Sampling to Assess Stratification of Groundwater Arsenic and Uranium Concentrations to Achieve Compliance in Selected Public Water Systems in the Texas Gulf Coast Aquifer

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Executive Summary

Field tests were performed on two wells in two PWS systems, including one well operated by the Riviera Water Supply (PWS 1370007) in Kleberg County and one well operated by the Benevides-Duval County Conservation District (PWS 0660001) located in Duval County. Analytical results and recommendations for both systems are presented in this report.

Stratification tests were conducted on one of the two wells operated by the Riviera Water Supply, which has 230 metered connections. Both wells are significantly in excess of the US EPA MCL concentration for combined uranium (30 µg/L). Water produced by the tested well has a median combined uranium concentration of 66 µg/L (range 62 to 91 µg/L) based on 12 samples between 2003 and 2008. The other system well has a median combined uranium concentration of 75 µg/L (range 69 to 95 µg/L) based on 5 samples between 2004 and 2008.

Test results at Riviera indicate that there is no uranium-compliant water in the tested well. Two depth intervals were characterized. The shallowest interval (599 to 640 ft depth) produced 45% of the flow and the deepest interval (662 to 710 ft depth) produced 55% of the flow. At the time of testing, the well head sample had a combined uranium concentration of 68 µg/L. The stratification test results indicate that in the shallowest zone the concentration was 67±9 µg/L and in the deepest zone the concentration was 68±1 µg/L.

Tests were also conducted on Benevides-Duval County CD Well 1. This system has 875 metered connections and operates two primary wells. Both wells produce water with arsenic concentrations significantly in excess of the US EPA MCL concentration (10 µg/L). Water produced by the tested well has a median arsenic concentration of 39 µg/L (range 28 to 45 µg/L) based on 15 samples between 2000 and 2009. The other system well has a median arsenic concentration of 28 µg/L (range 23 to 39 µg/L) based on 15 samples between 2003 and 2009.

Test results at Benevides indicate there is stratification of both water quantity and water quality in the tested well, and a probable arsenic-compliant interval was identified. Two intervals were tested in the well, 250 to 390 ft and 390 to 460 ft depths. The remaining third interval below the pump (460 to 482 ft depth) was not directly tested and both flow and quality for this interval were calculated by difference between the down-hole test results and the well head flow rate and sample concentrations. Ranging from shallowest to deepest, water production from the three depth intervals was 53%, 20%, and 27% of total production. At the time of testing, the well head sample had an arsenic concentration of 27 µg/L and concentrations in the three depth intervals (shallowest to deepest) were 37±1 µg/L, 0±8 µg/L, and 25±8 µg/L, respectively. While uncertainty related to the arsenic concentration in the second depth interval (390 to 460 ft depth) indicates probable compliant arsenic concentration, the interval provides only 20% of total well production and does seem to offer a sufficient source of compliant water.

Introduction

Many small public water supply systems that obtain all or part of their water supply from the Gulf Coast aquifer system are currently producing water that is not in compliance with US EPA and State of Texas water quality regulations. The most wide-spread contaminant in produced Gulf Coast groundwater is arsenic, which commonly exceeds the maximum contaminant level (MCL) concentration of 10 µg/L. Less commonly, the MCL for combined uranium (30 µg/L) is exceeded and generally occurs in the uranium mining regions in southwestern areas of the aquifer. The Gulf Coast aquifer system is comprised of three major aquifers; the Jasper, Evangeline, and Chicot aquifers, that range in age from Pliocene to Quaternary. The aquifers are typical of coastal plain aquifers and consist of inter-bedded sands, silts, and clays deposited in a fluvial-deltaic environment. The aquifer strata have relatively narrow outcrop area recharge zones that dip downward towards the coast line, transitioning from unconfined to confined hydraulic conditions.

This study was designed to characterize water quality stratification between or within different production strata in groundwater wells using a stratified aquifer sampling system. Results provide valuable guidance that may potentially reduce or eliminate production of non-compliant water through well modification or replacement.

Materials and Methods

The stratified aquifer sampler is a mobile test system designed to characterize water quality stratification in actively pumping groundwater wells. The system consists of two major subsystems:

1. A dye-tracer injection and monitoring system.
2. A discrete depth sampling system.

The system is designed to characterize the quantity and quality of groundwater produced from specific depth intervals and is based on a design originally developed by the U.S. Geological Survey (Izbicki et al., 1999, Izbicki, 2004), with several enhancements and modifications.

The dye-tracer injection and monitoring system measures the average flow velocity between tested depths, from which estimates of the cumulative well discharge and interval average aquifer discharge are calculated. A small volume (~ 10mL) of Rhodamine WT dye solution (~200 – 400 ppm) is injected into the pumping well and the dye concentration is monitored at the well head in the produced water. Dye concentrations are recorded at 1-second intervals using a data logger and are typically < 100 ppb.

The discrete depth sampling system obtains water samples withdrawn from the flowing well stream at specific depths within the well. Data processing of stratification test data integrates the well velocity/discharge results with the constituent concentration analysis results from discrete-depth water samples.

The total mass of dye, D^T, recovered during a tracer test is determined by integrating the total well discharge, Q^T, and tracer concentration, C^T, over time, t. Assuming that both Q^T and the concentration measurement time interval, Δt, are constant during the test period:

$$D^T = \int Q^T C^T dt = Q^T \int C^T dt = Q^T \Delta t \sum C^T \quad \text{(Eq. 1)}$$

The value of D^T is useful in examining consistency between tracer test injection volumes, and assumes that the injected mass of dye is conserved.

The dye-tracer center-of-mass arrival time is used to determine the average flow velocity between tested depths. The first-arrival time of dye is identified as the first data record at which a consistent increase above background concentration occurs. The cumulative sum of concentration measurements is calculated beginning at the first-arrival record and across all subsequent records until values return to background concentrations. Under the same assumptions of constant Q^T and Δt, the center-of-mass arrival time, t^m, is the elapsed test time at which the cumulative sum represents 50% of the total cumulative sum:

$$t^m = \frac{\sum C^T}{\sum C^T_{total}} = 0.50 \quad \text{(Eq. 2)}$$

The average flow velocity, ν^a, over a given depth interval, i, is the absolute difference between the bounding test interval depths z_1 (closest to the pump) and z_2 (farthest from the pump) divided by the difference between the respective center-of-mass arrival times:

$$\upsilon_i^a = \frac{|z_2 - z_1|}{t_2^m - t_1^m} \quad \text{(Eq. 3)}$$

Cumulative well discharge, Q^c, is estimated as an average over interval *i,* from the interval average flow velocity and the well cross-sectional area:

$$Q_i^c = \nu_i^a \pi r_i^2 \quad \text{(Eq. 4)}$$

Note that Equation 4 provides an actual discharge value for tested well depth intervals that are not open to and aquifer rather that an average discharge as for screened depth intervals. Finally, the cross-sectional area, πr_i^2, within the well casing radius, r_c, must be adjusted for displacement resulting from the sum of obstructions, r_o, due to riser pipes, electrical cables, etc., that may be present between the injection depths:

$$r_i^2 = r_c^2 - \sum r_o^2 \quad \text{(Eq. 5)}$$

The interval average aquifer discharge, Q^a, is estimated as the difference between the cumulative well discharges for the interval i and the interval i-1 next farthest from the pump:

$$Q_i^a = Q_i^c - Q_{i-1}^c \quad \text{(Eq. 6)}$$

Discrete depth samples provide a constituent flux concentration, C^f, in the flow stream at a given depth, z. The constituent average aquifer concentration, C^a, flowing into the well over the depth interval i between depths z_1 (closest to the pump) and z_2 (farthest from the pump) is estimated as:

$$C_i^a = \frac{Q_i^c C_{z_1}^f - Q_{i-1}^c C_{z_2}^f}{Q_i^a} \quad \text{(Eq. 7)}$$

The units of discharge cancel out in eq. 7. Thus, aquifer concentration calculations may be performed by substituting average discharge with either average velocity or percentage of total average velocity measurements, provided that the cross-sectional flow area remains constant between the tested depth intervals.

Uncertainty

Uncertainty in analytical results arises due to measurement errors, which propagate through the calculations. Errors are associated with both measurement systems; the velocity profile tests and the sample chemical constituent analyses. Sources of error in the velocity profile tests are related to accuracy of positioning of the equipment in the well at specified depths and to the accuracy of the dye injection and monitoring system. Depth positioning errors are estimated to be no greater than about 0.17 ft (2 in), as fixed depth reference points are used in the process. The accuracy of the dye injection and monitoring system is quantified by repeated testing at a given depth, which indicates that dye arrival times are generally repeatable to within about 1-2 seconds. Sources of error in the sample chemical analyses are minimized by employing stringent quality control standards on the sampling and analytical process. Analysis of major constituent anion and cation concentrations generally result in sample charge balance values well within 5% of neutral, and usually within ~2%. Spiked matrix samples generally result in 95 to 105% recovery, and usually range from 98 to 102% recovery for common anion and cation constituents.

Errors were propagated for both the discharge and the stratified chemistry values and incorporated both assumed and measured variance values as described above, including depth positioning error, measured dye center-of-mass arrival time variance, sample ionic charge balance, and spiked sample recoveries. Further confidence in discharge calculations is obtained by comparison of calculated discharge rates with well flow meter measurements (assuming the well flow meter is reasonably accurate). Also, results from velocity profile tests conducted over different depth intervals are compared for consistency within non-screened well sections.

Results and Discussion

Riviera Water Supply (PWS 1370007)

The Town of Riviera is located in Kleberg County, Texas and is serviced by a public water supply system with approximately 230 metered connections that relies solely on local groundwater resources. All groundwater is produced from the Evangeline aquifer.

The PWS currently has two operational wells that range in depth from 713 to 737 ft (Table 1). Both wells currently produce water with combined uranium (all isotopes) concentrations that exceed the USEPA MCL (30 µg/L) by approximately two to three times. Total dissolved solids (TDS) concentrations generally range between 850 and 950 mg/L and exceed the secondary MCL (500 mg/L). None of the produced drinking water is currently being treated other than by chlorination.

Table 1. Riveria Water Supply well identification, depths, status, and combined uranium and TDS concentrations. Ranges for combined uranium and TDS concentrations are shown and median concentrations are given in parenthesis. Wells 1 and 2 are both currently operational.

TCEQ Water Source ID	*TWDB Well ID*	*PWS Well ID*	*Drilled*	*Depth (ft)*	*Combined Uranium[1] (µg/L)*	*TDS[2] (mg/L)*
G1370007A	8342502	1	1960	737	69–95 (75)	840 – 886 (874)
G1370007B	-	2	2001	713	62–91 (66)	860 – 921 (891)

[1] source: TCEQ; 5 samples well 1, 2004-2008, 12 samples, well 2, 2003-2008
[2] source: TCEQ; 3 samples well 1, 2000-2009, 2 samples, well 2, 2006-2009

Construction logs indicate that both of the Riviera system wells are completed similarly and that both have a total of approximately 80 ft of screen over three depth intervals at approximately the same depths. Both wells are likely completed in the same geologic formations as they are separated by only about 1,400 ft distance. Well 2 was selected for testing because it has a larger casing ID (14 in) relative to Well 1 (8 in) (Table 2). The larger casing size provided sufficient room for the installation of an access tube that was required to obtain unobstructed access of the test equipment into the screened depths. Well 2 is also much newer (drilled in 2001) than Well 1 (drilled in 1960) and is therefore likely in better overall condition.

Table 2. Surface casing and screen depth intervals relative to ground level for Riviera Water Supply wells.

Well	*Description*	*Top Depth (ft)*	*Bottom Depth (ft)*	*Length (ft)*	*Diameter (in)*
1	Surface Casing	0	-615	615	8
	Screen 1	-619	-629	10	4
	Screen 2	-649	-684	35	4
	Screen 3	-695	-730	5	4
2	Surface Casing	+2	-599	601	14
	Screen 1	-599	-622	21	8
	Screen 2	-630	-640	10	8
	Screen 3	-662	-710	48	8

Water Quantity Stratification Results

According to system records, the pump in Well 2 is set at 265 ft depth. An access tube was installed in well 2 to a depth of 280 ft on July 27, 2010 and stratification testing on

Well 2 was conducted July 28-29 on all three screened intervals. Total well discharge based on the inline system flow meter varied between 208 and 210 gpm during testing, which was in very good agreement with the total discharge value calculated using the dye-tracer velocity test results (218 gpm).

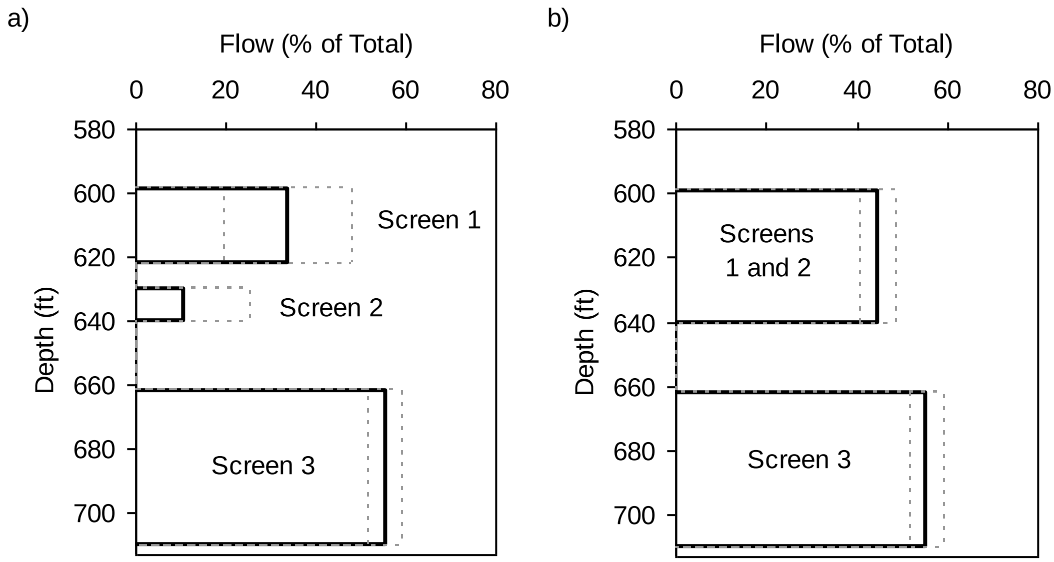

Figure 1. Riviera Water Supply Well 2 discharge profiles expressed as a percentage of total discharge for a) individual screens and b) combined screens 1 and 2. The pump is set at the 265 ft depth.

Table 3. Riviera Water Supply Well 2 velocity/discharge profile results. Velocity values not associated with a screen number represent results for blank sections of well liner above and between screen intervals and indicate actual flow rates. Velocity and discharge values for screens represent average values. Bold values indicate the values used to determine the water quality profiles (Figure 2, Tables 4 and 5).

Screen	*Top (ft)*	*Bottom (ft)*	*Length (ft)*	*Δt (sec)*	*v^a (ft/min)*	*Q^c (gpm)*	*Q^a (gpm)*	*Q^a (gpm/ft)*	*Q (%)*
-	505	599	94	67.5	83.6	218	-	-	
1	599	622	23	19.8	69.6		73.7	3.2	34 ± 14
-	622	630	8	8.7	55.4	145	**-**	-	
2	630	640	10	11.0	54.5		23.7	2.4	11 ± 15
1 and 2	599	640	41	39.5	62.3		97.4		**45 ± 4**
-	640	662	22	28.5	46.3	121	**-**	-	
3	662	710	48	-	-	-	121	2.5	**55 ± 4**

Top: test interval top depth, *Bottom*: test interval bottom depth, *Length*: test interval length, Δt: difference in arrival time between top and bottom depth dye-tracer injections (Eq. 2), v^a: average discharge velocity in tested interval (Eq. 3), Q^c: cumulative total well discharge (Eq. 4), Q^a: average or actual interval discharge and discharge normalized by tested interval length (Eq. 6), *Q*: percentage of total well discharge and calculated uncertainty.

Velocity test results for the individual screened depth intervals indicate that there are no “losing” sections of the well and that there is stratification in water quantity between the different screened intervals, with the largest percentage (55%) entering screen 3, followed by screen 1 (34%) and screen 2 (11%) (Figure 1a, Table 3). However, the short distance between screens 1 and 2 (8 ft) magnifed the timing errors in measured flow velocities over these intervals and resulted in a relatively large uncertainty (~15%). Therefore, flow from screens 1 and 2 were combined to reduce overall uncertainty and resulted in a total flow of 45±4% from both screens.

Water Quality Stratification Results

Water quality is not significantly stratified between the production horizons of Riviera Well 2 and no horizon was identified that is compliant with respect to the uranium MCL (Figure 2). The sample from the 650 ft depth (between screens 2 and 3) had a uranium concentration of 68±1 µg/L which reflects the water produced from screen 3 only. This value is essentially equal to the concentration of 67 µg/L in the well-head sample, which represents mixing of screen 3 water with the combined water produced from screens 1 and 2. Similar results were found for the remaining anions and cations analyzed (Tables 4 and 5), which generally indicate slight but non-significant differences in most constituent concentrations.

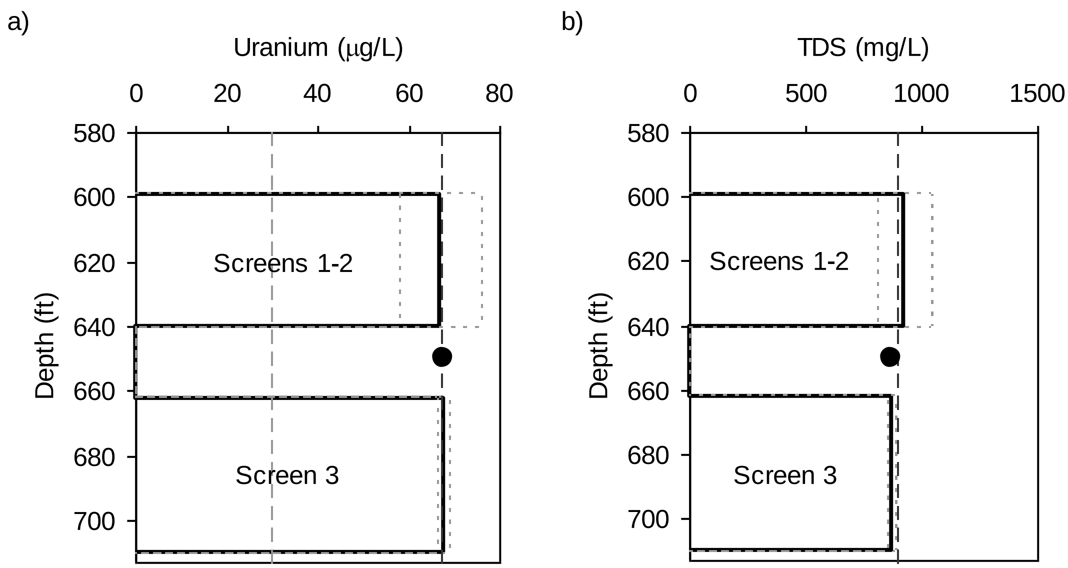

Figure 2. Riviera Water Supply Well 2 profiles for a) uranium and b) TDS concentrations. TDS was estimated as the sum total of major anion and cation concentrations (Tables 4 and 5). Charge balance for major constituents is within 2.4% for all samples (average 1.1%). Short-dash lines represent analytical uncertainty. Gray vertical dashed line in (a) represents the MCL for uranium (30 µg/L). Black vertical dashed lines represent concentrations for U (67 µg/L) and TDS (898 mg/L) in the well-head sample. Point represents concentration and depth location of down-hole samples.

Conclusion

Modification of Well 2 to improve water quality for the Riveria Water System is not indicated. Given that no significant stratification of water quality was identified in Well 2 and that Well 1 is located nearby and is likely producing water from the same horizons as Well 2, it is unlikely that testing of Well 1 using this method would reveal compliant horizons.

Table 4. Riviera Water Supply Well 2 water quality profile test results for uranium and major anion concentrations. Total represents well-head sample.

Screen	*Top (ft)*	*Bottom (ft)*	*U μg/L*	*Cl mg/L*	*HCO_3 mg/L*	*SO_4 mg/L*	*NO_3-N mg/L*	*F mg/L*
Total	-	-	63	200	351	181	0.71	0.98
1-2	599	640	67 ± 9	220 ± 27	327 ± 40	187 ± 24	0.94 ± 0.1	1.17 ± 0.14
3	662	710	68 ± 1	183 ± 4	371 ± 7	177 ± 4	0.52 ± 0.01	0.82 ± 0.02

Table 5. Riviera Water Supply Well 2 water quality profile test results for TDS and major cations. Total represents well-head sample.

Screen	*Top (ft)*	*Bottom (ft)*	*TDS mg/L*	*Na mg/L*	*K mg/L*	*Ca mg/L*	*Mg mg/L*
Total	-	-	898	295	8.4	24.5	7.6
1-2	599	640	924 ± 116	308 ± 39	8.6 ± 1.1	26.1 ± 3.3	8.1 ± 1.0
3	662	710	870 ± 17	285 ± 6	8.3 ± 0.2	23.2 ± 0.5	7.2 ± 0.1

Benevides-Duval County Conservation District (PWS 0660001)

The Benevides-Duval County CD serves the town of Benevides located in Duval County, Texas. The PWS system has approximately 875 metered connections and relies solely on local groundwater resources. All groundwater is produced from the Evangeline aquifer.

The PWS currently has two operational wells and one emergency use well (Table 6). All three system wells are completed over similar depth intervals and generally produce water from the same depth horizons (Table 7). Archival water quality sample data indicate that both operational wells consistently produce water with arsenic concentrations greater than the MCL (10 µg/L) and TDS concentrations exceed the secondary MCL (500 mg/L) by 2 to 4 times. The PWS system currently does not treat produced water for arsenic. No sample analysis data are available for the Barton (emergency use) well.

Table 6. Benevides-Duval County CD well identification, depths, and arsenic and TDS concentrations. Ranges for arsenic and TDS concentrations are shown and median concentrations are given in parenthesis. Wells 1 and 2 are both currently operational and the Barton well is for emergency use.

TCEQ Water Source ID	*TWDB Well ID*	*WCID Well ID*	*Drilled*	*Depth (ft)*	*Arsenic[1] (µg/L)*	*TDS[2] (mg/L)*
G0660001E	8429601	Barton	1977	590	-	-
G0660001F	8429311	1	2004	502	25-46 (39)	1010-1930 (1221)
G0660001G	-	2	2005	530	23-39 (28)	1060-1570 (1135)

[1] source: TCEQ; 15 samples each well 2003-2009
[2] source: TCEQ; 4 samples each well 2003-2009

Though the separate screen intervals would indicate that Well 2 is the preferred candidate for testing, sacrificial anodes have been installed in this well to combat persistent corrosion problems. The anodes presented an obstruction that could not be bypassed with an access tube. Therefore, an access tube was installed in Well 1 to a depth of 240 ft on July 27, 2010 and stratification testing was conducted on Well 1 August 3-4, 2009.

Table 7. Surface casing and screen depth intervals for Benevides-Duval County WCD wells.

Well	*Description*	*Top Depth (ft)*	*Bottom Depth (ft)*	*Length (ft)*	*Diameter (in)*
Barton	Casing	0	320	320	20
	Screen 1	320	460	140	12
	Screen 2	490	510	20	12
	Screen 3	540	580	40	12
1	Casing	0	248	248	16
	Screen 1	248	482	234	10
2	Casing	0	280	280	16
	Screen 1	280	430	50	10
	Screen 2	454	474	20	10
	Screen 3	506	530	24	10

Water Quantity Stratification Results

The original well service contractor report indicates that the pump for Well 1 was installed at a depth of 440 ft with a 6-inch ID riser pipe. During installation of the access tube, inspection of the riser pipe revealed that it is actually 4-inch ID. Additionally, the velocity testing revealed that the pump was actually set at 462 ft depth. Depths below the pump were inaccessible and therefore we were unable to independently verify the total flow rate from the well. This analysis therefore assumes that the inline system flow meter was accurate and the remaining proportion of flow that was not measured by the down-hole testing was calculated by difference and assigned to the screened interval below the deepest tested depth (460 to 482 ft depth).

Table 8. Benevides-Duval County CD Well 1 velocity profile test results.

Screen Section	*Top (ft)*	*Bottom (ft)*	*Length (ft)*	Δt *(sec)*	ν^a *(ft/min)*	Q^c *(gpm)*	Q^a *(gpm)*	Q^a *(gpm/ft)*	*Q (%)*
A	250	390	140	340.5	24.7	92	92	0.65	53 ± 1
B	390	460	70	108.7	38.7	126	34	0.49	20 ± 3
C	460	482	22	-	-	173	37	2.15	27 ± 3

Top: test interval top depth, *Bottom*: test interval bottom depth, *Length*: test interval length, Δt: difference in arrival time between top and bottom depth dye-tracer injections (Eq. 2), ν^a: average discharge velocity in tested interval (Eq. 3), Q^c: cumulative total well discharge (Eq. 4), Q^a: average or actual interval discharge and discharge normalized by tested interval screen length (Eq. 6), *Q*: percentage of total well discharge ± uncertainty.

Results of the velocity profile measurements indicate significant differences in discharge between the tested intervals (Table 8, Figure 3). Screen section A between 250 ft and 390 ft depth produced 53±1% of total well flow while section B between 390 ft and 460 ft produced 20±3%. Assuming that the system flow meter provided accurate measurements, the remaining 27±3% of flow originated from depths at or below the pump depth (460 ft to 482 ft).

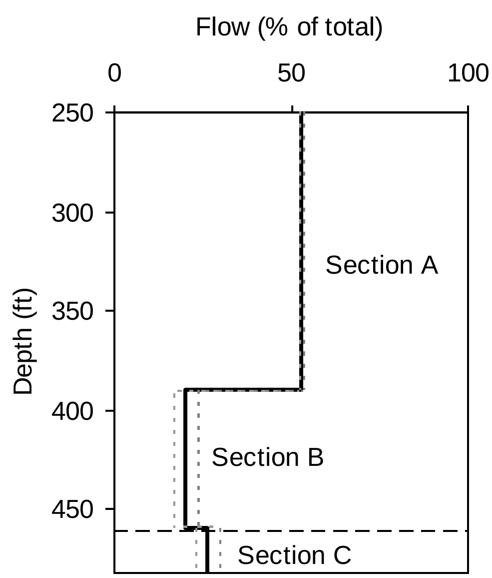

Figure 3. Benevides-Duval County CD Well 1 discharge profile showing the percentage of total well production originating from the tested screen sections (black line). Values for screen section C are based on the system flow meter. Short dashed lines represent flow percentage uncertainty. Horizontal long dashed line represents the pump setting depth (462 ft).

The geophysical log for this well indicates that there is a well-developed sand horizon between about 222 ft and 256 ft depth while the original well construction records indicate that the well is screened continuously between 248 and 482 ft depth. It is unclear as to why the well would have been completed with only a portion of the mentioned sand horizon screened. It seems logical to screen either all or none of the horizon. The stratification test plan for this well was developed and executed based on these records. The shallowest depth tested in this study was 250 ft, a depth that is 10 ft below the bottom of the access tube and ostensibly only 2 ft below the top of the screen. Additional tracer tests (not presented in this report) indicated that there was no significant change in flow between the 250 ft and 320 ft depth interval and that approximately 41% of total well flow originated from depths shallower than 250 ft. This indicates that either a very large proportion of flow originated from the shallowest 2 ft of the screen (248 to 250 ft depth) or, more likely, the construction records for this well are inaccurate and the well screen actually extends to a shallower depth that includes much or all of the noted sand horizon.

Water Quality Stratification Results

Water quality is also significantly stratified between the different horizons of Well 1 and one tested screen interval was identified that is likely compliant with respect to the arsenic MCL (Figure 4). Analytical results for the down-hole samples indicate large differences between the tested screen intervals for arsenic and for other constituent concentrations (Tables 9 and 10).

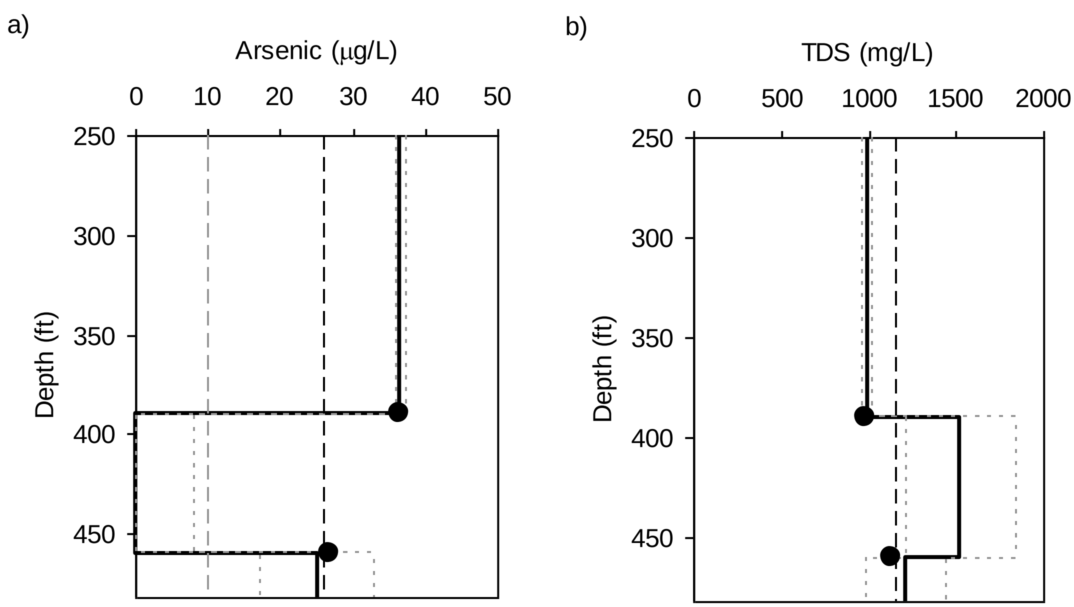

Figure 4. Benevides-Duval County CD Well 1 profiles for a) arsenic and b) TDS concentrations. TDS was estimated as the sum total of major anion and cation concentrations (Tables 9 and 10). Charge balance for major constituents is within ~0.5% for all samples. Short dashed lines represent analysis uncertainty. Gray vertical dashed line in (a) represents the MCL for arsenic (10 μg/L). Black vertical dashed lines represent concentrations for As (26 μg/L) and TDS (1155 mg/L) in well-head samples. Points represent concentrations and depth locations of down-hole samples.

The arsenic concentration was 37±1 μg/L in water produced from screen section A (above 390 ft depth) while the concentration in section B (between 390 ft and 460 ft depth) was 0±8 μg/L based on the reduced concentration found in the 460 ft-depth sample. Again assuming that the system flow meter is accurate, water produced from depths at and below the pump depth (below 460 ft) has an arsenic concentration of 25±8 µg/L based on the arsenic concentration in the well-head water (26 µg/L).

Table 9. Benevides-Duval County CD Well 1 water quality profile test results for arsenic and major anion concentrations. Total represents well-head sample.

Screen	*Top (ft)*	*Bottom (ft)*	*As µg/L*	*Cl mg/L*	*HCO_3 mg/L*	*SO_4 mg/L*	*NO_3-N mg/L*	*F mg/L*
Total	-	-	26	333	320	202	6.6	1.3
A	250	390	37 ± 1	305 ± 8	319 ± 8	121 ± 3	7.4 ± 0.2	1.0 ± 0.03
B	390	460	0 ± 8	394 ± 85	332 ± 78	379 ± 68	5.0 ± 1.5	2.0 ± 0.4
C	460	482	25 ± 8	343 ± 66	313 ± 63	227 ± 41	6.2 ± 1.3	1.2 ± 0.3

Table 10. Benevides-Duval County CD Well 1 water quality profile test results for TDS and major cations. Total represents well-head sample.

Screen	*Top (ft)*	*Bottom (ft)*	*TDS mg/L*	*Na mg/L*	*K mg/L*	*Ca mg/L*	*Mg mg/L*
Total	-	-	1155	354	10.7	45	18
A	250	390	989 ± 26	277 ± 7	10.9 ± 0.3	58 ± 1.5	21 ± 0.6
B	390	460	1524 ± 312	524 ± 102	9.6 ± 2.4	13 ± 8.7	9.8 ± 3.6
C	460	482	1211 ± 232	378 ± 71	10.9 ± 2.1	44 ± 8.8	17 ± 3.5

Conclusion

Modification of Well 1 to improve water quality for the Benevides-Duval County WD is a possibility. Significant stratification of water quality was identified in Well 1 and indicates probable arsenic-compliant water in screen section B (between the 390 ft and 460 ft depth interval). However, this interval provides only about 20% of total production, which seems unlikely to be sufficient for system requirements. Alternatively, production from screen sections B and C would result in approximately 47% of current total production, which may be sufficient for system requirements. In this scenario, the estimated arsenic concentration would be 14 µg/L, significantly reduced from current levels but still greater than the MCL.

References

Izbicki, J.A., Christensen, A.H., and Hanson, R.T., 1999, U.S. Geological Survey combined well-bore flow and depth-dependent water sampler; U.S. Geological Survey Fact Sheet FS 196-99.

Izbicki, J.A., 2004, A small-diameter sample pump for collection of depth-dependent samples from production wells under pumping conditions; U.S. Geological Survey Fact Sheet FS 2004-3096.