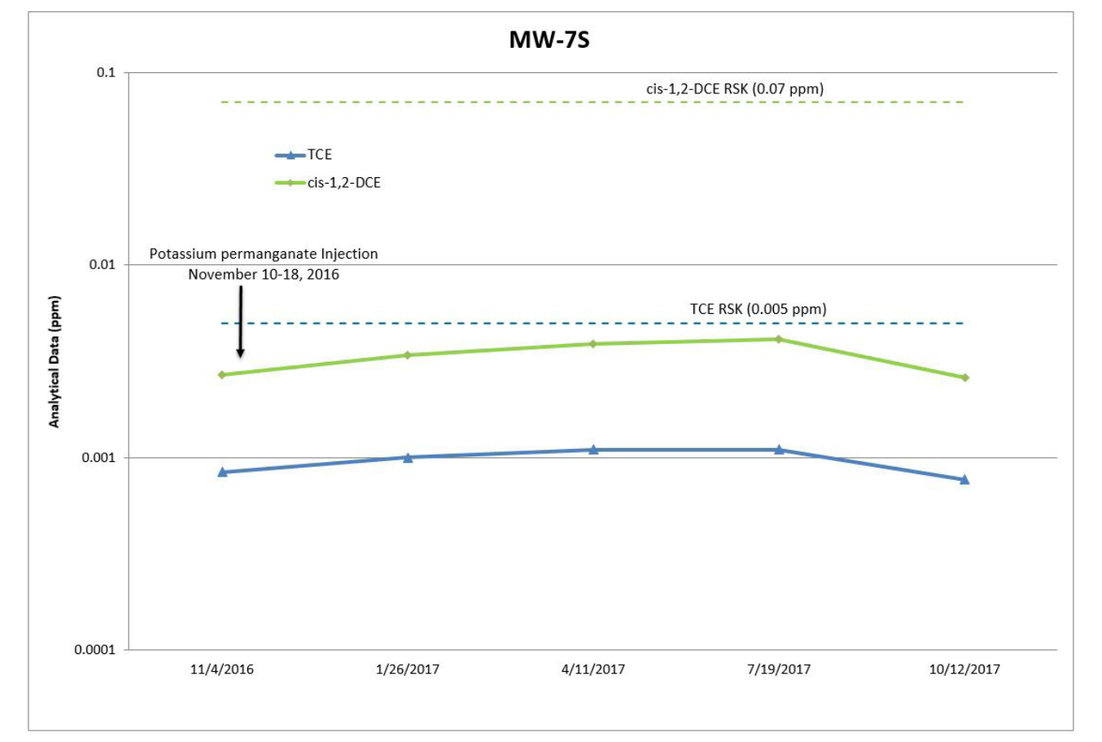

Figure 7d. *PCE, TCE, and DCE at MW-7S*

- PCE is detected in shallow groundwater and at concentrations below the residential RSK. TCE and cis-1,2-DCE show similar but overall stable to declining trends.
- As shown on the Trend Analysis Graphs for MW-7s in the heart of the source area, PCE, TCE and DCE are below the residential RSK level though detected in groundwater at nearly stable concentrations. PCE was not detected.

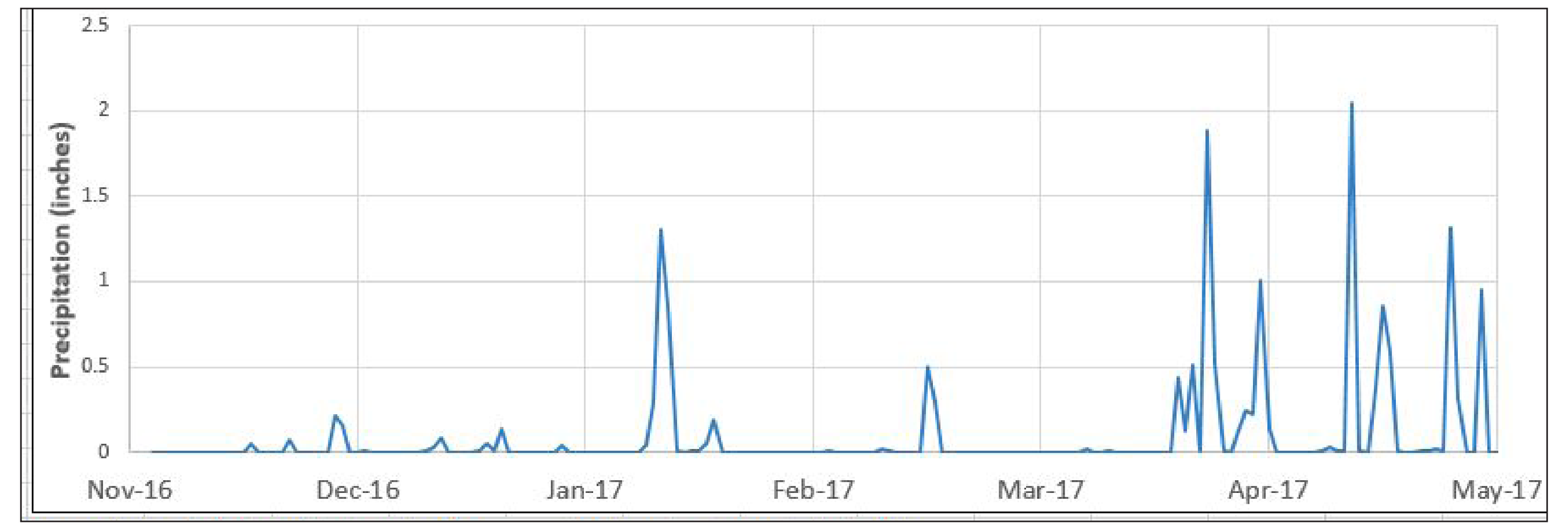

Figure 8. *Precipitation data from local community airport meteorological station*

- As a reference, precipitation data were downloaded from the local community airport meteorological monitoring station and graphed as a function of time as shown on **Figure 8**.
- Data collected from the real-time groundwater monitoring probes are presented graphically in **Figures 9** and **10a**, **10b**, **10c**, and **10d**. Pressure spikes were observed during injection activities which correlated to the observed gauge readings. A sharp rise in ORP was observed in MW-07S as the injection progressed and the aquifer became an oxidizing environment to react with the contaminants in the groundwater. Groundwater elevation measurements showed appreciable water level changes during injection periods; however, water levels quickly returned to normal when injection ceased.

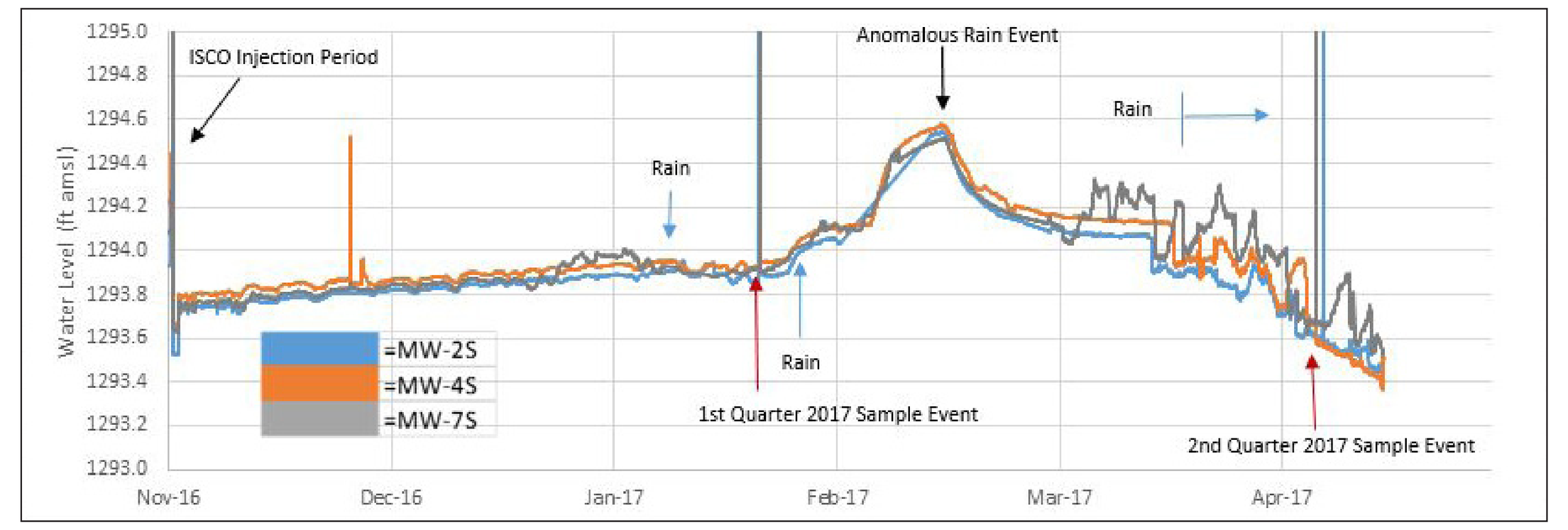

Figure 9. *Depth to Groundwater at MW-4s, -7s, and -2s*

- As shown on **Figure 10b**, during April 2017, total dissolved solids remained consistent for MW-2S, MW-4S, and MW-7S with concentrations measured between 500 to 1,000 mg/L.
  - The pH remained approximately neutral around about 7.0 standards units for all three wells, except that MW-2s took several days to normalize after calibration on April 20.
  - Dissolved oxygen has remained consistently low ranging between approximately 0 and 0.4 mg/L.
  - Oxidation reduction potential generally declined since the November 2016 permanganate injection, but stabilized toward the end of the month with readings around 0 millivolts (mV) for MW-2S and approximately 100 mV for MW-4S.
  - These data suggest these remediation monitoring parameters had returned to pre-injection levels between February 5 and February 20, 2017.

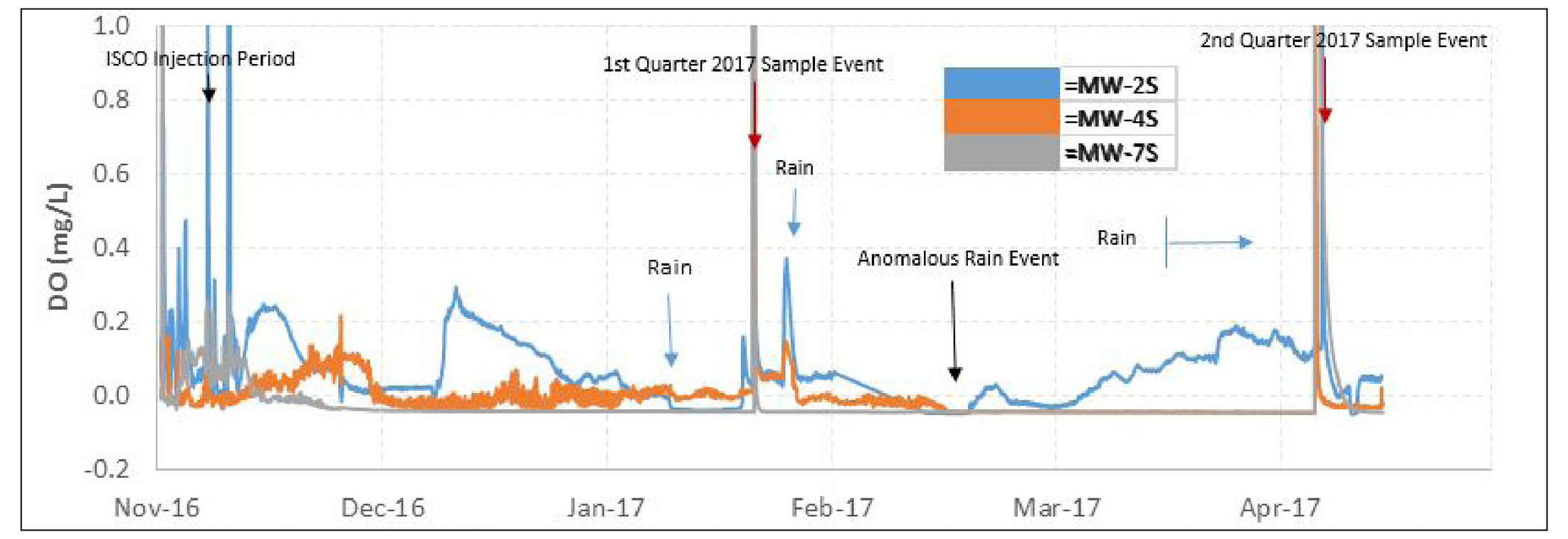

Figure 10a. *Dissolved oxygen (DO) at MW-7s, -4s, and -2s*

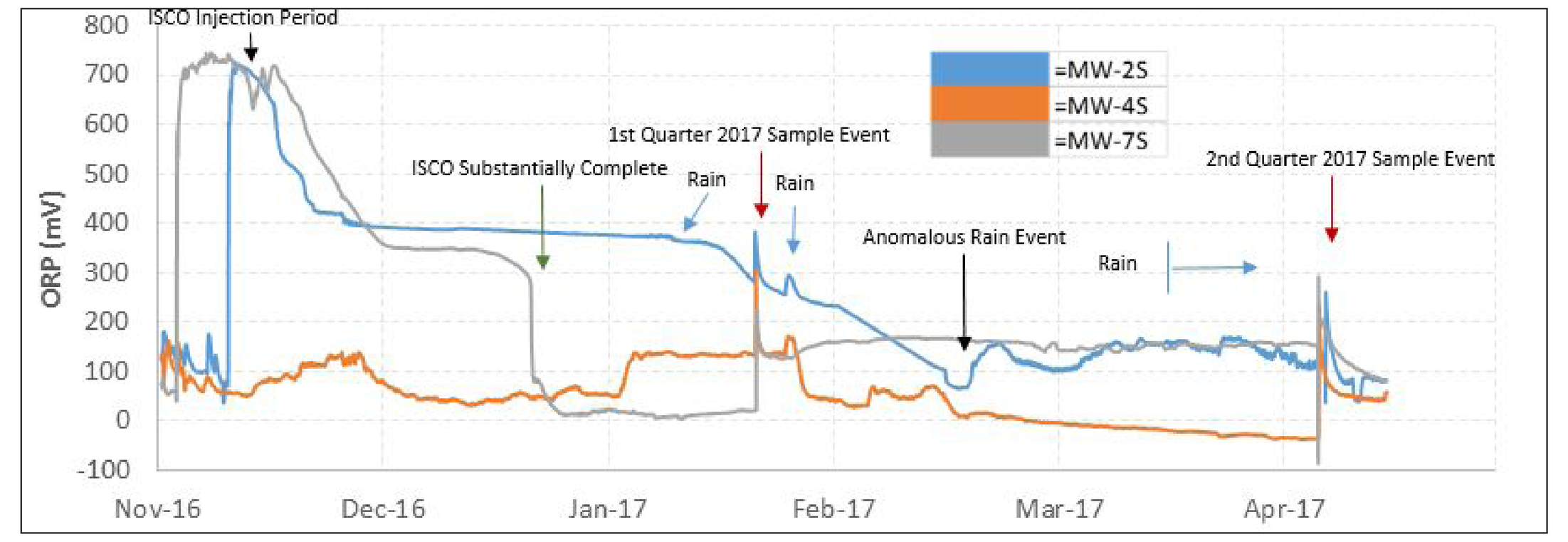

Figure 10b. *Oxygen reduction potential (ORP) at MW-7s, -4s, and -2s*

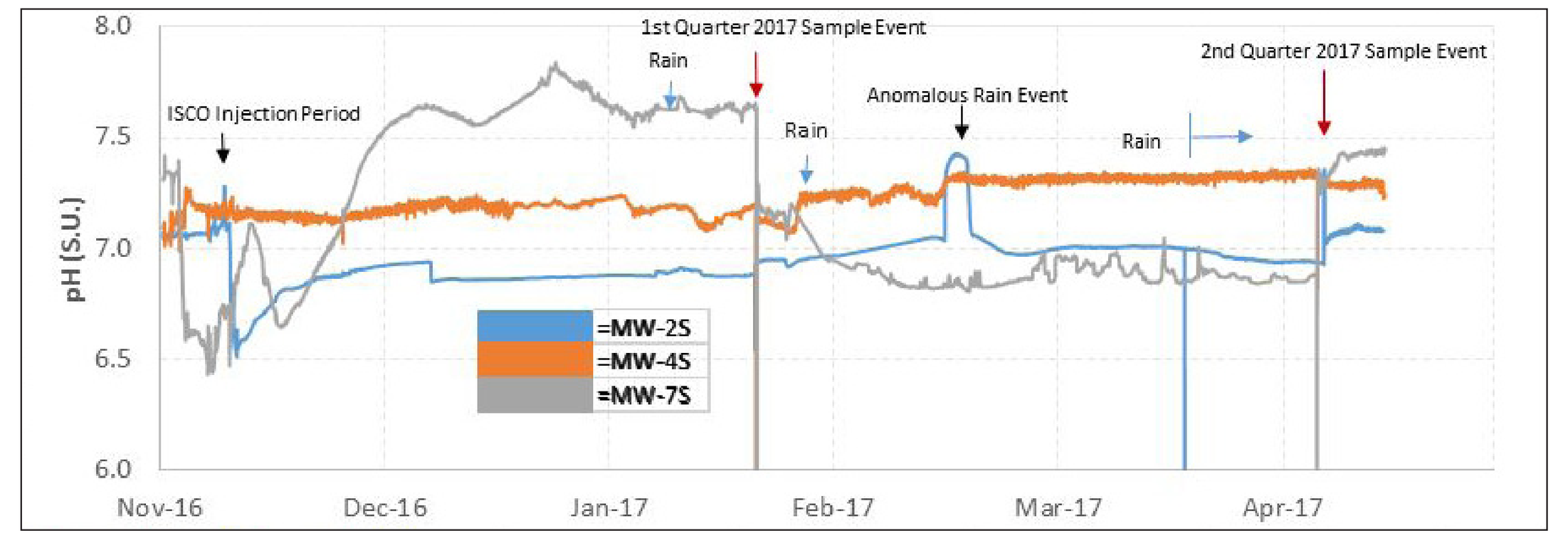

Figure 10c. *pH at MW-7s, -4s, and -2s*

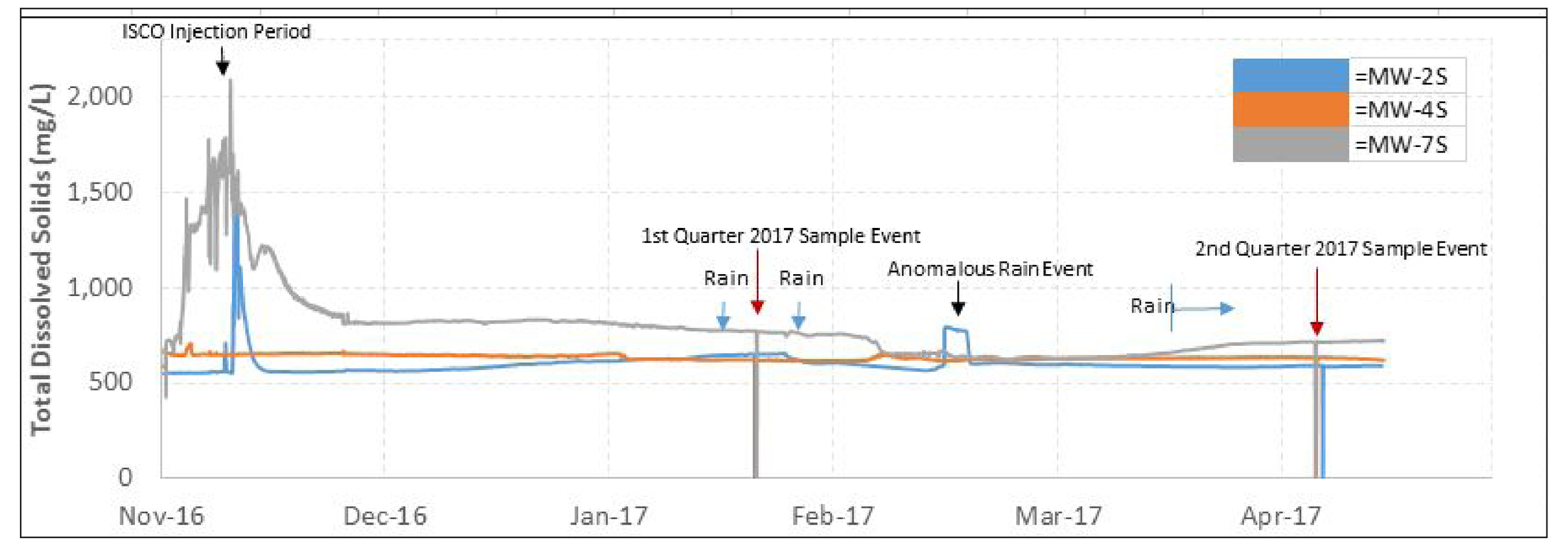

Figure 10d. *Total dissolved solids (TDS) at MW-7s, -4s, and -2s*

Field groundwater data were consistent with lab data (dissolved iron in particular) and In-Situ probe data (pH, DO, temperature, redox, conductivity) and also consistent with a marginally impacted aquifer. In summary,

- pH is neutral, about 7.0.
- Temperature is about 70o F.
- Total dissolved solids are relatively low, but range between 500 to 1000 mg/L.
- Dissolved Oxygen is relatively low (0 to 0.4 mg/L), but not totally anaerobic.
- Redox (ORP) is low (0-200 uS/cm) suggesting anoxic conditions.

- A review of inorganic parameters, including calcium, iron, magnesium, manganese, chloride, nitrate, nitrite, sulfate, total organic carbon (TOC), and hardness, indicates that groundwater conditions have essentially returned to pre-injection levels as of October 2017.
- A review of the manually collected field parameters included with field notes suggests the field parameters continue to reflect stable conditions for pH, temperature, conductivity, oxygen reduction potential (ORP), and dissolved oxygen (D.O.). These parameters had returned to pre-injection conditions by the time of the second quarter 2017 groundwater monitoring event in April 2017.
  - Values for pH were near neutral pH (7.04 to 7.58). The temperature of groundwater was approximately 20 °C.
  - Specific conductivity varied from 0.931to 1.09 mS/cm. TOC was generally between 2.1 and 2.7 mg/L.
  - ORP was generally positive in the shallow aquifer.
  - D.O. in the shallow aquifer varied from 0.40 to 2.88 mg/L.

As a whole, these field parameters reflect the higher influence of surface water infiltration and ambient atmospheric conditions on shallow groundwater.

Conclusions

1. Providing real-time data that allow aquifer conditions to be continually monitored to accurately determine when reactant has been spent, rather than relying only on periodic groundwater sampling and analysis.
2. ORP and pH are the most sensitive parameters to monitor for evaluating KMnO4 performance.
3. ISCO reaction essentially complete by end of December 2016 (less than 60 days after injection on November 10-18) as reflected by big drop in ORP at MW-7S. Slower drop in MW-4S (a cross-gradient well) extended through February 2017). Groundwater sampling in late January 2017 was considered ideal (after reaction mostly complete, but before rebound).
4. The multiparameter probes can detect short-term events that can then be further evaluated for overall environmental significance. One event at this Site increased pH by 0.5 units and TDS by 200 mg/L and decreased ORP by 50 mV and DO to about 0.0, and also affected groundwater temperatures at all three wells.
5. ISCO and rainfall had some short-term, but only minimal long-term influence on dissolved oxygen due to residual oxygen demand, low net recharge on-site and up-gradient groundwater impacts that deplete upgradient flow of dissolved oxygen.
6. The multiparameter probe is a useful tool and recommended for similar applications.

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