Testing Partially Treated Surface Water for Aquifer Storage and Recovery at the Peace River Facility

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The Peace River Manasota Regional Water Supply Authority (authority) operates a potable water aquifer storage and recovery (ASR) system that includes ASR Wellfield No. 1 (WF1) and ASR Wellfield No. 2 (WF2) at the Peace River Regional Water Supply Facility (PRF). The authority continuously explores options to increase regional water supply system reliability by increasing water supply capacity and storage for drought tolerance. Using partially treated surface water (PTSW) instead of fully treated potable water as a recharge water source for the ASR system would provide for additional storage, with a significant decrease in overall delivery cost from the ASR system. Rather than the current ASR operating practice of treating stored river water to potable standards twice before distributing treated water to the public (once on injection/recharge to ASR and again after recovery from ASR), the authority would only need to treat the water once.

Background

The authority supplies wholesale drinking water to four member counties (Charlotte, DeSoto, Sarasota, and Manatee) and one nonmember customer (City of North Port) in southwest Florida. The authority's water supply source is the Peace River, where a small percentage of seasonal high flows is harvested and stored in a 6.5-bil-gal (BG) offstream surface reservoir system. The authority also stores water in two ASR wellfields with a design capacity of 6.3 BG. Currently, the ASR system stores fully treated drinking water that is recovered into the surface reservoir system during dry periods and retreated prior to delivery to the authority's customers.

The PRF is a 51-mil-gal-per-day (mgd) conventional surface water treatment plant using alum coagulation; the current demand on the PRF is approximately 26 mgd. The development of a reliable public water supply at this scale on the Peace River using a seasonally available water resource is only feasible through the availability of large-volume offstream water storage (reservoirs and ASR), which must supply water to meet customer demand during the dry season when little or no water is available for harvest from the river. This ensures that withdrawals for public supply do not adversely affect flows in the river needed to support the Charlotte Harbor estuary downstream.

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The authority's two ASR wellfields consist of 21 potable water ASR wells. The WF1 consists of eight Suwannee Zone ASR wells and a single Tampa Zone ASR well located on the PRF property and has been in operation since the mid-1980s. A test ASR well completed in the Avon Park High Permeability Zone is also located within WF1, but has not been used for ASR to date. The WF2 was constructed in 2002 and consists of 12 Suwannee Zone ASR wells located immediately south of the authority's Reservoir No.1 and approximately one mi southwest of the PRF. Each well has a capacity to inject or recover approximately 1 mgd. Figure 1 shows WF2 and its monitoring wells.

The potable water ASR system, as currently permitted and operated, requires that the stored water be fully treated prior to recharge into the aquifer and then fully treated again when the stored water is recovered. This makes storing water in the ASR system economically less favorable for the authority than storing raw surface water in the offstream reservoirs, which only requires treatment once prior to delivery to its customers. Replacement of potable water with PTSW for the authority's ASR recharge program would provide cost, efficiency, reliability, environmental, permitting, and resource recovery benefits.

To successfully permit the ASR system to a PTSW system, a demonstration was necessary to show that the total coliform bacteria (which is present in all Florida surface waterbodies)

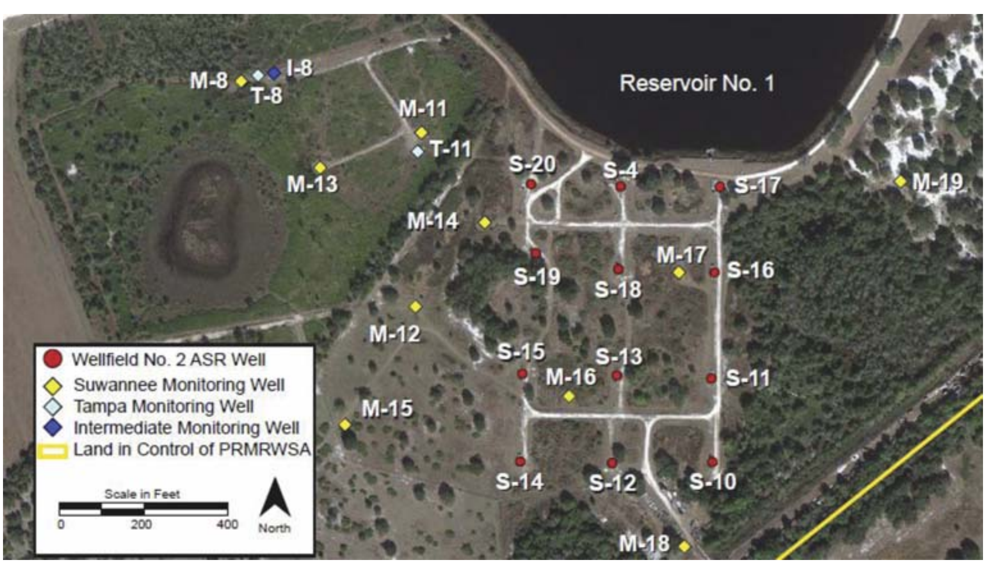

Figure 1. Wellfield No. 2

would be deactivated with residence time in the aquifer, and that the groundwater standard for total coliform of 4 colony-forming units (CFU)/100 mL could be achieved within the property under the control of the authority.

To provide the data necessary to support the PTSW ASR, a pilot test was designed using two wells at WF2 (S-4 and S-20) and recharging PTSW from Reservoir No.1 (see Figure 1). Cycle testing began in February 2017 and was completed in January 2018. The following sections detail the cycle test design, water quality results, well performance, and recommendations and considerations for future development of this alternative water supply concept.

Table 1. Cycle Test 1 Operational Summary

CT1 Operational Status	Date Range	Avg. S-4 Rate (mgd)	Avg. S-20 Rate (mgd)	Avg. WF2 Rate (mgd)*	Avg. WF2 Rate (mgd)
CT1 Recharge	2/09/17 – 3/09/17	0.71	1.34	-	2.05
CT1 Storage	3/10/17 – 3/26/17	-	-	-	-
CT1 Recovery	3/27/17 – 4/09/17	-0.64	-1.15	-	-1.79
CT1 & WF2 Recovery	4/10/17 – 6/05/17	-0.65	-1.12	-10.71	-12.49
WF2 Recovery	6/06/17 – 6/15/17	-	-	-6.44	-6.44

* = Excludes S-4 and S-20
\- = 0.00

Pilot Test Overview

The objective of the PTSW ASR pilot testing was to conduct small-scale cycle tests using recharge volumes large enough to arrive in the monitor wells, but not so large that it potentially left the property under the control of the authority. The pilot test was implemented at WF2 using wells S-4 and S-20. Surface water stored in Reservoir No. 1 was filtered and recharged in the wells and then later recovered back to Reservoir No. 1. The ASR wells S-4 and S-20 were selected as the pilot test wells for the following reasons:

- They are closest to Reservoir No. 1 and require the least amount of temporary piping.
- They are some of the furthest wells from the property boundary, maximizing the buffer and the maximum possible distance to assess water quality prior to leaving the entity-controlled property.
- The grouping of monitor wells near S-4 and S-20 provides a comprehensive monitoring network to evaluate water quality at different distances (travel times) from the ASR well.

The S-20 has a relatively high-specific injectivity, and S-4 has a relatively moderate-specific injectivity that is representative of most of the other ASR wells in WF2. This will allow for the comparison of well performance regarding the effect of PTSW on a well where the capacity relies primarily on matrix primary porosity (S-4) and one with a more secondary porosity (fractured) flow profile (S-20).

Pilot testing was conducted in conjunction with the authority's normal potable water ASR system operations at this storage site and is an integral part of the authority's water reliability strategy. It could not be shut down for the extended period of time necessary to complete the PTSW pilot testing.

A cycle test program was proposed to the Florida Department of Environmental Protection (FDEP) in a permit modification request to implement PTSW pilot testing that consisted of up to three cycles at progressively increasing volumes. The target recharge volume proposed for the first cycle was relatively low (50 mgd) to allow for evaluation of water quality changes at monitor wells near the point of recharge before the PTSW left the property under control of the authority. After the first cycle was completed, it was decided to only conduct two cycles and increase the recharge volume and storage duration between recharge and recovery for the second cycle test.

Description of Pilot Test Equipment

Temporary piping and pumping equipment was installed at S-4 and S-20 so that the wells could be recharged directly from Reservoir No. 1 during the temporary test program. A single electric-driven centrifugal pump, filtration, and piping system was rented from Xylem Dewatering Solutions Inc. to temporarily supply PTSW to S-4 and S-20 during the demonstration period. The pump was powered using one of the authority's nearby control panels and operated locally with an adjustable frequency drive. The pump intake was a floating high-density polyethylene (HDPE) tee with 0.25-in. diameter holes, which served to mitigate the intake of aquatic organisms. The pump intake was located at Reservoir No. 1 near S-4 and S-20 to minimize the distance of temporary piping to the wells. A pressurized filtration system, consisting of four parallel filter pods, was installed downstream of the pump to remove particulates and total suspended solids (TSS). The filter pods were fitted with a stainless steel filter basket with one-eighth-in. openings and allowed for the installation of 100-micron and 50-micron mesh filter bags to be utilized without the risk of losing a mesh bag to the formation of the ASR wells. During operation, pressure data upstream and downstream of each filter pod were observed to determine the replacement schedule for the mesh filter bags. A pump operation indicator was added to the authority's supervisory control and data acquisition (SCADA) program to alert the PRF operators of a failure.

Temporary recharge piping was installed from the filters to existing tees located at S-4 and S-20, which allowed use of the existing flow meters at the well headers. In case S-4 and S-20 needed to be purged (backflushed) during recharge periods, isolation valves were installed on the recharge piping to allow the purged water to be stored in the onsite dry ponds. The existing ASR well system piping was used during recovery to convey recovered water back to the reservoir.

Cycle Testing Recharge and Recovery Summary

Cycle Test 1 (CT1) began on Feb. 9, 2017, with the recharge of PTSW at ASR wells S-4 and S-20; the recharge phase of CT1 continued until March 9, 2017. Recharge consisted of the injection of 59.4 mil gal (MG) of PTSW at ASR wells S-4 and S-20. The additional ASR wells within WF2 (S-10 through S-19) were not in operation during the CT1 recharge phase. Following the recharge phase of CT1, S-4 and S-20 remained in storage until March 27, 2017, when the recovery phase of CT1 was initiated. The S-4 and S-20 began the recovery phase of CT1 exclusive of the other WF2 ASR wells from March 27 to April 9, 2017, recovering a total of 25.1 MG during that time, which was approximately 42 percent of the total PTSW injected during the CT1 recharge phase.

On April 10, 2017, the remaining WF2 ASR

Continued on page 38

Continued from page 37

wells began recovery, increasing the WF2 recovery rate from an average of 1.8 mgd (S-4 and S-20) to a maximum of 14.4 mgd during CT1. Recovery was ceased on June 5, 2017, at S-4 and S-20, but continued at five of the WF2 ASR wells (S-11, S-14, S-15, S-16, and S-18) until June 15, 2017. A total volume of 801.2 MG was recovered from WF2 from the start of PTSW CT1 to June 15, 2017, when recovery ceased at all of the WF2 ASR wells. Table 1 provides a summary of the operational recharge, storage, and recovery of CT1.

The normal seasonal recharge cycle at WF2 using potable water began on June 19, 2017, at ASR wells S10 through S19. A volume of 102.7 MG of potable water was recharged prior to beginning PTSW Cycle Test 2 (CT2). The PTSW CT2 recharge began at S-4 and S-20 on July 6, 2017, and the PTSW CT2 recharge at S-4 and S-20 and recharge of potable water with ASR wells S-10 through S-19 continued until Nov. 1, 2017; however, PTSW injection was interrupted sporadically due to mechanical issues with the PTSW supply pump, which was not in operation between the dates of July 14 through July 17, July 18 through July 24, and July 28 through Aug. 2, 2017. Additionally, recharge was temporarily suspended at S-4 and S-20 from Sept. 7 through 17, 2017.

During this time, the S-10 through S-19 recharge was also temporarily suspended for a shorter period between Sept. 10 and Sept. 12, 2017. On September 28, the use of mesh filter bags for filtration was discontinued, and the stainless steel baskets with one-eighth-in. holes were utilized as the only filtration for the remainder of the recharge period. A total of 783 MG of potable water and 178.3 MG of PTSW were recharged during the PTSW CT2 recharge phase. The PTSW CT2 recharge phase was completed at S-4 and S-20 on Nov. 1, 2017. Immediately thereafter, a storage phase was initiated until Dec. 5, 2017, when recovery from S-4 and S-20 was initiated. Between Dec 5, 2017, and Jan. 2, 2018, water was recovered from the test wells uninterrupted and totaled 55.9 MG. Table 2 provides a summary of the operational recharge, storage, and recovery of CT2.

Over the PTSW recharge periods, the range of specific injectivity (SI) values observed at S-4 and S-20 were within the range recorded at these wells over the period of record, as shown in Figures 2 and 3. During PTSW recharge, the SI at S-4 ranged from 3 gal per minute (gpm)/ft to 11 gpm/ft and S-20 ranged from10 gpm/ft to 30 gpm/ft, both within the range of SI observed over the historic period of record. The PTSW cycle test recharge data suggest that a small but gradual decline in well performance is observed; however, this is expected to be manageable through purging the wells periodically and/or installation of improved filtration.

Though SI data after the mesh filter bags were removed did not conclusively indicate plugging at a greater rate than when the mesh filter bags were installed, the data could have been skewed by other variables in the calculation of SI (e.g., changing head conditions from varying wellfield flow rates). Based on the visual evidence of the particulate matter collected in the bags, it could be expected that the filtration was providing some degree of benefit, possibly slowing the rate of plugging in the wells. It's recommended that filtration should be included in longer-term implementation of PTSW, or that a more rigorous, long-term testing of PTSW without filters be conducted to assess the long-term impacts of recharge without filtration.

Table 2. Cycle Test 2 Operational Summary

CT2 Operational Status	Date Range	Avg. S-4 Rate (mgd)	Avg. S-20 Rate (mgd)	Avg. WF2 Rate (mgd)*	Avg. WF2 Rate (mgd)
WF2 Recharge	6/19/17 – 7/05/17	-	-	6.04	6.04
CT2 & WF2 Recharge	7/06/17 – 9/06/17	0.37+	1.04+	7.65	9.06
WF2 Recharge	9/07/17 – 9/09/17	-	-	4.76	4.76
Recharge Interrupted	9/10/17 – 9/12/17	-	-	-	-
WF2 Recharge Only	9/13/17 – 9/17/17	-	-	1.89	1.89
CT2 & WF2 Recharge	9/18/17 – 10/31/17	0.67	1.58	6.50	8.52
CT2 Recharge	11/01/17	0.13	0.49	-	0.62
CT2 Storage	11/02/17 – 12/04/17	-	-	-	-
CT2 Recovery	12/05/17 – 1/02/18	-0.66	-1.31	-	-1.97

* = Excludes S-4 and S-20
\+ = S-4 and S-20 Recharge interrupted multiple times due to PTSW supply pump malfunction. Averages include days with zero flow.
\- = 0.00

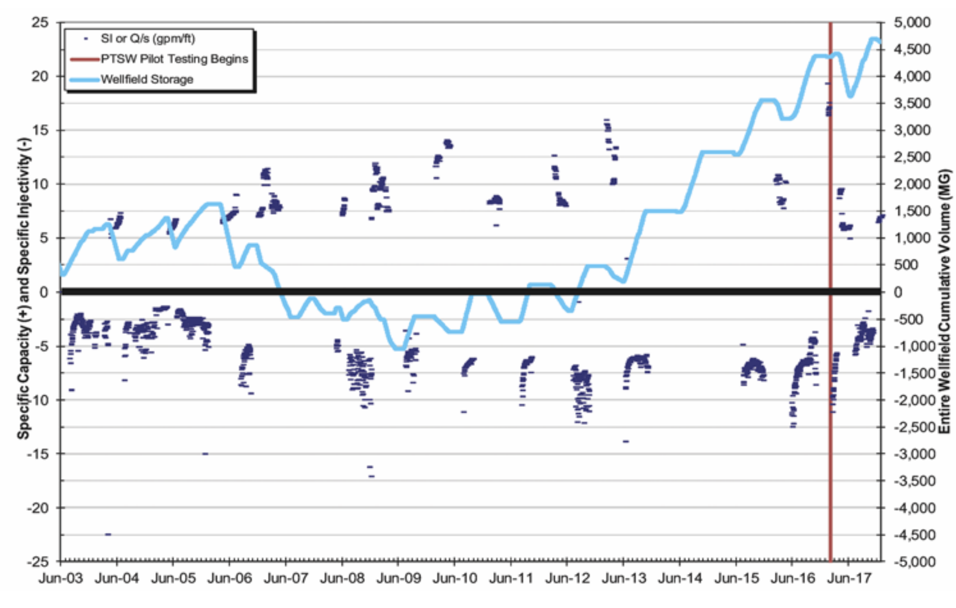

Figure 2. S-4 Specific Injectivity/Specific Capacity

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Continued from page 38

Cycle Testing Water Quality Summary

The PTSW is of good quality, meeting most primary and secondary drinking water standards; however, there are some differences when compared to native groundwater or potable water. For example, total coliform is present in the PTSW, where typically it's not in native groundwater or potable water sources.

The regulatory groundwater discharge standard for total coliform is 4 CFU/100 mL. Since total coliform levels are significantly higher in PTSW, it was important to determine how long coliform can persist in the aquifer after recharge of PTSW and identify the rate of total coliform inactivation. The PTSW cycle testing data showed that total coliform arrived at the monitor wells at relatively high concentrations during recharge. This large concentration was possibly due to the floating intake tee becoming a perch location for birds, and due to the intake of top water rather than deeper waters.

Total coliform is recorded in terms of the most probable number (MPN) of CFUs, with the laboratory maximum level established at >2420 CFU/100 mL, or too numerous to count (TNTC). In samples with results of >2420 CFU/100 mL, the actual number of total coliform bacteria present can be significantly higher, and therefore a value of >2420 CFU/100 mL at the monitor wells does not necessarily mean that the level of total coliform is the same level as the source water, which is the reservoir (i.e., the reservoir bacteria count could be significantly higher). Figure 4 is a graph of total coliform concentration at each of the sampled wells. The graph includes the PTSW total coliform, PTSW storage volume, and WF2 potable water storage volume so that the mode of ASR operation can be viewed in line with the total coliform data set.

During CT1 recharge, total coliform was observed at M-14 and ASR well S-19. At the nearest downgradient monitor well (M-14) PTSW water arrived within hours of initiation of recharge, suggesting fractured flow between the monitor well and S-20 and/or S-4. After recharge was stopped, total coliform decreased by two orders of magnitude at M-14 over a storage period of approximately two weeks.

During longer recharge periods (CT2), total coliform was observed at multiple monitor wells, and predominantly in the southwestern direction, as M-14, M-12, and M-15 showed the highest concentrations of total coliform reaching TNTC. Total coliform was also detected in high concentrations at M-11. Cycle testing data suggested that total coliform was persistent in the Floridan aquifer in the immediate vicinity of these monitor wells for as long as recharge of PTSW continued; however, as observed during CT1, total coliform decreased rapidly once recharge ceased.

Besides total coliform, other differences between the PTSW characteristics and native groundwater and potable water were useful in determining the presence of the PTSW at the monitor wells. Being able to differentiate the PTSW water from potable water was necessary, since the other wells in WF2 were recharged with potable water during PTSW cycle testing. Several parameters from the reservoir analysis had concentrations that were distinguishable from native groundwater or potable water.

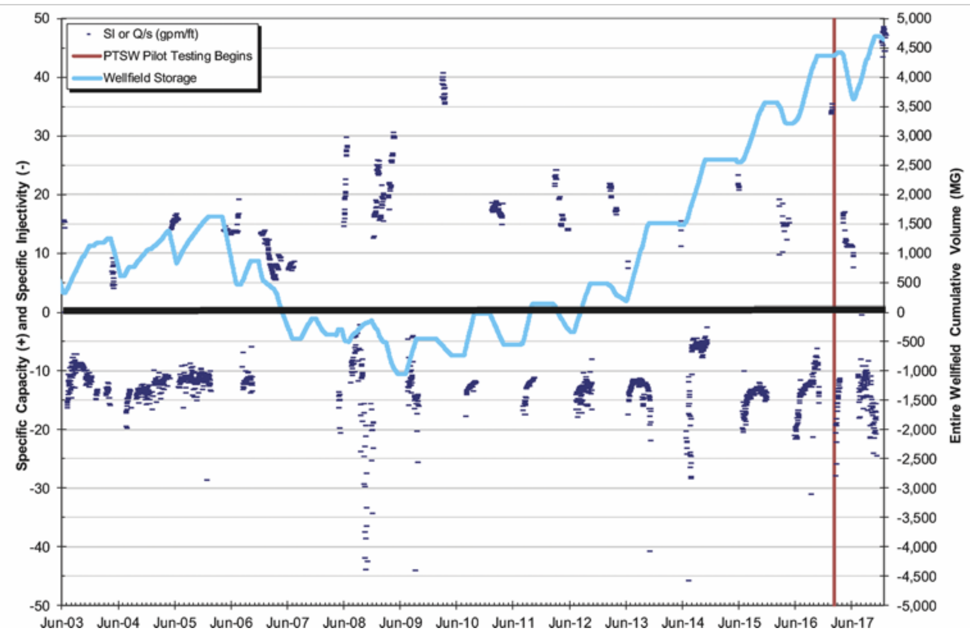

Figure 3. S-20 Specific Injectivity/Specific Capacity

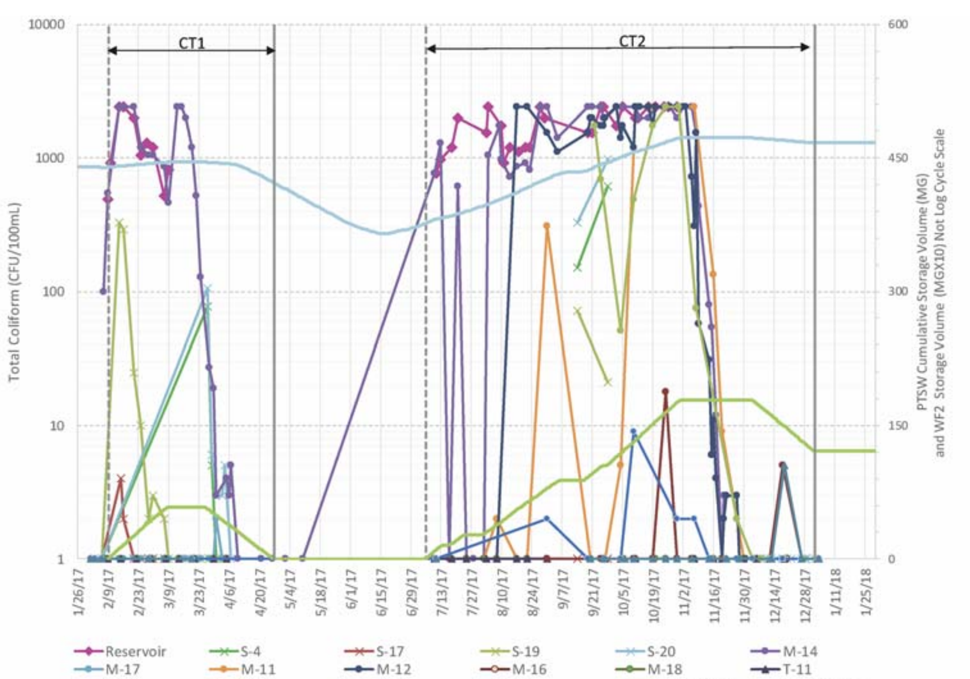

Figure 4. Partially Treated Surface Water Cycle Testing – Total Coliform

Continued on page 42

Continued from page 40

The following is a list of some of the parameters that were considered as potential indicators for PTSW:

- *Total Dissolved Solids (TDS) and Chloride* – The TDS and chloride are higher in the native groundwater compared to potable water and PTSW; however, potable water and PTSW are similar. Therefore, changes during CT2 when both PTSW and potable water were recharged could not be differentiated by TDS and chloride concentrations.
- *Sulfate* – Native groundwater sulfate concentrations are higher than potable water and PTSW; however, the sulfate concentration in potable water (typically 100 to 150 mg/L during recharge months) is higher than PTSW (between 50 and 90 mg/L). Sulfate was a good indicator of PTSW arrival as decreases in concentrations were observed at wells where other PTSW indicator parameters (e.g., total coliform) were also observed. Since both potable and PTSW sulfate concentrations are lower than native groundwater, the observed decreases in sulfate during CT2 may be partially attributed to the influence from potable recharge, since potable ASR operations at WF2 coincided with PTSW recharge at S-4 and S-20.
- *Total Suspended Solids and Turbidity* – The TSS and turbidity of native groundwater are very low, with turbidity generally below 1 nephelometric turbidity unit (NTU) and suspended solids less than 1 mg/L. Turbidity of the reservoir water is slightly higher, ranging from 5-20 NTUs, and TSS ranged from 5-25 mg/L. Since turbidity and suspended solids are also low in potable water, this difference appeared to make turbidity and TSS good tracers for the PTSW; however, there were some disparities observed. Turbidity and TSS increased in wells where other indicator parameters increased; however, turbidity and TSS were significantly higher than the reservoir water in some of the wells (e.g., M-12 and M-11).

  This increase in suspended solids at M-11 and M-12 would suggest early arrival of the PTSW (the first sample after recharge began), whereas other indicators (including total coliform) did not show the same at these wells. Since TSS can be generated in wells from pumping the well (e.g., purging for sampling), it was not a conclusive indicator, yet TSS and turbidity quickly returned to the background in M-12 and M-11 once PTSW recharge ceased, suggesting that the increased TSS and turbidity at these wells had some link to the PTSW recharge activity, though not completely understood.
- *Total Organic Carbon (TOC)* – The TOC was found to be the most useful indicator parameter for PTSW as it's detected at relatively high concentrations compared to potable water and native groundwater, where TOC concentrations are low or nondetectable. Concentrations of TOC in the reservoir ranged between 10 mg/L and 20 mg/L during recharge events. The TOC was used to establish approximate percentages of PTSW observed at the monitor wells.

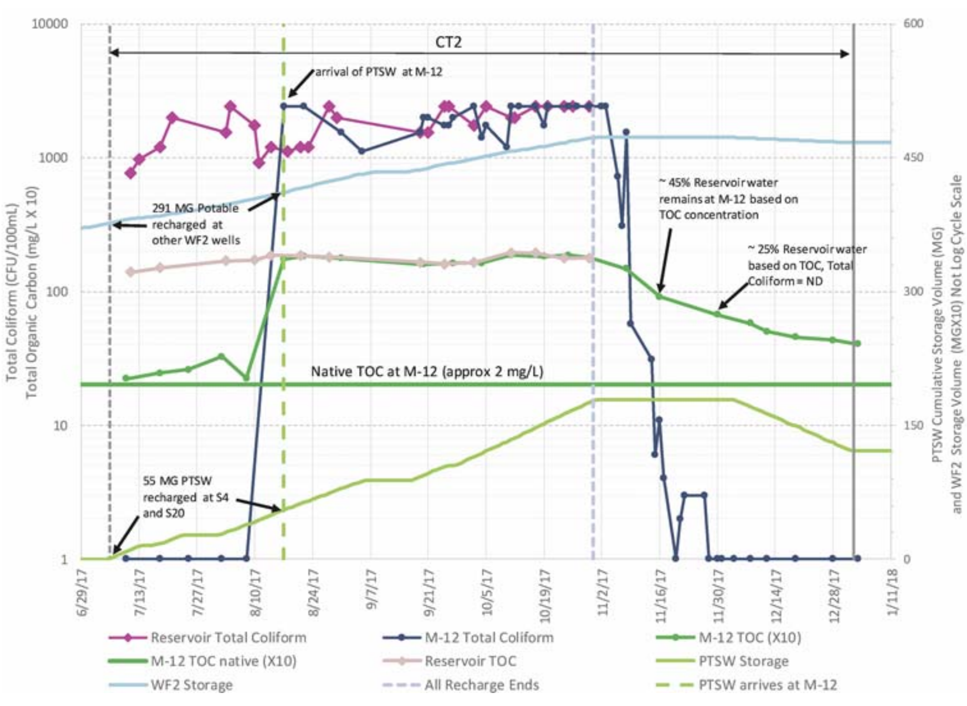

Figure 5. Partially Treated Surface Water Cycle Testing – M-12 Total Coliform and Total Organic Carbon

Being able to establish whether the decrease in total coliform observed in the monitor wells after recharge ceased was due to inactivation or movement of PTSW out of the monitoring well area of influence was an important aspect of the water quality evaluation. Since the presence of TOC was a decisive indicator of arrival of PTSW at the monitor wells, and since it's recorded in actual concentration to allow for an estimation of the ratio of PTSW present, it was selected as the most useful tracer to evaluate the fate of total coliform.

Figure 5 is a graph showing the concentration of total coliform and TOC of monitor well M-12 (located about 450 ft southwest of test well S-20) and PTSW during recharge to illustrate the fate of total coliform in the aquifer.

The graph shows the PTSW CT2 from the start of recharge through storage and recovery. The arrival of PTSW at M-12 was indicated by the sharp increase in TOC and total coliform, shown on the figure as a vertical green dashed line. After approximately 55 MG of recharge of PTSW (approximately six weeks), concentrations of TOC and total coliform at M-12 reached the same levels observed at PTSW, suggesting that nearly 100 percent of the water pulled from the monitor well was PTSW. This trend was consistent through the remainder of the recharge period.

Recharge stopped (at both PTSW and WF2 potable recharge) on Oct. 31, 2017, indicated by the vertical grey dashed line in the figure. A sharp decreasing trend in total coliform is observed after recharge ceased, reaching nondetect in approximately three weeks and remaining below 4 CFU/100 mL through the remainder of storage and recovery.

The TOC also showed a decreasing trend after recharge ceased, presumably by either dilution from PTSW moving out of the monitoring interval or uptake of the carbon source by natural sources. In either case, when comparing TOC and total coliform concentrations, TOC declined at a significantly slower rate. For example, on Nov. 16, 2017, the TOC concentration suggested that approximately 45 percent of the sampled water from M-12 was PTSW, yet total coliform had decreased to 11 CFU/100 mL. By Nov. 30, 2017, TOC concentrations suggested that approximately 25 percent of PTSW remained; however, total coliform had been less than 4 CFU/100 mL for approximately 10 days. These data provide evidence that the decreased concentrations of total coliform were a result of die-off in the aquifer rather than dilution or movement of water past the monitoring interval. Similar TOC-to-total-coliform ratios can be calculated at the other monitor wells where PTSW arrival was observed, supporting this conclusion.

Water quality analysis during cycle testing also included *Escherichia coli (E. coli),* which is a common coliform bacterium in the environment that is found in the intestines of humans and other animals. The *E. coli* concentrations from the PTSW were low, with only eight of the 28 samples measured above the detection limit (1 CFU/100 mL) and the highest concentration recorded at 6 CFU/100 mL. The *E. coli* concentrations at the monitor wells where PTSW was detected were also low and frequently below detection limits. The highest level recorded was 12 CFU/100 mL in M-12; however, most monitor well samples where *E. coli* was detected were 4 CFU/100 mL or less. As observed with total coliform, once PTSW recharge ceased, *E. coli* showed rapid die-off in the aquifer, as indicated by the data.

Analysis of the water quality data provided some insight to the directional flow paths at WF2. Arrival of PTSW during CT1 was observed at M-14 within hours of initiating recharge, suggesting a direct conduit system to this well from S-20 and/or S-4. Some PTSW arrival was noted at S-19 and S-17; however, only a small percentage of PTSW was observed based on the TOC and total coliform concentrations. During CT1, only PTSW was recharged using S-4 and S-20; a total of 58 MG was recharged and the other WF2 wells were not in operation.

During CT2, a larger volume of PTSW was recharged compared to CT1, totaling 178 MG. During this cycle, arrival of PTSW was first seen at M-14, followed by M-12, M-15, and M-11, with each exhibiting TOC and total coliform concentrations that suggest nearly 100 percent PTSW at the monitor well. The exact time of arrival at M-15 was uncertain since sampling for PTSW parameters at this well did not begin until it was observed that PTSW had arrived at M-12, the next closest monitor well in the direction of M-15.

The relatively fast arrival of PTSW at M-12 and M-15, and the fact that other wells at equidistance (e.g., M-13) from S-20 and S-4 did not show indications of PTSW, suggests a preferential flow path from S-4 and S-20 in the direction of M-14, M-12, and M-15. This directional flow may have been influenced by potable recharge activities that occurred simultaneously at the other WF2 ASR wells during PTSW recharge, which may have prevented movement of PTSW to the east or southeast directions. Mixing of potable water with PTSW would have been expected at M-12 and M-15, yet despite the 4:1 volume of potable to PTSW recharged during CT2, the monitor wells exhibited water quality suggesting nearly 100 percent PTSW. This may have been a result of the higher flow rate at S-20 compared to the other wells. The average flow rate at S-20 was 1.4 mgd compared with 0.5 mgd to 0.75 mgd at the other WF2 wells. This disparity in the flow rate may have contributed to the flow of PTSW along a conduit system (i.e., fractures or solution channels within the aquifer) that potentially exist in the direction of M-14, M-12, and M-15.

The mobilization of arsenic (which is naturally present in the formation matrix) through geochemical interactions resulting from ASR activities has been well-documented at the PRF ASR system and other ASR systems throughout the region. During PTSW cycle testing, arsenic was monitored to observe if any changes in this geochemical interaction occurred as a result of the differing water quality characteristics of PTSW. Figure 6 is a graph of the arsenic data from the

Continued on page 44

Continued from page 43

PTSW cycle testing, showing arsenic concentrations from each of the monitor wells sampled. Arsenic detections were observed in most M-series wells, but were recorded in highest concentrations at M-11, M-12, M-14, M-15, and M-16. Not all of these increases are necessarily attributed to PTSW cycle testing; the WF2 potable water storage volumes had been increasing each year since 2013.

Arsenic detections began to increase at M-15, M-18, and M-19 once storage volumes increased, but before PTSW testing, though M-18 and M-19 have remained below 10 µg/L. Elevated concentrations of arsenic observed at M-11, M-12, and M-16 began in 2017, suggesting a possible relationship to PTSW testing; however, PTSW CT2 coincided with the potable water storage, reaching the highest volumes at WF2 since operations began, which may be the cause of the higher arsenic concentrations observed at the monitor wells.

Arrival of PTSW was observed at M-11 and M-12, but not at M-16. Arsenic responses during CT2 storage and subsequent recovery are similar to M-11 and M-12, suggesting that the increases may be related to the increase in WF2 storage volume. Overall, arsenic concentration remained low at the monitor wells, with only M-12, M-14, and M-15 exceeding 10 µg/L. Arsenic concentrations at M-15 are relatively low, with the highest concentration recorded at 16 µg/L. Increased monitoring frequency at this well has been initiated to track arsenic concentration changes.

Summary and Recommendations

Pilot testing of PTSW included two cycle tests conducted between February and December 2017, using two wells in WF2, S-4, and S-20. During CT1, a total of 58 MG of PTSW was recharged. Following a two-week storage period, all of the PTSW was recovered. The CT2 consisted of 178 MG of recharge (a one-month storage period) and recovery of 57 MG from S-4 and S-20. Recharge capacity of the wells was not significantly impacted by injection of PTSW, and recovery efforts helped restore lost capacity. The intake screen was valuable for keeping large aquatic organisms out of the pump, helping to protect the temporary PTSW system.

The filtration system proved to be effective at removing algae that was suspended in the reservoir. Changing of the filter bags on a routine basis was necessary as they became blinded within approximately two to three days. Near the end of the CT2 recharge, the mesh filter bags were left out, leaving only filtration through a stainless steel basket with one-eighth-in. openings. This coarser filtration appeared to have some short-term impact on S-4, but the well capacity was restored through intermittent short-term well development, as well as a sufficient recovery period.

Arrival of PTSW was observed at select monitor wells primarily in the southwest direction, indicating a preferential flow path. At monitor wells M-14, M-11, M-12, and M-15, water quality analysis suggested PTSW arrival approaching 100 percent at these wells. Total coliform was present at high concentrations; however, once recharge of PTSW ceased total coliform inactivation was observed, with total coliform counts reaching less than 4 CFU/100 mL after approximately three to four weeks. Arsenic concentration increased at some of the monitor wells, near the end of CT2 recharge. It was uncertain, however, if these increases were a result of PTSW or the increase in WF2 overall storage volumes.

For full-scale PTSW implementation, a zone of discharge or other regulatory relief mechanism will be needed to allow exceedances of some drinking water standards to naturally attenuate before leaving the property under the control of the PRF.

Implementation of PTSW appears to be feasible after the PTSW pilot study; however, there are long-term unknowns for utilization of this source water that may not become immediately apparent. Should the authority choose to implement PTSW as a source water, the following are some mitigation strategies for consideration if water quality standards are not met at compliance wells:

- Stop recharge at ASR wells that are closer to the monitoring wells with exceedances.
- Limit wellfield storage volumes to keep PTSW within the property boundary.
- Add additional monitor wells within the PTSW flow path on authority-controlled land (e.g., to the west-southwest of WF2).
- Expand the ASR wellfield to the west further onto authority-controlled property and discontinue use of ASR wells closer to property boundaries.
- Acquire or otherwise expand control of property near the ASR production wells.
- Add in-line disinfection to the PTSW conveyance system to preemptively treat coliform and algae as needed.

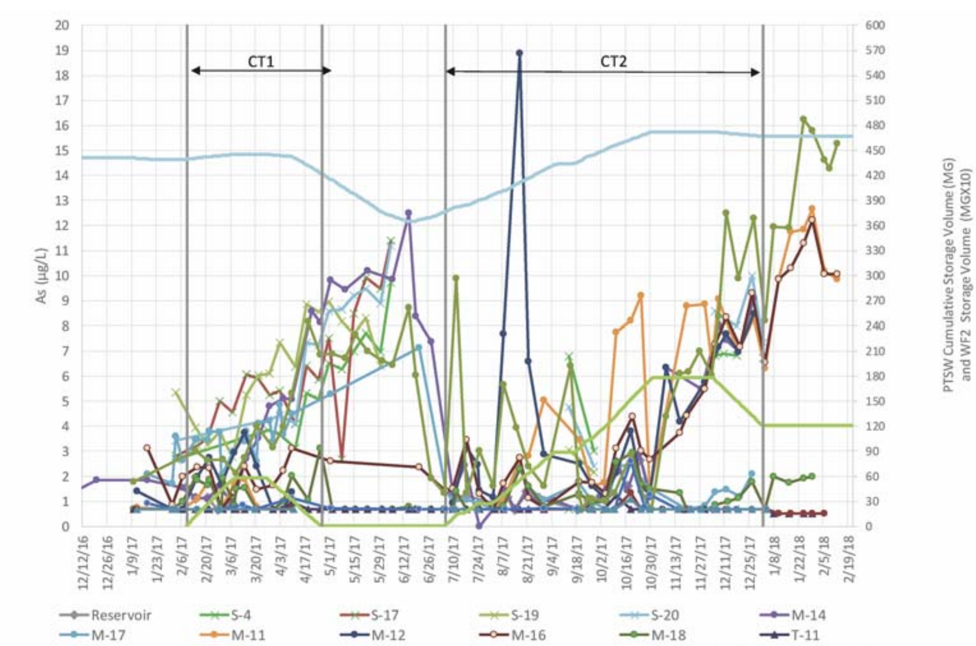

Figure 5. Partially Treated Surface Water Cycle Testing – Arsenic

References

1. CH2M and ASRus, August 2016. "Florida Department of Environmental Protection Class V, Group 7, Operation Permit Aquifer Storage Recovery – Request for Major Modification to Permit Peace River Manasota Regional Water Supply Authority Peace River Facility." Prepared for the Florida Department of Environmental Protection on behalf of the Peace River Manasota Regional Water Supply Authority.
2. CH2M and ASRus, March 2016. "Partially Treated Surface Water Desktop Study." Prepared for the Peace River/Manasota Regional Water Supply Authority, Bradenton, Fla.