

Memorandum

To Joseph Cerutti, MassDEP, UIC Program Coordinator
CC Betsy Shreve, AICP, AECOM Project Director
James Begley, LSP, MT Environmental
AECOM PRB Team
Subject **Town of Orleans, MA
Water Quality and Wastewater Planning
Eldredge Park Permeable Reactive Barrier Demonstration Project
PRB Extension**
Project Number 60476644
From Thomas Parece, P.E., AECOM Project Manager
Date April 20, 2018

1. Introduction

The Eldredge Parkway Demonstration Test Permeable Reactive Barrier (PRB) was installed at the parking lot area southwest of the Nauset Middle School in November 2016. Demonstration Test initial activities are summarized in *Technical Memorandum for Eldredge Park Permeable Reactive Barriers Demonstration Overview of Baseline Sampling, Injection Activities and Post-Injection Groundwater Monitoring – Final* (AECOM, March 2017). MassDEP issued UIC Registration ID#MAS41A224209-5B6 for the Demonstration Test on September 15, 2016. This memorandum has been prepared to inform you that a modification of the PRB injection line is proposed extending the groundwater treatment line up to 110 feet to the north as shown in the attached site plan (Figure 1).

Baseline groundwater monitoring was completed before the PRB installation. Groundwater monitoring since construction has included sampling events in 2017 (January, February, June, and September) and 2018 (January). While groundwater flow at the location has been found to be complex, some clear trends have developed that provide for interpretation of PRB performance to date. Based on multiple lines of evidence including groundwater flow direction, dissolved organic carbon concentrations in groundwater derived from the injected PRB substrate, and reductions in nitrate concentration, the PRB is performing well in the monitored area downgradient of the PRB to the east northeast.

A portion of the area originally targeted for assessment of PRB performance further to the north northeast of the PRB has been found to be potentially outside of the area of influence of the PRB due a difference in groundwater flow direction in this northerly area. Consistent with the Adaptive Management Approach, a modification of the Demonstrations Test PRB is recommended that includes extending the PRB treatment line to the north to intercept and treat nitrate in groundwater along this untreated flow path.

2. PRB Demonstration Test Performance Monitoring Results To Date

A. Monitoring Schedule

Baseline and cumulative quarterly field and laboratory test results are all shown in Table 3. Baseline groundwater monitoring samples were collected on October 4, 2016, November 3, 2016 and November 4, 2016, prior to the injection activities in mid-November. During injections, limited monitoring was completed. Overall, no distinct patterns between the field parameters (temperature, pH, dissolved oxygen, conductivity, and turbidity) were observed before, during, and immediately following the injections. EVO was not observed following completion of injection indicating the injected material was stable and not migrating.

A preliminary post-injection sampling occurred approximately 7 weeks after injections in January 2017. Quarterly sampling has occurred in February 2017, June 2017, September 2017, and January 2018.

B. Summary of Recent Results

1) Q-4 January 2018

The fourth post-injection quarterly sampling (Q-4) event occurred on January 8, 2018 through January 10, 2018, approximately fourteen months post-injection. During the January 2018 quarterly sampling event, groundwater samples were collected from 24 monitoring wells and analyzed for nitrate, nitrite, ammonia, Total Nitrogen, chloride, sulfate, DOC, dissolved iron and dissolved manganese. Two select wells were also analyzed for boron. Field-measured parameters, such as water level, pH, temperature, DO, ORP, conductivity, and turbidity, were also measured. Additionally, water levels were collected from seven monitoring wells outside of the core monitoring well network.

a) Assessment of Groundwater Flow Through the PRB January 2018

Groundwater elevations calculated from the January 2018 data were interpolated to develop groundwater contour lines (Figure 6, Figure 7, and Figure 8). The groundwater data again indicated a similar groundwater flow pattern to that observed in June 2017 and September 2017. These data again confirmed that flow through the PRB does not appear to reach the full set of monitoring wells along the established monitoring well transects and treated water may only be reaching the monitoring wells approximately 20 feet north of the PRB due to groundwater flow directions.

b) Assessment of Groundwater Chemistry Data

Groundwater quality at sample locations closest to the PRB, including MW-B1010C on Transect 1 (A-A') and MW-B2010C on Transect 2 (B to B'), appear to be significantly improved by the PRB. Graphs of nitrate and DOC concentrations show generally decreasing nitrate concentration trends and increasing DOC concentration trends (Chart 1 and Chart 2). Decreasing nitrate concentrations and increasing DOC concentrations provide two lines of evidence for PRB performance. The January Quarter-4 (Q-4) sample at MW-B1010C indicated a slight decrease in DOC from 21.4 mg/L at Q-3 to 13.6 mg/L at Q-4. MW-B2010C indicated an increase in DOC from 69.4 mg/L during Q-3 to 94.3 mg/L in Q-4. The nitrate concentrations at MW-B1010C increased slightly to 2.76 mg/L, which is still well below the baseline concentration of 13.6 mg/L. The nitrate concentrations at MW-B2010C was below detection at <0.03 mg/L, dissolved oxygen was less than 0.5 mg/L, and the oxidation-reduction potential (ORP) at MW-B2010C was negative (-102.1 mV), all indicators of reducing conditions favorable to denitrification.

The monitoring wells located 20 feet from the PRB including MW-B1020B and MW-B1020C on Transect 1 (A to A'), and MW-2020B and MW-2020C on Transect 2 (B to B') also appeared to be significantly affected by the PRB with increased DOC concentrations and decreased nitrogen concentrations (Chart 3, Chart 4, Chart 5, and Chart 6). Dissolved iron increased at MW-1010C from 3.88 mg/L in Q-3 to 9.69 mg/L in Q-4. There was no major increase in dissolved manganese at this location. It was also noted that dissolved iron increased from 46.2 mg/L at Q-3 to 88.2 mg/L at Q-4 and dissolved manganese increased from 2.6 mg/L at Q-3 to 5.2 mg/L at Q-4 in MW-B2010C. The increases in iron and manganese are also indications of the reducing conditions favorable to denitrification. Dissolved manganese increased from 2.1 mg/L at Q-3 to 5.1 mg/L at Q-4 in MW-B2020C, however, dissolved iron decreased from 13.1 mg/L at Q-3 to 1.8 mg/L at Q-4. No significant changes for dissolved iron and manganese were noted between the Q-3 (or Q-2 when Q-3 unavailable) and Q-4 sampling at other locations where this was analyzed. No migration of EVO material was indicated by sampling observations or test results.

Nitrate concentrations also decreased at all monitoring wells located in an area approximately 50 feet north from the PRB. The largest decreases were at MW-1050A, from 26.7 mg/L in Q-3 to 4.89 mg/L in Q-4 and MW-B2050A, from 25.5 mg/L in Q-3 to 11.6 mg/L in Q-4. Nitrate was also noted to have decreased at the monitoring wells MW-BX1B and MW-BX1C from 39.0 mg/L at Q-3 to 10 mg/L at Q-4 and at MW-BX1C from 37.8 mg/L at Q-3 to 11.1 mg/L at Q-4. The lower nitrate concentrations in the area 50 feet north of the PRB were not associated with increased DOC concentrations (Chart 7 and Chart 8). These nitrate test results are similar to concentrations observed during the first sampling event for MW-BX1B in March 2017. BX1B and MW-BX1C appear to be located upgradient from MW-1050A and MW-2050A based on groundwater contours. Changes in concentration in the area 50 feet north of the PRB are not likely associated with the PRB.

Nitrate concentration data for baseline and quarterly sampling is included in Table 3 and on the cross-sections shown in Figure 4 and Figure 5. Nitrate data are also included with January 2018 groundwater contours and flow direction for shallow, intermediate depth, and deep groundwater monitoring wells on Figure 6, Figure 7, and Figure 8 respectively.

3. Recommended Demonstration Test PRB Extension

A. Demonstration Test Layout

The recommended PRB Demonstration Test extension line should be oriented to capture flow from the north northeast of the existing PRB. Exact orientation of the expansion PRB shall be determined after additional monitoring wells are installed in this area and sampled. The PRB is anticipated to be up to 110 feet long. A vertical treatment interval from the top of the groundwater table to approximately 38 feet into the saturated soils is recommended, similar to the initial demonstration.

B. PRB Demonstration Test Substrate and System Details

An EVO solution with a larger droplet size was selected so that the EVO droplets will adhere to sand grains in the formation to minimize the advection, or distribution, of EVO after injection. EVO adheres to the sandy aquifer material in the treatment zone and provides a slow release of soluble organic carbon compounds that are distributed by advection, dispersion, and diffusion in groundwater. A larger droplet size will also maximize the persistence of the carbon substrate within the PRB. For this demonstration test, Terra System's 60 percent Large Droplet Slow Release EVO for Nitrate Reduction (SRS-NR) will be used. The SRS NR is a modified formulation developed so that the emulsion is "stickier" in order to reduce migration after injection and increase persistence. Sodium lactate will also be added to the injection to supply additional carbon substrate and sodium bicarbonate will be added as a pH buffer with the EVO, in order to allow for the most favorable conditions for denitrifying bacteria. The 60 percent EVO will be mixed with water making an approximately 15.5 percent solution for injection. Representative parameters are included in Table 3-1.

**Table 3-1 - Summary of Design Parameters for
 Permeable Reactive Barrier Demonstration Test Extension**

Parameter	Demonstration Test Site
Area Description	Parking lot between the playing fields off Eldredge Park/portion in the soccer field by the track
Depth to Ground Water	30 to 40 feet below grade
Demonstration Test PRB Length	110 feet
Injection Interval	38 to 68 feet below grade
Injection Point Spacing	10 feet
Injection Points	20
Injection Pore Volume	12 percent (assumed effective porosity of 25 percent)
Total Injection Volume (gal)	14,800
Injection Volume Per Point (gal)	740
EVO Dilution	15.5 percent (~3.9:1 dilution from 60 percent EVO delivered)
Total EVO (gal)	3,700 (60 percent soy bean oil)

C. Substrate Delivery Methodology and Field Injection Activities

It is anticipated that ISOTEC, Inc. will perform the injections with oversight by the AECOM PRB Team. ISOTEC, Inc. performed the November 2016 injections and will use similar methodology. Injection of carbon substrate will be performed directly through direct-push (i.e., GeoProbe®) rods, configured in 4-foot or 8-foot intervals with thin, laser cut injection holes, while monitoring pressure on the injection wellheads.

Based on the results of the preliminary results from the eastern side of the PRB from the November 2016 injections, it is proposed that the expansion consists of injection points configured in two parallel, offset lines.

Similar to the November 2016 injections, the system for preparation, mixing, and injection of substrate solutions will consist of mixing tanks, mixers, pumps, piping, meters, valves, and fittings. Injection batches will be prepared in 300-gallon plastic tanks by adding appropriate quantities of water to achieve the selected dilution concentration. Mobile above-ground pumps and hoses will be used to convey EVO directly to the injection points. Flow totalizers, pressure gauges, and shut-off valves will monitor injection pressure, flow rates, and total volume added to each injection interval at each injection point.

At each injection point, a direct-push drill rig will be advanced injection tooling to a targeted depth of 68 feet below grade. Approximately seventy-five gallons of the diluted EVO solution will be injected per four-foot interval. Both 4-foot and 8-foot injection points may be used for injection. The injection rods will be lifted up four (or eight) feet to the subsequent injection target depth and the process repeated. This method of direct-push injection is referred to as bottom-up injection. To minimize mounding and improve delivery, injection generally will not be performed at adjacent points at the same time. A field log will be maintained to record the solution composition, volume of solution delivered to each injection interval at injection point, length of time required for injection, and the injection pressure. Electricity to power remediation equipment will be provided by a gasoline-powered generator. Potable water for batching and injection may either be collected from a nearby hydrant or a rental water tank.

4. Permitting

The EPA Underground Injection Control (UIC) Program is responsible for regulating the construction, operation, permitting, and closure of injection wells that place fluids underground for storage and disposal. The UIC Program requirements were developed by EPA and designed to be adopted by states. The Massachusetts Department of Environmental Protection (MassDEP) UIC Program is defined in 310 CMR 27.00: Underground Injection Control Regulations and details the regulation of injection of fluids within Massachusetts.

To implement the Demonstration Test with the initial injection in November 2016, a UIC permit application (MassDEP form BRPWS 06) was filed with MassDEP under the category "Aquifer Remediation." Similar injections of carbon substrates to enhance biodegradation of chemicals in groundwater have been commonly implemented in Massachusetts. Many of these sites are exempt from the UIC registration process if the injections are conducted for waste site cleanup in accordance with the Massachusetts Contingency Plan (MCP, 310 CMR 40.0000) or similar federal statutes. In implementing the Demonstration Test all initial injections associated with the PRB complied with the requirements of the Massachusetts UIC regulations and the MCP requirements, including all required monitoring. MassDEP issued UIC Registration ID#MAS41A224209-5B6 for the Demonstration Test on November 14, 2016 through 18, 2016.

This document summarizes a modification for the same project site.

5. Summary, Schedule, and Coordination

A modification of the PRB line is necessary to improve the demonstration. This modification will require additional monitoring well installation to verify flow directions north of the PRB and establish an additional PRB injections zone starting at the west end of the current PRB injection zone and extending to the north up to 110 feet, roughly along the edge of the field and parking lot areas. The monitoring wells are necessary to verify groundwater contours for orientation of the new section of PRB perpendicular to the direction of groundwater flow in the target area. This modification of the PRB is being coordinated with Nauset Public Schools Superintendent's office and planned for the Spring of 2018.

A tentative schedule includes:

- Installation of additional monitoring wells: April 2018
- PRB injections: June 2018
- Monitoring: Baseline between new well installation and injection and then quarterly

The current plan includes collecting quarterly samples for a period of three years. Periodic reporting will be conducted to share results and observations with the Town, regulatory agencies, and the public.

6. References

AECOM – Technical Memorandum Final for Preliminary Engineering Work Plan for Permeable Reactive Barriers. Submitted to Town of Orleans, MA. May 19, 2016.

AECOM - Technical Memorandum for Eldredge Park Permeable Reactive Barrier Demonstration Overview of Baseline Sampling, Injection Activities and Post-Injection Groundwater Monitoring – Final. March 1, 2017.

AECOM - Technical Memorandum for Eldredge Park Permeable Reactive Barrier Demonstration Project –Groundwater Monitoring Quarterly Report – Final. June 25, 2017.

AECOM - Technical Memorandum for Eldredge Park Permeable Reactive Barriers Demonstration Project – Groundwater Monitoring Quarterly Report – Final. February 2017.

Technical Memorandum for Eldredge Park Permeable Reactive Barrier Demonstration Project – Q-3 September 2017 Groundwater Monitoring Quarterly Report – Final. March 2018.

Cape Cod Commission - Cape Code Regional Wastewater Management Plan Technology Assessment – Conventional Infrastructure, March 2013.

Cape Cod Commission - Cape Cod Area Wide Water Quality Management Plan Update, June 2015.

Interstate Technology & Regulatory Council (ITRC) - Permeable Reactive Barrier: Technology Update (PRB-5), November 2011.

Terra Systems - Personal communications with Michael Lee, PhD, 2016.

Tables

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Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	MW-4 ³				MW-8 ³				MW-12A					
	Top of Screen Elevation (ft)	Bottom of Screen Elevation (ft)	Sampling Date	Type of Sample	10/4/2016	10/4/2016	10/4/2016	10/4/2016	11/03/2016 ¹	1/5/2017	2/23/2017	6/28/2017	9/12/2017	1/8/2018
	4.50	-5.50	10/4/2016	Sample		9.70	9.70				-24.4			
											-34.4			
Field Measurements														
pH (SU)	5.52				5.23			6.94	5.46	5.53	5.58	5.59	4.89	
Temperature (°C)	15.54				15.87			14.38	11.78	13.81	13.91	14.02	13.62	
Dissolved Oxygen (DO, mg/L)	7.89				9.58			1.13	3.69	7.03	14.81	6.92	7.65	
Redox Potential (ORP; mV)	57.90				135.00			70.90	197.60	183.10	173.60	146.50	288.30	
Specific Conductivity (µS/cm) ^c	171.00				190.00			667.00	572.00	550.00	537.00	518.00	563.00	
Turbidity (NTU)	-				-			17.70	5.50	5.31	5.13	7.68	3.58	
Laboratory Analyses														
Nitrogen														
Nitrate as N (mg/L)	2.45				9.24			0.783	0.669	0.849	0.786	0.794	0.242	
Nitrite as N (mg/L)	-				-			<0.01	<0.01	<0.01	<0.01	<0.01	0.074	
Ammonia (mg/L)	0.1				<0.1			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
Total Kjeldahl Nitrogen (TKN) (mg/L)	0.71				1.7			-	<0.2	0.4	-	-	0.22	
Total Nitrogen (mg/L)	3.15				10.9			1	0.669	1.25	0.79	1.11	0.533	
Anions														
Chloride (mg/L)	27.2				18.3			190	230	141	154	146	160	
Sulfate (mg/L)	12.8				10.1			10	16.1	13.4	12.6	12.3	12.2	
Elements														
Dissolved Iron (mg/L)	-				-			0.7	-	<0.1	<0.1	-	<0.1	
Dissolved Manganese (mg/L)	-				-			0.325	-	0.033	<0.02	-	<0.02	
Boron (mg/L)	-				-			<0.05	-	<0.05	-	-	-	
Sodium (mg/L)	-				-			-	-	98.3	-	-	-	
Other														
DOC (mg/L)	<0.5				<0.5			0.55	-	<0.5	2.16	0.792	1.7	
Methane (µg/L)	-				-			-	-	-	-	-	-	
Alkalinity as CaCO3 (mg/L)	-				-			-	5	7	-	-	-	

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D - Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: <http://www.hbuehrer.ch/Rechner/O2satur.html>

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	MW-12B										MW-12C ^{1,3}		
	-9.4										8.60		
Top of Screen Elevation (ft)											-1.40		
Bottom of Screen Elevation (ft)											-1.40		
Sampling Date	11/03/2016 ¹	1/5/2017	2/23/2017	6/28/2017	9/12/2017	1/8/2018	10/4/2016	11/03/2016 ¹	11/17/2016	1/5/2017	2/23/2017		
Type of Sample	Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample	Sample	Sample	Sample	Sample	Q1 Sample ⁴		
Field Measurements													
pH (SU)	6.90	5.43	5.40	5.39	5.45	4.78	4.98	6.45	5.23	5.09	NS		
Temperature (°C)	14.50	11.82	14.18	14.37	14.56	13.80	17.50	14.08	14.42	12.60	NS		
Dissolved Oxygen (DO, mg/L)	1.05	1.16	6.39	12.40	5.51	5.67	6.93	0.83	0.68	1.61	NS		
Redox Potential (ORP; mV)	20.30	212.80	263.10	225.20	170.30	275.70	167.80	246.00	279.70	205.60	NS		
Specific Conductivity (µS/cm) ⁵	231.00	243.00	235.00	253.00	257.00	249.00	178.00	216.00	156.00	199.00	NS		
Turbidity (NTU)	8.73	1.89	0.91	2.62	1.52	1.48	-	0.60	2.58	0.84	NS		
Laboratory Analyses													
Nitrogen													
Nitrate as N (mg/L)	6.17	5.08	5.33	6.19	4.9	1.91	6.74	6.51	-	6.03	NS		
Nitrite as N (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	<0.01	NS		
Ammonia (mg/L)	<0.1	0.19	<0.1	0.12	0.26	<0.1	<0.1	0.11	-	0.12	NS		
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	0.79	1.18	-	0.26	<0.2	1.34	-	-	1.24	NS		
Total Nitrogen (mg/L)	6.44	5.87	6.52	6.83	4.9	1.91	8.08	6.51	-	7.27	NS		
Anions													
Chloride (mg/L)	34.1	24.2	41.6	48.9	50.5	47.3	24.1	-	-	22.4	NS		
Sulfate (mg/L)	9.8	13.6	9.7	9.2	12.1	11.2	8.7	9.3	-	8.6	NS		
Elements													
Dissolved Iron (mg/L)	0.36	-	<0.05	<0.1	-	<0.1	-	<0.05	-	-	NS		
Dissolved Manganese (mg/L)	0.228	-	0.046	<0.02	-	<0.02	-	0.02	-	-	NS		
Boron (mg/L)	<0.05	-	<0.05	-	-	-	-	<0.05	-	-	NS		
Sodium (mg/L)	-	-	18.7	-	-	-	-	-	-	-	-		
Other													
DOC (mg/L)	1.82	-	<0.5	1.02	1.1	2.29	<0.5	0.87	0.674	-	NS		
Methane (µg/L)	-	-	-	-	-	-	-	-	-	-	NS		
Alkalinity as CaCO3 (mg/L)	-	2	10	-	-	-	-	-	4	6	NS		

Notes:

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D - Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: <http://www.hbuehrer.ch/Rechner/O2satur.html>

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	MA-BU1A			MW-BU1C			MW-BU2A			
	Top of Screen Elevation (ft)	Bottom of Screen Elevation (ft)	Sampling Date	Sample	Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample
	-26.3	-36.3	10/4/2016	5.44	5.27	6.73	5.72	5.68	5.72	5.23
				13.75	13.95	14.15	13.71	14.00	14.47	13.86
				7.60	8.75	1.18	6.82	15.26	6.87	7.63
				70.90	130.90	37.50	149.50	225.20	172.00	211.40
	1464.00			421.00	406.00	406.00	427.00	439.00	442.00	421.00
				257.00	44.50	378.00	378.00	2.55	4.02	20.90
Laboratory Analyses										
Nitrogen										
Nitrate as N (mg/L)	0.443			1.97	1.97	0.357	0.452	0.408	0.61	0.467
Nitrite as N (mg/L)				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.065
Ammonia (mg/L)	0.24			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	0.38			0.4	0.4	-	0.3	-	-	<0.2
Total Nitrogen (mg/L)	0.827			2.37	2.37	0.357	0.76	0.408	0.834	0.532
Anions										
Chloride (mg/L)	458			96.1	96.1	103	117	120	123	114
Sulfate (mg/L)	6.9			9.1	9.1	7.2	5.3	<5	<5	5.3
Elements										
Dissolved Iron (mg/L)	0.799			0.099	0.099	1.09	0.477	<0.1	-	<0.1
Dissolved Manganese (mg/L)	0.185			0.047	0.047	0.18	0.03	<0.02	-	<0.02
Boron (mg/L)	<0.05			<0.05	<0.05	<0.05	<0.05	-	-	-
Sodium (mg/L)				-	-	-	63	-	-	-
Other										
DOC (mg/L)	<0.5			<0.5	<0.5	<0.5	0.53	<0.5	0.707	1.14
Methane (µg/L)	<2			<2	<2	-	-	-	-	-
Alkalinity as CaCO3 (mg/L)				-	-	-	10	-	-	-

Notes:

NS - Not Sampled

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D - Duplicate

- DO was measured in the field as DO(%) and was converted using the online tool at: <http://www.hbuehrer.ch/Rechner/O2satur.html>
- MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.
- Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.
- MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	MW-BU2B										MW-BU2C			
	-9.9										5.10			
Top of Screen Elevation (ft)														
Bottom of Screen Elevation (ft)	-19.9													
Sampling Date	11/03/2016 ¹	1/5/2017	2/23/2017	6/29/2017	9/12/2017	1/10/2018	11/03/2016 ¹	11/17/2016	1/10/2017	2/23/2017	6/29/2017	9/12/2017	1/10/2018	
Type of Sample	Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample	Sample	Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample	
Field Measurements														
pH (SU)	7.11	5.94	5.73	5.68	5.75	5.24	7.14	5.46	5.49	5.62	5.27	5.26	4.85	
Temperature (°C)	14.70	12.07	14.18	14.70	15.21	14.53	15.20	14.89	12.78	14.78	15.22	15.67	14.76	
Dissolved Oxygen (DO, mg/L)	1.30	1.07	6.25	13.80	6.19	6.42	1.31	2.17	2.40	5.96	11.94	5.59	6.22	
Redox Potential (ORP; mV)	20.20	136.30	177.60	221.40	156.50	213.20	203.00	51.20	194.10	227.50	249.50	208.60	243.90	
Specific Conductivity (µS/cm) ^c	379.00	362.00	343.00	336.00	350.00	410.00	535.00	516.00	569.00	367.00	579.00	658.00	630.00	
Turbidity (NTU)	102.00	146.00	32.60	4.16	8.58	26.40	11.40	14.20	5.55	7.33	2.08	11.35	3.86	
Laboratory Analyses														
Nitrogen														
Nitrate as N (mg/L)	1.06	0.826	1.01	0.768	1.07	2.78	5.39	-	7.42	1.78	5.39	6.35	8.03	
Nitrite as N (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	
Ammonia (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	0.1	<0.1	<0.1	<0.1	<0.1	
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	<0.2	0.43	-	-	<0.2	-	-	<0.2	0.55	-	<0.2	<0.2	
Total Nitrogen (mg/L)	1.06	0.826	1.44	0.768	1.07	2.78	5.39	-	-	2.32	5.39	6.35	8.03	
Anions														
Chloride (mg/L)	97.3	92.2	90.7	88.3	93.2	106	134	-	143	96.8	146	174	165	
Sulfate (mg/L)	<5	<5	<5	<5	<5	<5	<5	-	<5	<5	<5	<5	<5	
Elements														
Dissolved Iron (mg/L)	0.667	-	0.138	<0.1	-	<0.1	0.817	-	-	<0.1	<0.1	-	<0.1	
Dissolved Manganese (mg/L)	0.088	-	<0.02	<0.02	-	<0.02	0.26	-	-	0.077	0.081	-	0.076	
Boron (mg/L)	<0.05	-	<0.05	-	-	-	<0.05	-	-	<0.05	-	-	-	
Sodium (mg/L)	-	-	37.2	-	-	-	-	-	-	44.9	-	-	-	
Other														
DOC (mg/L)	0.612	-	<0.5	0.579	0.856	2.26	0.684	0.728	<0.5	<0.5	0.599	1.35	2.2	
Methane (µg/L)	<2	-	-	-	-	-	<2	-	-	-	-	-	-	
Alkalinity as CaCO3 (mg/L)	-	18	16	-	-	-	-	13	11	17	-	-	-	

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D - Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: <http://www.hbuehrer.ch/Rechner/O2satur.html>

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	MW-BC1C				MW-BC2C				MW-BC3B			
	10/4/2016	11/04/2016	11/17/2016	1/10/2017	2/24/2017	6/29/2017	9/13/2017	1/10/2018	3/27/2017	6/29/2017	9/13/2017	1/10/2018
Top of Screen Elevation (ft)	2.5				N/A						-10.80	
Bottom of Screen Elevation (ft)	-7.5				N/A						-20.80	
Sampling Date	10/4/2016	11/04/2016	11/17/2016	1/10/2017	2/24/2017	6/29/2017	9/13/2017	1/10/2018	3/27/2017	6/29/2017	9/13/2017	1/10/2018
Type of Sample	Sample	Sample	Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample	Sample	Q2 Sample	Q3 Sample	Q4 Sample
Field Measurements												
pH (SU)	5.48	7.05	5.40	5.55	5.17	5.28	5.30	5.01	5.38	5.31	5.41	5.09
Temperature (°C)	13.37	15.25	14.54	12.65	15.10	15.07	15.49	14.62	14.19	14.13	14.24	14.22
Dissolved Oxygen (DO, mg/L)	7.75	1.65	1.67	1.87	5.73	12.16	4.94	5.20	2.50	6.98	3.29	3.27
Redox Potential (ORP; mV)	70.10	74.80	100.70	169.00	259.10	239.90	256.70	184.90	113.80	251.90	238.30	137.40
Specific Conductivity (µS/cm) ^c	1029.00	368.00	340.00	363.00	332.00	361.00	416.00	391.00	518.00	611.00	630.00	559.00
Turbidity (NTU)	-	6.00	19.20	16.60	20.40	3.76	2.62	2.40	5.69	16.40	5.82	4.65
Laboratory Analyses												
Nitrogen												
Nitrate as N (mg/L)	0.481	4.16	-	5.91	3.32	3.42	3.13	4.25	2.2	4.59	3.45	4.26
Nitrite as N (mg/L)	-	-	-	<0.01	<0.01	<0.01	<0.01	0.08	0.032	<0.01	<0.01	<0.01
Ammonia (mg/L)	-	<0.1	-	<0.1	<0.1	<0.1	0.12	<0.1	0.91	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	-	-	<0.2	0.92	-	-	<0.2	-	-	-	<0.2
Total Nitrogen (mg/L)	0.481	4.43	-	4.24	3.42	3.42	3.13	4.33	2.59	4.59	3.45	4.26
Anions												
Chloride (mg/L)	438	83.8	-	85.4	83.3	86.5	92.5	96	143	161	153	140
Sulfate (mg/L)	11.5	6.4	-	<5	6.3	<5	<5	5.3	8.3	6.8	9.1	13.6
Elements												
Dissolved Iron (mg/L)	-	-	-	-	<0.1	<0.1	-	<0.1	<0.1	<0.1	-	<0.1
Dissolved Manganese (mg/L)	-	-	-	-	0.092	0.062	-	0.063	0.298	0.077	-	0.078
Boron (mg/L)	-	-	-	-	<0.05	-	-	-	-	-	-	-
Sodium (mg/L)	-	-	-	-	41.8	-	-	-	-	-	-	-
Other												
DOC (mg/L)	<0.5	0.764	0.576	<0.5	1.54	1.68	3.32	1.67	1.86	1.02	3.79	2.36
Methane (µg/L)	-	-	-	-	-	-	-	-	-	-	-	-
Alkalinity as CaCO3 (mg/L)	-	-	8	9	9	-	-	-	-	-	-	-

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D - Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: <http://www.hbuehrer.ch/Rechner/O2satur.html>

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	MW-BX1B				MW-BX1C			
	3/27/2017	6/28/2017	9/12/2017	1/8/2018	3/27/2017	6/28/2017	9/12/2017	1/8/2018
Top of Screen Elevation (ft)			-9.40				5.70	
Bottom of Screen Elevation (ft)			-19.40				-4.30	
Sampling Date								
Type of Sample	Sample	Q2 Sample	Q3 Sample	Q4 Sample	Sample	Q2 Sample	Q3 Sample	Q4 Sample
Field Measurements								
pH (SU)	4.67	5.05	5.03	4.04	4.44	4.70	4.80	3.89
Temperature (°C)	13.76	14.28	14.50	13.33	13.87	14.32	14.44	13.44
Dissolved Oxygen (DO, mg/L)	1.73	1.87	0.07	0.09	0.63	2.30	0.79	1.56
Redox Potential (ORP; mV)	153.70	283.60	202.90	302.90	199.90	315.80	232.40	328.60
Specific Conductivity (µS/cm) ^c	367.00	446.00	470.00	468.00	521.00	473.00	447.00	499.00
Turbidity (NTU)	29.80	326.00	19.44	68.80	0.98	55.80	7.11	5.93
Laboratory Analyses								
Nitrogen								
Nitrate as N (mg/L)	11.4	34.4	39	10	0.25	38.7	37.8	11.1
Nitrite as N (mg/L)	0.018	<0.01	<0.01	<0.01	0.012	<0.01	<0.01	0.074
Ammonia (mg/L)	0.4	0.7	0.39	0.51	1.09	0.5	0.22	0.18
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	-	-	<0.2	-	-	-	<0.2
Total Nitrogen (mg/L)	12.9	37	39	10	1.52	42	37.8	11.2
Anions								
Chloride (mg/L)	43.1	41	37.9	33.4	49.6	40.8	37.3	34.5
Sulfate (mg/L)	7.6	<5	<5	<5	<5	<5	<5	<5
Elements								
Dissolved Iron (mg/L)	<0.1	<0.1	-	<0.1	<0.1	<0.1	-	<0.1
Dissolved Manganese (mg/L)	0.335	0.478	-	0.631	0.566	0.517	-	0.553
Boron (mg/L)	-	-	-	0.052	-	-	-	0.052
Sodium (mg/L)	-	-	-	-	-	-	-	-
Other								
DOC (mg/L)	2.97	1.55	2.31	5.16	2.7	2.02	2.69	4.53
Methane (µg/L)	-	-	-	-	-	-	-	-
Alkalinity as CaCO3 (mg/L)	-	-	-	-	-	-	-	-

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D - Duplicate

- DO was measured in the field as DO(%) and was converted using the online tool at: <http://www.hbuehrer.ch/Rechner/O2satur.html>
- MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.
- Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.
- MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	MW-B1010C										MW-B1020B			
	-0.10										-10.4			
Top of Screen Elevation (ft)														
Bottom of Screen Elevation (ft)														
Sampling Date	11/03/2016 ¹	11/17/2016	1/5/2017	2/23/2017	6/28/2017	9/12/2017	1/9/2018	11/04/2016 ¹	1/5/2017	2/23/2017	6/28/2017	9/12/2017	1/8/2018	
Type of Sample	Sample	Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample	Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample	
Field Measurements														
pH (SU)	6.90	5.18	5.61	5.32	5.36	5.68	5.23	6.78	5.20	5.01	5.00	5.12	4.54	
Temperature (°C)	14.60	14.28	12.22	14.69	15.04	15.97	13.43	13.70	11.94	14.13	14.71	15.69	13.82	
Dissolved Oxygen (DO, mg/L)	0.87	0.71	0.49	1.07	1.39	0.12	2.11	1.03	0.60	2.77	1.44	0.20	0.16	
Redox Potential (ORP; mV)	110.70	231.60	190.80	252.20	204.80	2.70	86.20	45.00	190.70	251.30	276.30	160.30	166.20	
Specific Conductivity (µS/cm) ^c	262.00	230.00	289.00	258.00	269.00	238.00	249.00	465.00	355.00	353.00	352.00	332.00	288.00	
Turbidity (NTU)	16.00	5.97	10.60	5.62	2.73	2.99	5.15	67.90	321.00	11.00	14.60	2.50	2.84	
Laboratory Analyses														
Nitrogen														
Nitrate as N (mg/L)	13.6	-	6.74	9.94	13.8	2.49	2.76	28.4	17.9	20.1	24.9	19.7	4.71	
Nitrite as N (mg/L)	-	-	0.509	0.474	0.171	0.185	0.052	-	<0.01	<0.01	0.158	0.076	0.091	
Ammonia (mg/L)	<0.1	-	<0.1	0.18	<0.1	<0.1	0.13	0.53	0.11	<0.1	<0.1	<0.1	0.14	
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	-	1.36	1.95	-	-	0.88	-	1.79	2.92	-	-	<0.2	
Total Nitrogen (mg/L)	13.9	-	8.61	12.4	15.7	4.22	3.69	28.5	19.6	23	27.1	19.7	4.8	
Anions														
Chloride (mg/L)	27.5	-	24.3	25.2	24.2	23.6	22.6	49.8	33.6	34	32.3	30	25.1	
Sulfate (mg/L)	-	-	23.7	16.5	11	22.6	10.8	-	<5	<5	<5	<5	6.8	
Elements														
Dissolved Iron (mg/L)	-	-	-	<0.1	0.143	3.88	9.69	2.52	-	0.153	<0.1	<0.1	<0.1	
Dissolved Manganese (mg/L)	-	-	-	0.234	0.324	0.996	0.531	0.948	-	0.293	0.333	0.32	0.307	
Boron (mg/L)	-	-	-	<0.05	-	-	-	<0.05	-	0.053	-	-	-	
Sodium (mg/L)	-	-	-	22.8	-	-	-	27.5	-	24.6	-	-	-	
Other														
DOC (mg/L)	-	0.696	-	13.9	16.9	21.4	13.6	-	-	1.11	3.24	3.67	6.02	
Methane (µg/L)	-	-	-	-	<2	-	-	-	-	-	-	-	-	
Alkalinity as CaCO3 (mg/L)	-	11	31	15	-	-	-	-	9	6	-	-	-	

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D - Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: <http://www.hbuehrer.ch/Rechner/O2satur.html>

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	MW-B1020C										MW-B1050A			
	4.50										-26.1			
Top of Screen Elevation (ft)														
Bottom of Screen Elevation (ft)	-5.50													
Sampling Date	11/04/2016 ¹	11/17/2016	1/5/2017	2/23/2017	6/28/2017	9/12/2017	1/8/2018	11/04/2016 ¹	1/5/2017	2/23/2017	6/28/2017	9/12/2017	1/9/2018	
Type of Sample	Sample	Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample	Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample	
Field Measurements														
pH (SU)	6.88	5.27	5.38	5.17	5.16	5.22	4.54	7.15	5.60	5.50	5.00	5.27	5.06	
Temperature (°C)	14.24	14.66	12.73	15.06	15.26	15.97	13.97	13.77	11.87	14.05	14.27	15.87	14.11	
Dissolved Oxygen (DO, mg/L)	1.44	0.56	0.31	2.69	3.72	1.81	3.78	1.34	0.26	4.24	1.75	0.06	0.75	
Redox Potential (ORP; mV)	50.30	106.70	194.80	292.20	277.20	161.90	204.20	43.00	142.20	226.20	264.40	174.20	129.60	
Specific Conductivity (µS/cm) ^c	242.00	227.00	269.00	253.00	247.00	161.90	201.00	612.00	505.00	1648.00	508.00	422.00	1486.00	
Turbidity (NTU)	321.00	15.60	6.31	18.00	8.87	243.00	14.60	962.00	297.00	76.60	4.10	3.10	9.57	
Laboratory Analyses														
Nitrogen														
Nitrate as N (mg/L)	10.6	-	11.1	12.6	13.9	12.4	2.97	37	26.6	11.8	26.8	26.7	4.89	
Nitrite as N (mg/L)	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	-	0.105	<0.01	0.038	0.048	0.141	
Ammonia (mg/L)	<0.1	-	0.19	<0.1	<0.1	<0.1	0.14	1.93	1.72	0.54	0.57	1.24	0.38	
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	-	1.99	2.25	-	-	<0.2	-	3.75	1.83	-	-	<0.2	
Total Nitrogen (mg/L)	10.6	-	13.1	14.9	15	12.4	2.97	37.2	30.5	13.7	26.8	26.7	5.03	
Anions														
Chloride (mg/L)	25.5	-	25.6	25.6	24.8	24.1	18.7	54.8	48.9	399	48.9	41.4	429	
Sulfate (mg/L)	-	-	5.6	6.1	5.8	5.8	6.7	-	6.1	<5	<5	<5	<5	
Elements														
Dissolved Iron (mg/L)	2.23	-	-	<0.1	<0.1	<0.1	<0.1	4.29	-	<0.1	<0.1	-	<0.1	
Dissolved Manganese (mg/L)	0.249	-	-	0.076	0.057	0.042	0.054	0.655	-	0.18	0.654	-	0.236	
Boron (mg/L)	0.085	-	-	0.083	-	-	-	<0.05	-	<0.05	-	-	-	
Sodium (mg/L)	13.4	-	-	18.4	-	-	-	33.7	-	345	-	-	-	
Other														
DOC (mg/L)	-	0.85	-	1.02	1.34	2.19	4.52	-	-	0.808	1.85	3.72	2.83	
Methane (µg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	
Alkalinity as CaCO3 (mg/L)	-	13	11	8	-	-	-	-	24	11	-	-	-	

Notes:

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Bold - detected above the Minimum Detection Limit

D - Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: <http://www.hbuehrer.ch/Rechner/O2satur.html>

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	MW-B1050B					MW-B1050C				
	-11.1					4.9				
Top of Screen Elevation (ft)										
Bottom of Screen Elevation (ft)	-5.1									
Sampling Date	11/04/2016 ¹	2/23/2017	6/28/2017	9/12/2017	1/9/2018	11/04/2016 ¹	2/23/2017	6/28/2017	9/12/2017	1/9/2018
Type of Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample
Field Measurements										
pH (SU)	7.06	5.13	5.10	5.22	4.74	7.20	5.43	5.34	5.38	4.96
Temperature (°C)	14.08	14.27	14.70	15.48	14.19	14.55	14.95	15.06	15.77	14.51
Dissolved Oxygen (DO, mg/L)	1.17	2.12	4.53	1.06	2.17	1.34	1.83	5.39	1.85	1.64
Redox Potential (ORP; mV)	80.30	304.40	260.10	203.80	160.40	48.60	205.90	230.20	176.50	167.20
Specific Conductivity (µS/cm) ^c	446.00	463.00	387.00	340.00	392.00	571.00	511.00	542.00	478.00	413.00
Turbidity (NTU)	3.97	7.20	0.72	2.75	5.06	8.21	2.27	0.98	3.23	1.90
Laboratory Analyses										
Nitrogen										
Nitrate as N (mg/L)	25.7	28.7	18.2	18	10.8	3.83	3.96	3.26	4.18	2
Nitrite as N (mg/L)	-	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	0.088
Ammonia (mg/L)	0.19	<0.1	<0.1	0.14	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	1.85	-	<0.2	<0.2	-	1.28	-	<0.1	<0.2
Total Nitrogen (mg/L)	26	30.5	18.2	18	10.8	4.05	5.24	3.26	4.4	2.08
Anions										
Chloride (mg/L)	48.2	50.7	41.7	38.2	36.7	141	123	134	120	85.7
Sulfate (mg/L)	-	<5	<5	<5	<5	-	20.1	15.2	14.6	17.9
Elements										
Dissolved Iron (mg/L)	0.734	<0.1	<0.1	-	<0.1	0.493	<0.1	<0.1	-	<0.1
Dissolved Manganese (mg/L)	0.332	0.142	0.101	-	0.115	0.146	0.042	0.057	-	0.034
Boron (mg/L)	<0.05	<0.05	-	-	-	<0.05	<0.05	-	-	-
Sodium (mg/L)	26.8	16.9	-	-	-	81.6	94.5	-	-	-
Other										
DOC (mg/L)	-	0.722	1.31	3.43	3.21	-	0.592	1.62	2.19	3.26
Methane (µg/L)	-	-	-	-	-	-	-	-	-	-
Alkalinity as CaCO3 (mg/L)	-	7	-	-	-	-	17	-	-	-

Notes:

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D - Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: <http://www.hbuehrer.ch/Rechner/O2satur.html>

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	MW-B1075B										MW-B2010C			
	-11.5					-21.5					0			
Top of Screen Elevation (ft)														
Bottom of Screen Elevation (ft)														
Sampling Date	11/04/2016 ¹	2/23/2017	6/28/2017	9/13/2017	1/9/2018	11/03/2016 ¹	11/17/2016	2/24/2017	6/28/2017	9/13/2017	1/10/2018			
Type of Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample	Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample			
Field Measurements														
pH (SU)	7.19	5.59	5.66	5.83	5.53	7.04	5.32	5.70	6.11	6.29	6.20			
Temperature (°C)	15.20	14.20	14.74	14.93	14.13	15.12	14.58	14.81	15.39	15.69	14.71			
Dissolved Oxygen (DO, mg/L)	0.71	1.50	1.95	0.12	0.11	0.67	0.61	3.38	1.78	0.10	0.10			
Redox Potential (ORP; mV)	82.20	157.90	223.10	99.00	135.00	12.40	213.80	103.30	-41.60	-119.80	-102.10			
Specific Conductivity (µS/cm) ^c	631.00	1755.00	736.00	719.00	2688.00	333.00	304.00	302.00	431.00	689.00	862.00			
Turbidity (NTU)	13.00	126.00	1.87	24.23	173.00	149.00	44.40	19.90	6.89	5.10	3.32			
Laboratory Analyses														
Nitrogen														
Nitrate as N (mg/L)	1.93	1	0.553	0.751	0.609	15.7	-	5.06	5.74	0.182	<0.03			
Nitrite as N (mg/L)	-	0.048	0.05	0.064	0.201	-	-	0.499	0.128	0.081	0.027			
Ammonia (mg/L)	3.73	5.26	11	12.2	14.3	0.14	-	<0.1	0.24	<0.1	0.17			
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	7.2	-	-	14.4	-	-	14.7	-	-	1.75			
Total Nitrogen (mg/L)	6.36	8.25	13.6	15.1	15.3	16.1	-	20.3	7.69	2.26	1.75			
Anions														
Chloride (mg/L)	96.3	440	170	147	764	38.6	-	27.5	30	37.4	35.5			
Sulfate (mg/L)	-	25.6	28.9	26.8	31.6	11	-	24.3	39.8	73.5	57			
Elements														
Dissolved Iron (mg/L)	-	0.342	<0.1	-	0.886	-	-	1.84	24.2	46.2	88.2			
Dissolved Manganese (mg/L)	-	0.119	0.111	-	0.142	-	-	0.189	1.62	2.56	5.15			
Boron (mg/L)	-	<0.05	-	-	-	-	-	<0.05	-	-	-			
Sodium (mg/L)	-	379	-	-	-	-	-	28.5	-	-	-			
Other														
DOC (mg/L)	-	1.96	4.86	9.48	8.77	2.18	0.852	19.4	83.3	69.4	94.3			
Methane (µg/L)	-	-	-	-	-	-	-	-	11.3	-	-			
Alkalinity as CaCO3 (mg/L)	-	46	-	-	-	-	16	48	-	-	-			

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D - Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: <http://www.hbuehrer.ch/Rechner/O2satur.html>

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	MW-B2020B										MW-B2020C			
	-10.1										4.8			
Top of Screen Elevation (ft)														
Bottom of Screen Elevation (ft)	-20.1										-5.2			
Sampling Date	11/03/2016 ¹	11/17/2016	1/10/2017	2/24/2017	6/28/2017	9/13/2017	1/9/2018	11/03/2016 ¹	1/10/2017	2/24/2017	6/28/2017	9/13/2017	1/9/2018	
Type of Sample	Sample	Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample	Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample	
Field Measurements														
pH (SU)	7.00	5.22	5.05	5.10	5.04	5.45	4.95	7.00	5.12	5.09	5.60	5.76	5.16	
Temperature (°C)	14.91	14.39	12.23	14.53	14.86	15.14	14.28	15.20	12.90	15.42	15.57	15.80	14.72	
Dissolved Oxygen (DO, mg/L)	1.15	0.63	0.85	2.03	3.88	0.08	0.08	1.31	1.30	3.96	1.70	0.13	0.06	
Redox Potential (ORP; mV)	90.80	182.60	170.50	308.10	285.90	120.70	173.60	29.80	201.50	316.20	73.80	-15.70	8.50	
Specific Conductivity (µS/cm) ^c	321.00	307.00	344.00	338.00	354.00	323.00	370.00	249.00	251.00	225.00	264.00	248.00	250.00	
Turbidity (NTU)	14.30	17.40	6.95	6.11	8.12	5.91	10.00	28.00	5.81	5.17	6.23	1.30	6.09	
Laboratory Analyses														
Nitrogen														
Nitrate as N (mg/L)	16.9	-	25.6	14.8	22.4	5.96	3.26	8.71	12.6	6.95	0.457	<0.03	<0.03	
Nitrite as N (mg/L)	0.022	-	<0.01	<0.01	<0.01	0.54	2.98	0.016	<0.01	<0.01	0.072	0.01	0.083	
Ammonia (mg/L)	0.1	-	<0.1	<0.1	<0.1	<0.1	0.23	0.24	<0.1	<0.1	<0.1	<0.1	0.14	
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	-	<0.2	3.86	-	-	4.32	-	<0.2	2.33	-	-	1.04	
Total Nitrogen (mg/L)	17.2	-	-	18.7	24.2	7.84	10.6	9.02	-	9.28	0.85	0.424	1.1	
Anions														
Chloride (mg/L)	32.5	-	34.9	32.7	39.3	38	51.4	26.8	31	28.4	32.2	31.2	33	
Sulfate (mg/L)	7.7	-	6	7.1	6.4	29.7	19.3	11.6	9.7	11.9	36.8	20.9	29	
Elements														
Dissolved Iron (mg/L)	1.2	-	-	<0.1	<0.1	<0.1	<0.1	1.42	-	<0.1	7.97	13.1	1.83	
Dissolved Manganese (mg/L)	0.126	-	-	0.028	0.029	0.187	0.374	1.14	-	0.067	0.964	2.08	5.09	
Boron (mg/L)	<0.05	-	-	0.054	-	-	-	<0.05	-	<0.05	-	-	-	
Sodium (mg/L)	-	-	-	21.6	-	-	-	-	-	15.2	-	-	-	
Other														
DOC (mg/L)	1.45	0.694	<0.5	1.02	3.47	29.8	16.5	1.17	<0.5	2.04	23.3	14.2	11.8	
Methane (µg/L)	<2	-	-	-	-	-	-	<2	-	-	-	-	-	
Alkalinity as CaCO3 (mg/L)	-	20	12	8	-	-	-	-	10	7	-	-	-	

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D - Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: <http://www.hbuehrer.ch/Rechner/O2satur.html>

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	MW-B2050A										MW-B2050B				
	-25.4					-35.4					-10.4				
Top of Screen Elevation (ft)															
Bottom of Screen Elevation (ft)															
Sampling Date	11/03/2016 ¹	1/10/2017	2/24/2017	6/28/2017	9/13/2017	1/9/2018	11/03/2016 ¹	2/24/2017	6/28/2017	9/13/2017	1/9/2018	2/24/2017	6/28/2017	9/13/2017	1/9/2018
Type of Sample	Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample
Field Measurements															
pH (SU)	7.11	5.39	5.29	5.27	5.34	4.85	7.06	5.22	5.29	5.30	4.79	5.22	5.29	5.30	4.79
Temperature (°C)	14.44	11.96	14.06	14.47	14.58	14.05	14.95	14.64	15.27	15.31	14.32	14.64	15.27	15.31	14.32
Dissolved Oxygen (DO, mg/L)	0.60	0.09	0.83	1.66	0.06	0.07	1.29	3.75	5.97	1.27	1.43	3.75	5.97	1.27	1.43
Redox Potential (ORP; mV)	0.80	182.80	251.80	217.00	98.90	147.00	80.50	304.60	242.20	169.70	156.90	304.60	242.20	169.70	156.90
Specific Conductivity (µS/cm) ^c	540.00	520.00	550.00	505.00	509.00	660.00	512.00	645.00	502.00	510.00	495.00	645.00	502.00	510.00	495.00
Turbidity (NTU)	50.70	8.10	14.10	26.70	5.04	4.16	123.00	4.67	5.78	0.61	1.54	4.67	5.78	0.61	1.54
Laboratory Analyses															
Nitrogen															
Nitrate as N (mg/L)	35	39.3	27	32.8	25.5	11.6	4.75	3.64	5.27	3.94	1.72	3.64	5.27	3.94	1.72
Nitrite as N (mg/L)	-	0.025	<0.010	<0.01	0.166	0.04	-	<0.010	<0.01	<0.01	0.046	<0.010	<0.01	<0.01	0.046
Ammonia (mg/L)	1.05	0.87	0.89	1	0.63	0.78	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	3.32	3.5	-	-	<0.2	-	1.22	-	-	<0.2	1.22	-	-	<0.2
Total Nitrogen (mg/L)	35.3	-	30.5	35.4	25.6	11.6	5.15	4.86	5.91	3.94	1.76	4.86	5.91	3.94	1.76
Anions															
Chloride (mg/L)	49.9	64.5	63.3	66.8	65.8	114	123	173	124	119	121	173	124	119	121
Sulfate (mg/L)	5.6	5.6	6.2	7.5	5.3	6.1	11.5	11.5	11	8.7	11.4	11.5	11	8.7	11.4
Elements															
Dissolved Iron (mg/L)	3.2	-	<0.1	<0.1	-	<0.1	0.551	<0.1	<0.1	-	<0.1	<0.1	<0.1	-	<0.1
Dissolved Manganese (mg/L)	0.407	-	0.293	0.26	-	0.258	0.258	0.297	0.258	-	0.315	0.297	0.258	-	0.315
Boron (mg/L)	<0.05	-	<0.05	-	-	-	<0.05	<0.05	-	-	-	<0.05	-	-	-
Sodium (mg/L)	-	-	40	-	-	-	-	81.7	-	-	-	81.7	-	-	-
Other															
DOC (mg/L)	1.61	-	1.08	1.37	5.63	2.76	1.15	1.08	0.754	5.01	4.25	1.08	0.754	5.01	4.25
Methane (µg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alkalinity as CaCO3 (mg/L)	-	17	13	-	-	-	-	11	-	-	-	11	-	-	-

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D - Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: <http://www.hbuehrer.ch/Rechner/O2satur.html>

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	MW-B2050C						MW-B2075A			
	4.6						-20.40			
Top of Screen Elevation (ft)										
Bottom of Screen Elevation (ft)	-30.40									
Sampling Date	11/03/2016 ¹	2/24/2017	6/28/2017	9/13/2017	1/9/2018	3/27/2017	6/28/2017	9/12/2017	1/10/2018	
Type of Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample	Sample	Q2 Sample	Q3 Sample	Q4 Sample	Q4 Sample
Field Measurements										
pH (SU)	7.22	5.49	5.38	5.40	5.11	5.21	5.50	5.53	5.27	5.27
Temperature (°C)	16.72	16.56	16.90	17.37	14.40	14.42	14.98	15.40	14.53	14.53
Dissolved Oxygen (DO, mg/L)	1.09	5.76	8.95	4.51	5.82	4.08	7.83	7.02	5.27	5.27
Redox Potential (ORP; mV)	82.50	179.50	236.30	177.90	171.50	130.70	234.90	205.30	173.40	173.40
Specific Conductivity (µS/cm) ^c	658.00	932.00	896.00	970.00	903.00	744.00	748.00	883.00	856.00	856.00
Turbidity (NTU)	212.00	36.10	9.68	20.03	16.10	159.00	3.85	43.20	333.00	333.00
Laboratory Analyses										
Nitrogen										
Nitrate as N (mg/L)	3.01	1.68	3.05	2.19	1.41	0.348	0.539	0.676	0.762	0.762
Nitrite as N (mg/L)	-	<0.010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ammonia (mg/L)	0.11	<0.1	0.12	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	0.66	-	-	<0.2	-	-	-	0.31	0.31
Total Nitrogen (mg/L)	3.3	2.34	3.75	2.53	1.41	0.35	0.779	1.09	1.07	1.07
Anions										
Chloride (mg/L)	-	251	253	278	257	246	214	261	257	257
Sulfate (mg/L)	11.9	11.1	10.1	8.9	9.6	5.7	<5	5.4	6.5	6.5
Elements										
Dissolved Iron (mg/L)	-	0.308	<0.1	-	<0.1	0.119	<0.1	-	<0.1	<0.1
Dissolved Manganese (mg/L)	-	0.254	0.13	-	0.102	0.529	0.062	-	0.069	0.069
Boron (mg/L)	-	<0.05	-	-	-	-	-	-	-	-
Sodium (mg/L)	-	120	-	-	-	-	-	-	-	-
Other										
DOC (mg/L)	1.13	0.87	0.639	3.73	2.75	1.08	0.668	0.722	2.26	2.26
Methane (µg/L)	-	-	-	-	-	-	-	-	-	-
Alkalinity as CaCO3 (mg/L)	-	9	-	-	-	-	-	-	-	-

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D - Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: <http://www.hbuehrer.ch/Rechner/O2satur.html>

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	MW-B2100C									
Top of Screen Elevation (ft)	9.6									
Bottom of Screen Elevation (ft)	-0.4									
Sampling Date	10/4/2016	11/03/2016 ¹	2/24/2017	6/28/2017	9/12/2017	1/10/2018				
Type of Sample	Sample	Sample	Q1 Sample	Q2 Sample	Q3 Sample	Q4 Sample				
Field Measurements										
pH (SU)	5.26	6.98	5.46	5.27	5.41	4.93				
Temperature (°C)	14.42	14.95	16.84	14.44	14.43	14.55				
Dissolved Oxygen (DO, mg/L)	5.90	1.50	7.37	10.84	5.09	4.99				
Redox Potential (ORP; mV)	110.50	124.70	189.80	217.40	216.7	206				
Specific Conductivity (µS/cm) ^c	272.00	297.00	346.00	364.00	377	378				
Turbidity (NTU)	-	8.44	OVER	5.71	2.97	2.87				
Laboratory Analyses										
Nitrogen										
Nitrate as N (mg/L)	1.29	1.29	0.959	0.724	0.903	1.13				
Nitrite as N (mg/L)	-	-	<0.010	<0.01	<0.01	<0.01				
Ammonia (mg/L)	<0.1	<0.1	<0.1	<0.1	0.1	<0.1				
Total Kjeldahl Nitrogen (TKN) (mg/L)	0.72	-	0.54	-	-	0.21				
Total Nitrogen (mg/L)	2.01	1.29	1.5	0.724	1.31	1.33				
Anions										
Chloride (mg/L)	65.4	67.8	83.2	96.4	97.3	97.8				
Sulfate (mg/L)	14.1	16.2	12.1	10	8.3	10.8				
Elements										
Dissolved Iron (mg/L)	0.115	-	0.147	<0.1	-	<0.1				
Dissolved Manganese (mg/L)	0.126	-	0.196	0.114	-	0.102				
Boron (mg/L)	<0.05	-	<0.05	-	-	-				
Sodium (mg/L)	-	-	53.7	-	-	-				
Other										
DOC (mg/L)	<0.5	0.866	0.862	0.959	0.78	2.28				
Methane (µg/L)	<2	-	-	-	-	-				
Alkalinity as CaCO3 (mg/L)	-	-	14	-	-	-				

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D - Duplicate

- DO was measured in the field as DO(%) and was converted using the online tool at: <http://www.hbuehrer.ch/Rechner/O2satur.html>
- MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.
- Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.
- MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Figures

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Chart 1
Nitrate and DOC Concentrations at Eldredge Park Way PRB
Demonstration
MW-B1010C

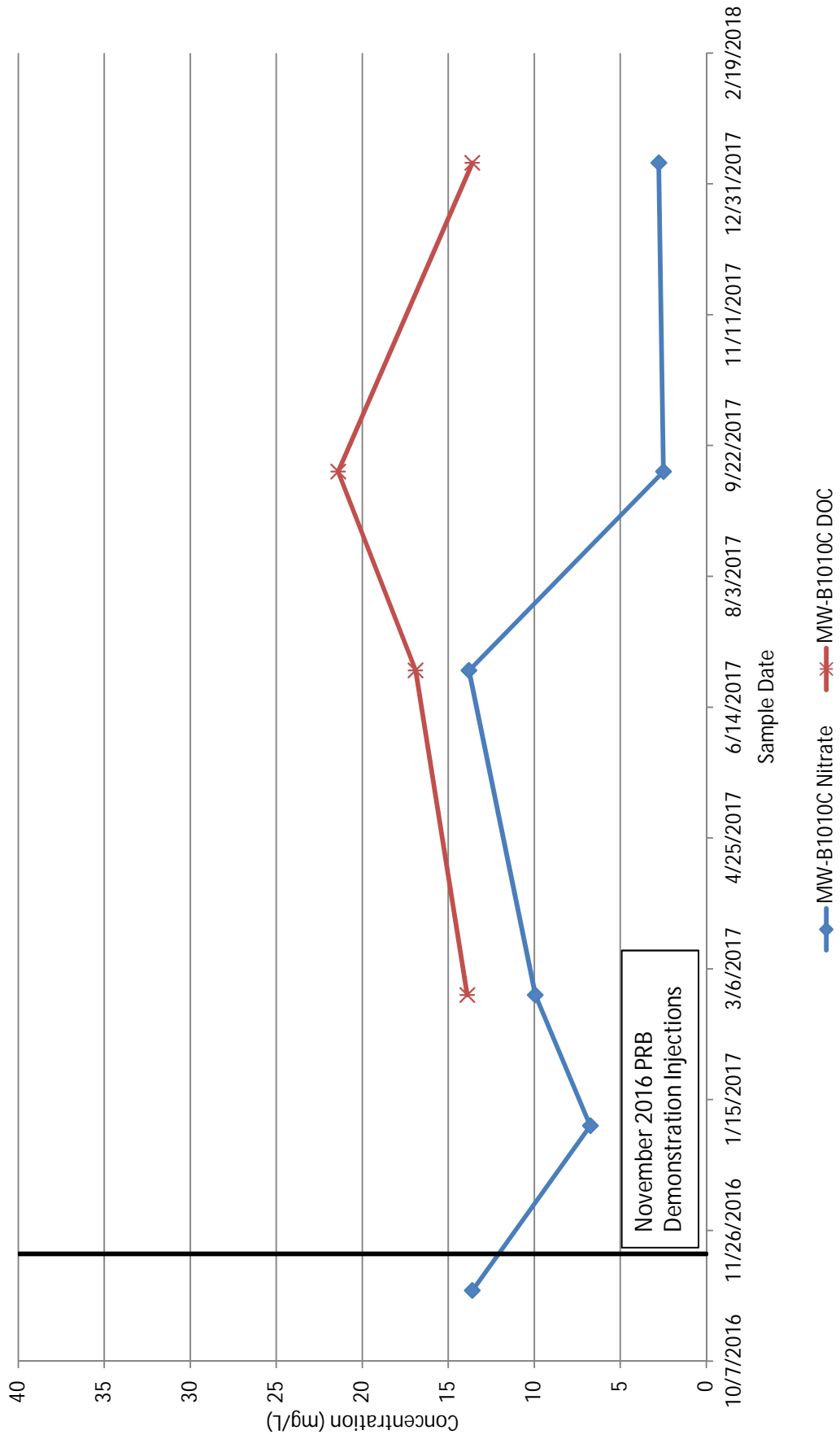


Chart 2
 Nitrate Concentrations at Eldredge Park Way PRB Demonstration
 MW-B2010C

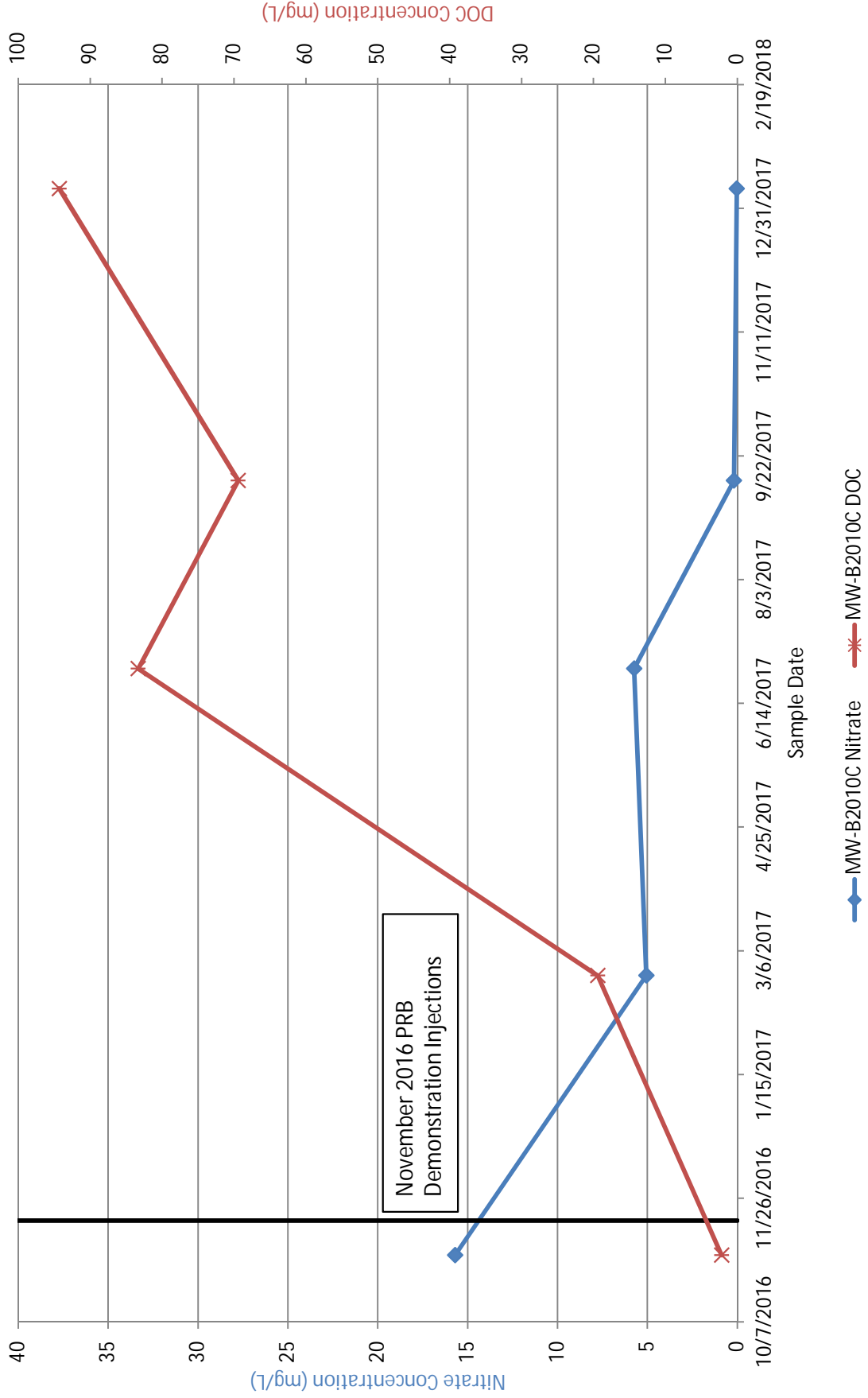


Chart 3
Nitrate and DOC Concentrations at Eldredge Park Way PRB
Demonstration
MW-B1020B

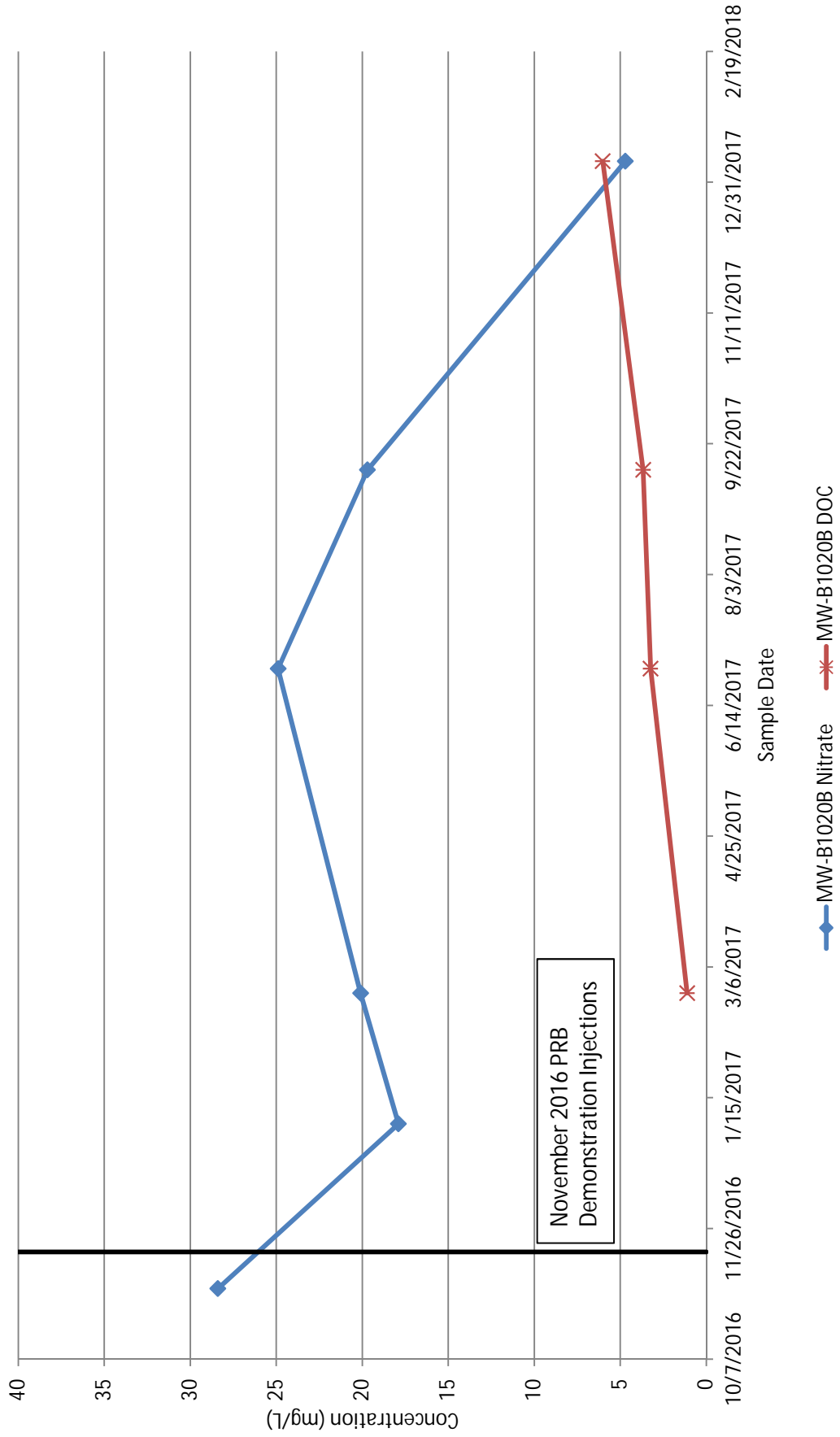


Chart 4
Nitrate and DOC Concentrations at Eldredge Park Way PRB
Demonstration
MW-B1020C

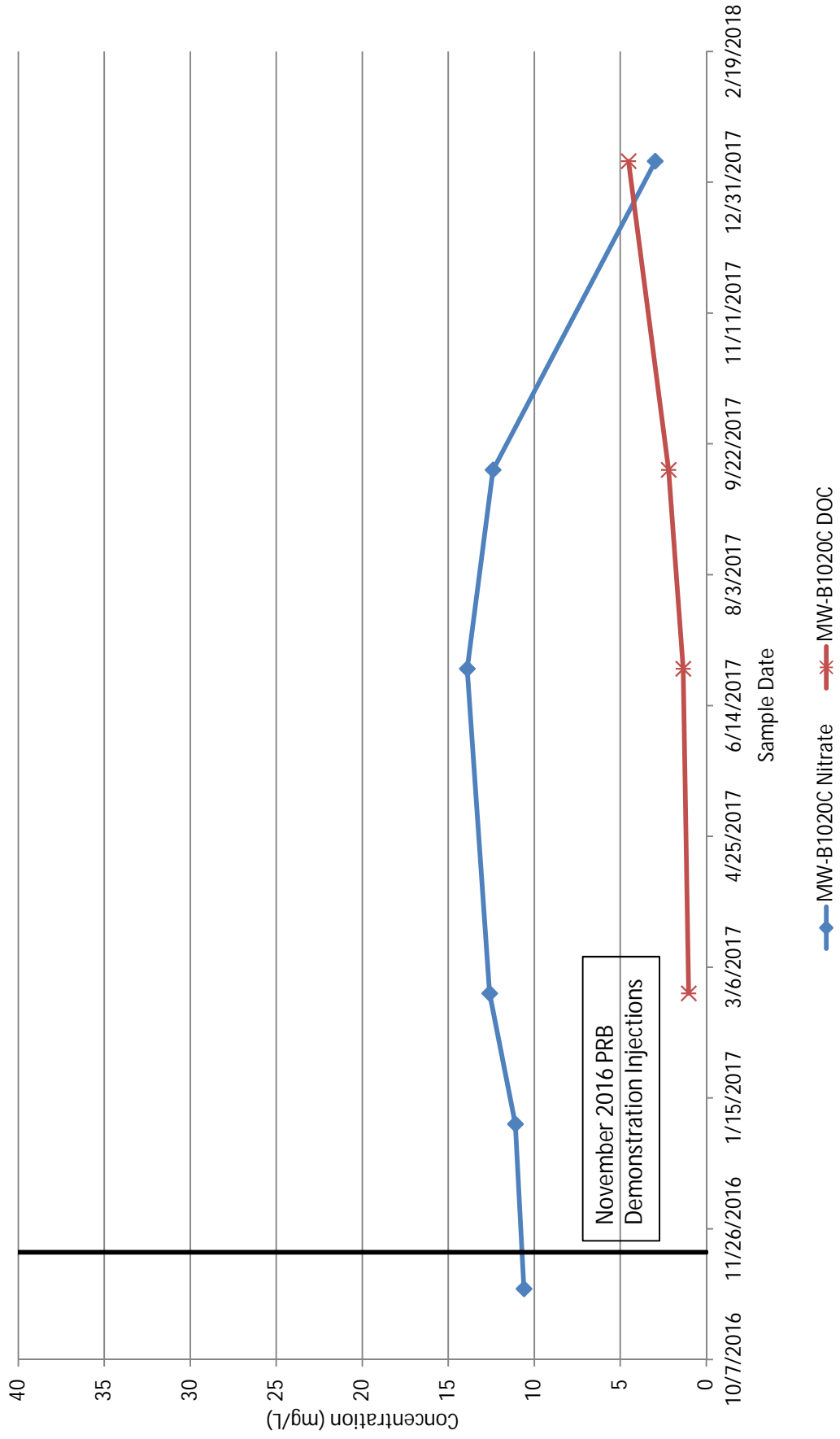


Chart 5
Nitrate Concentrations at Eldredge Park Way PRB Demonstration
MW-B2020B

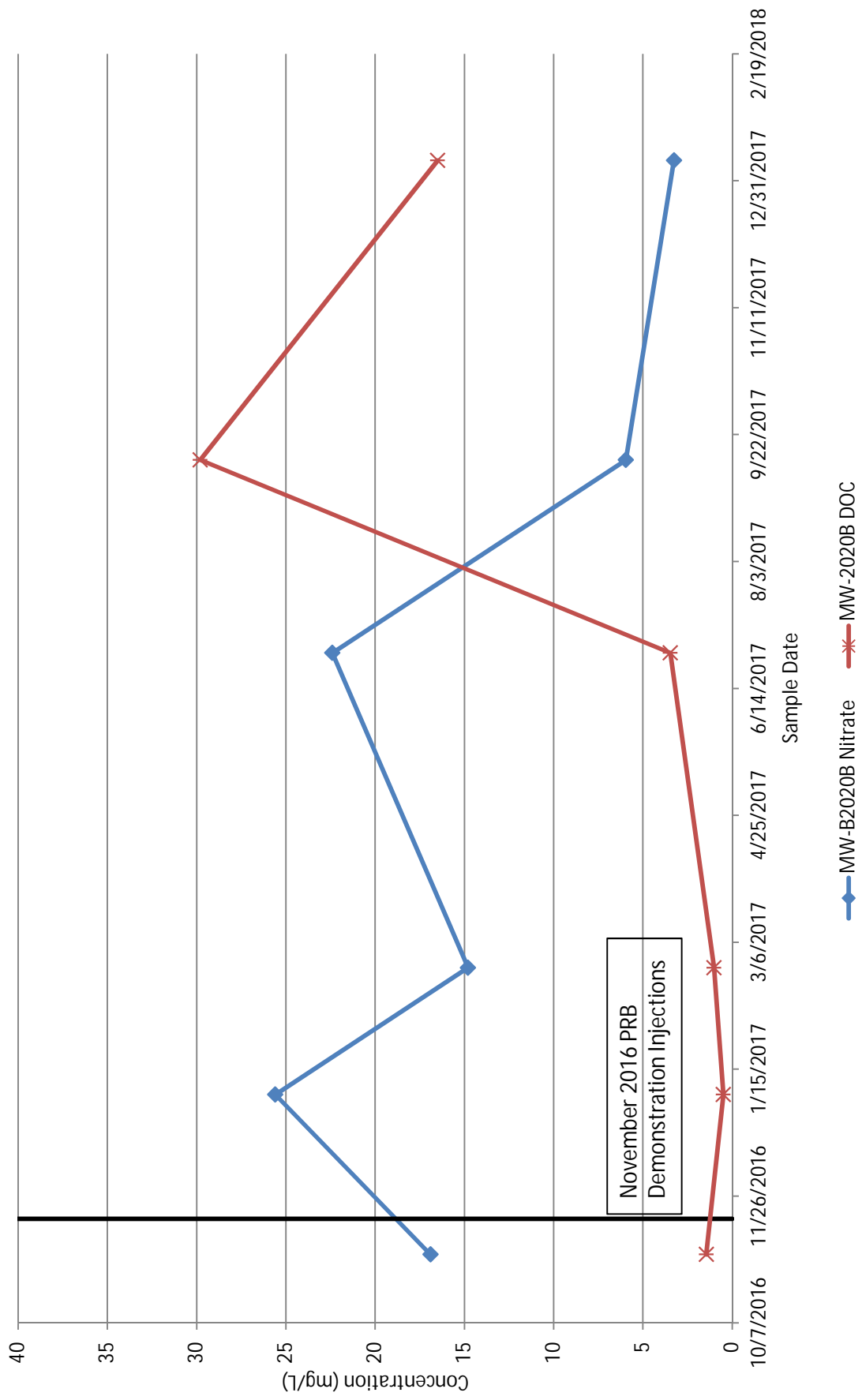


Chart 6
 Nitrate Concentrations at Eldredge Park Way PRB Demonstration
 MW-B2020C

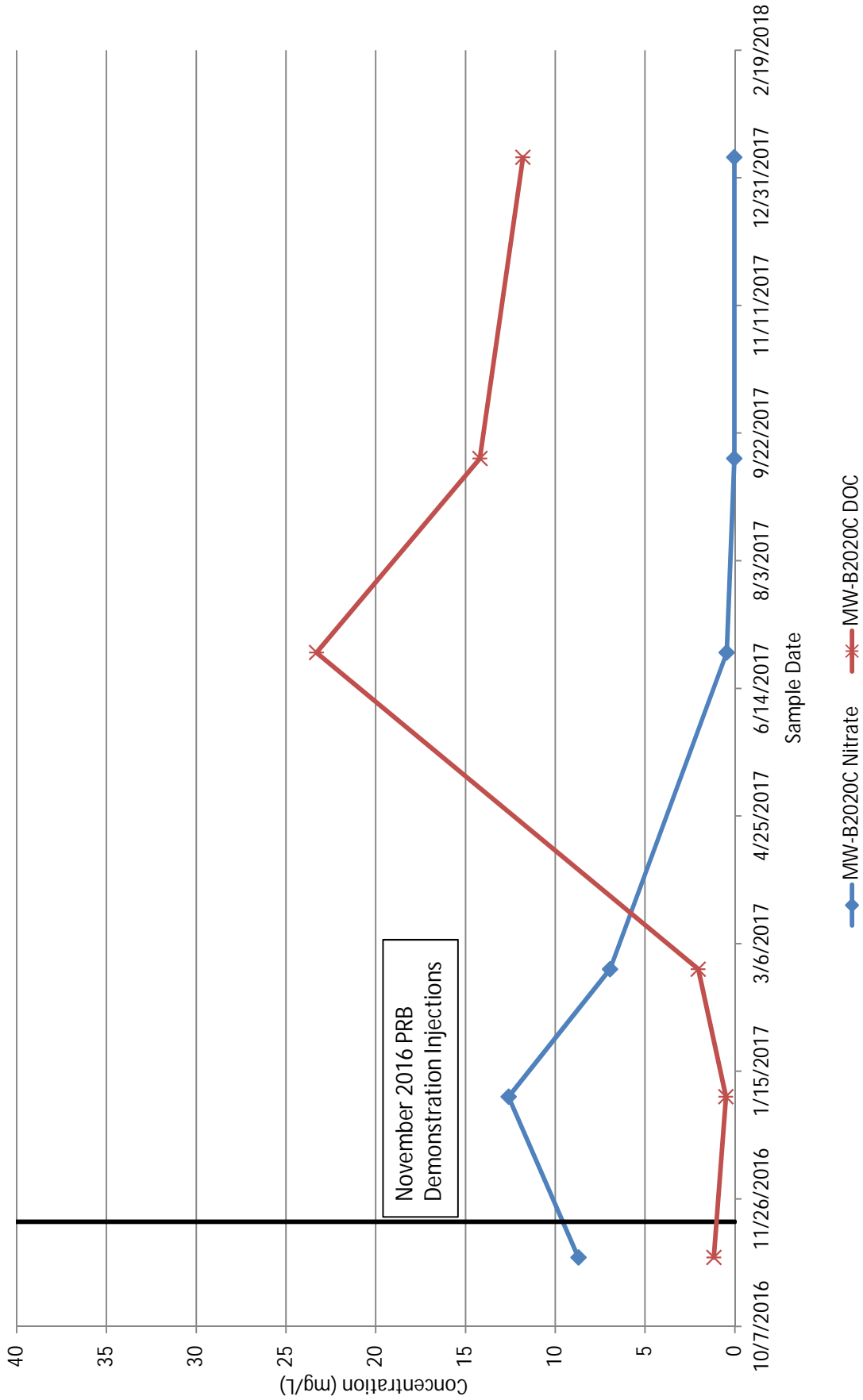


Chart 7
Nitrate Concentrations at Eldredge Park Way PRB Demonstration
MW-B1050A

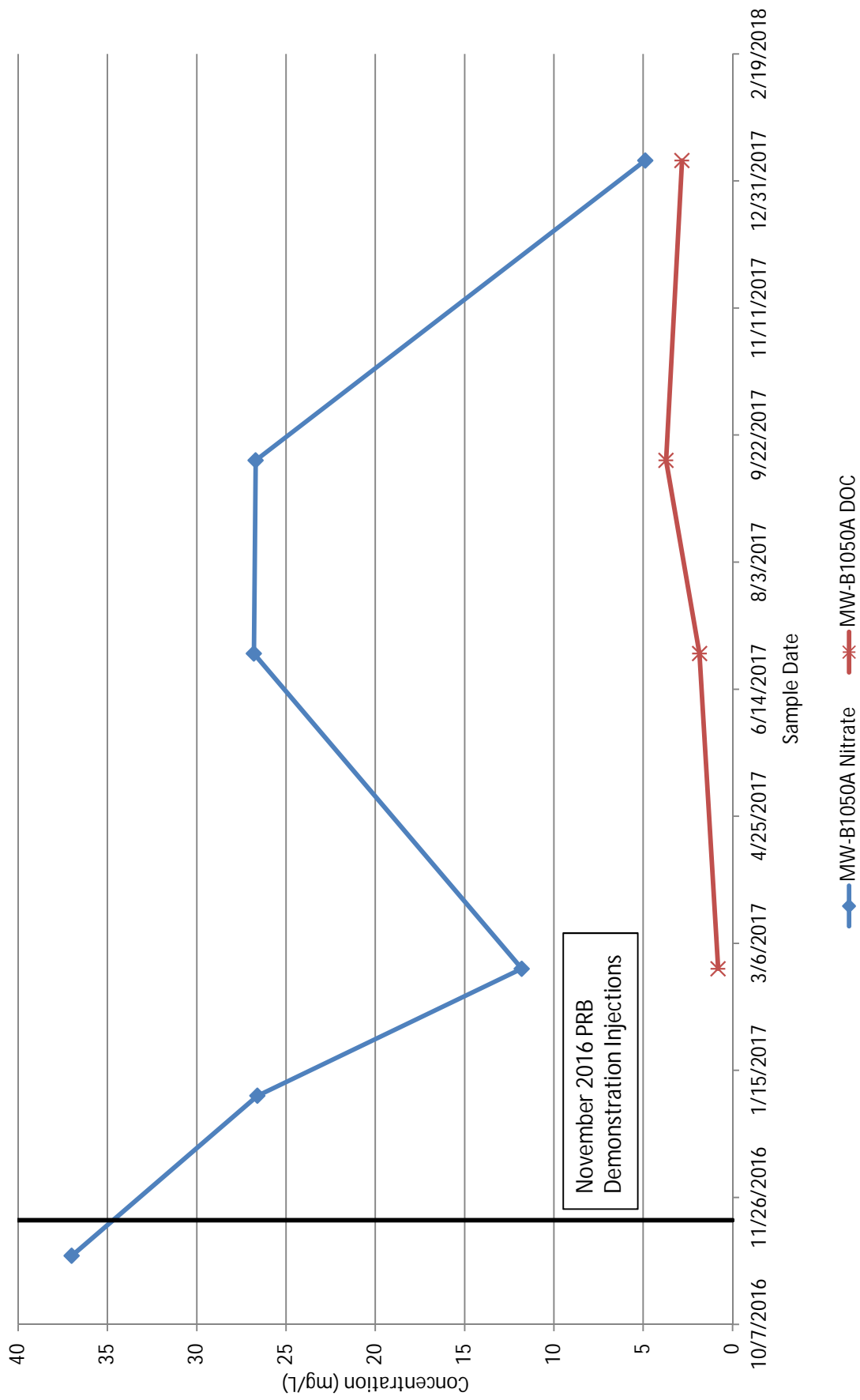
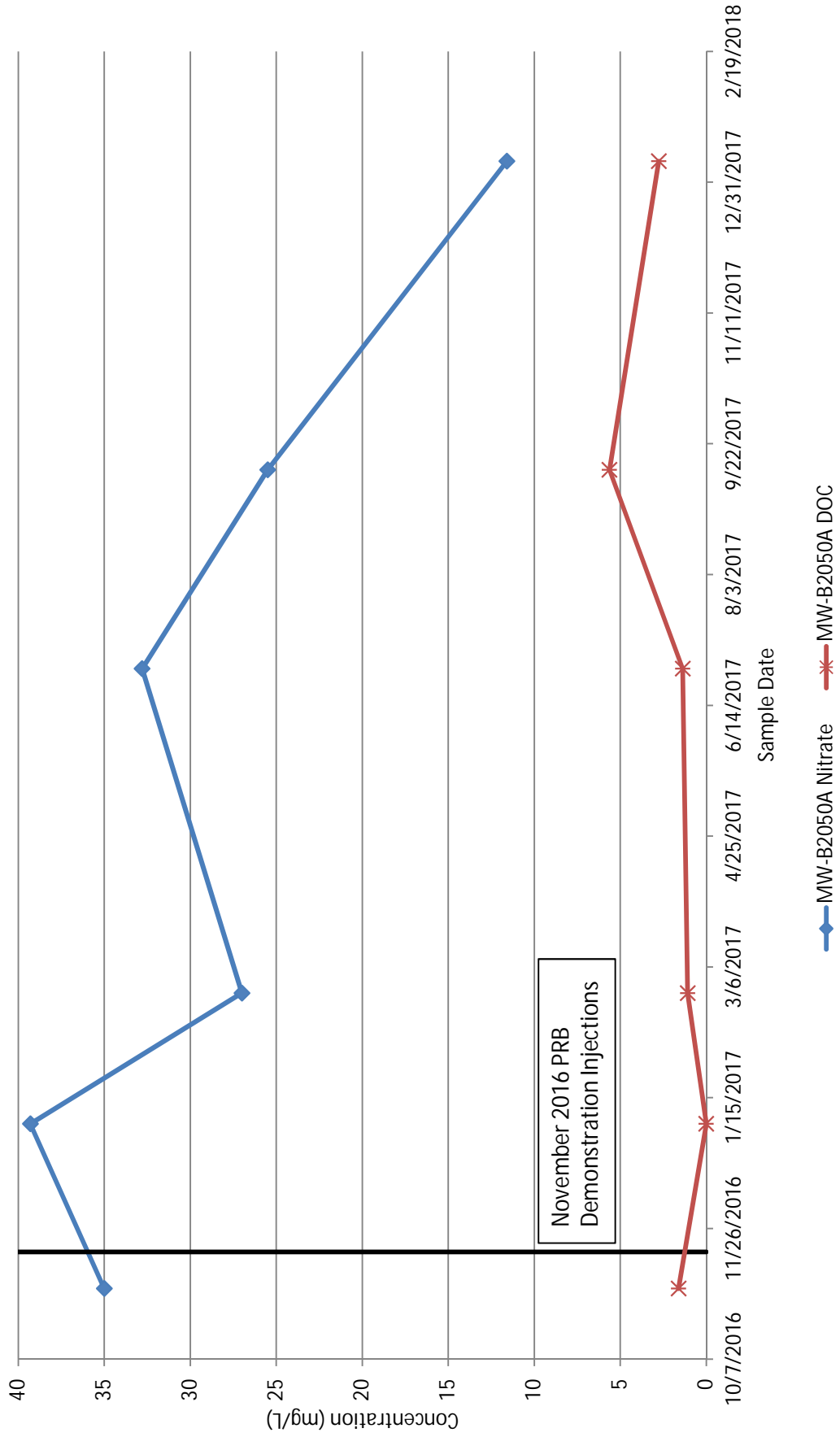


Chart 8
Nitrate and DOC Concentrations at Eldredge Park Way PRB
Demonstration
MW-B2050A



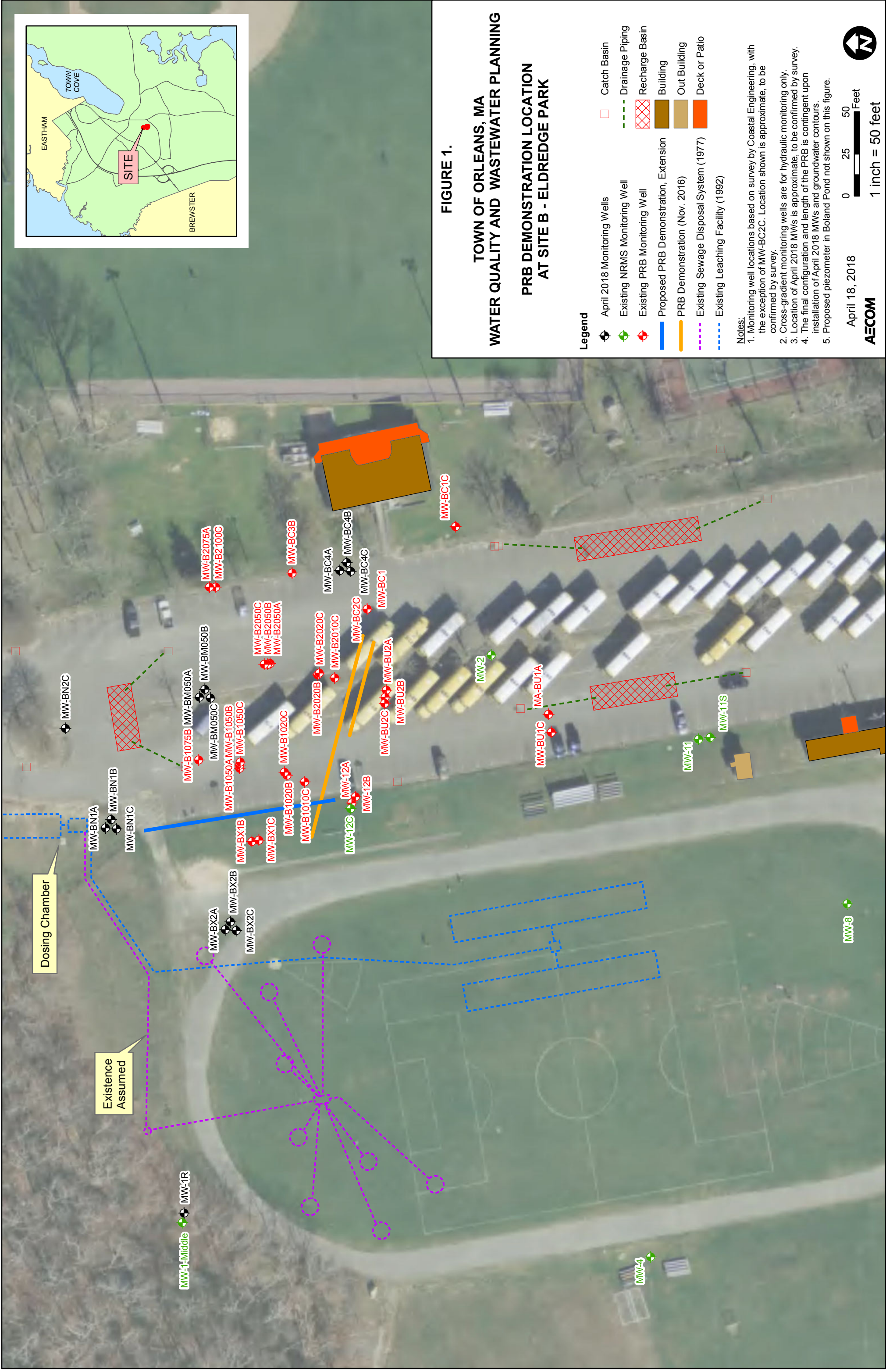
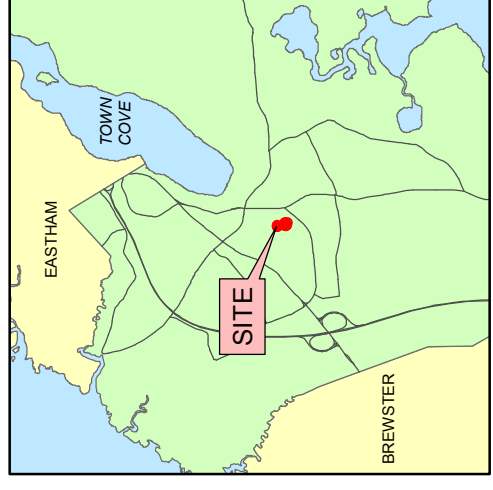


FIGURE 1.

**TOWN OF ORLEANS, MA
WATER QUALITY AND WASTEWATER PLANNING
PRB DEMONSTRATION LOCATION
AT SITE B - ELDRIDGE PARK**



Dosing Chamber

Existence Assumed

MW-1-Middle MW-1R

MW-4

MW-8

MW-11

MW-11S

MW-2

MW-BU1C MA-BU1A

MW-BU2C MW-BU2A MW-BU2B

MW-12C MW-12A MW-12B

MW-B1020B MW-B1020C MW-B1020A

MW-BX1B MW-BX1C MW-BX2A MW-BX2B MW-BX2C

MW-B1050A MW-B1050B MW-B1050C

MW-B1075B MW-BM050A MW-BM050C MW-BM050B

MW-BN1A MW-BN1B MW-BN1C MW-BN2C

MW-B2075A MW-B2100C

MW-B2050C MW-B2050B MW-B2050A

MW-B2020B MW-B2020C MW-B2010C

MW-BC2C MW-BC1 MW-BC4A MW-BC4B MW-BC4C

MW-BC1C





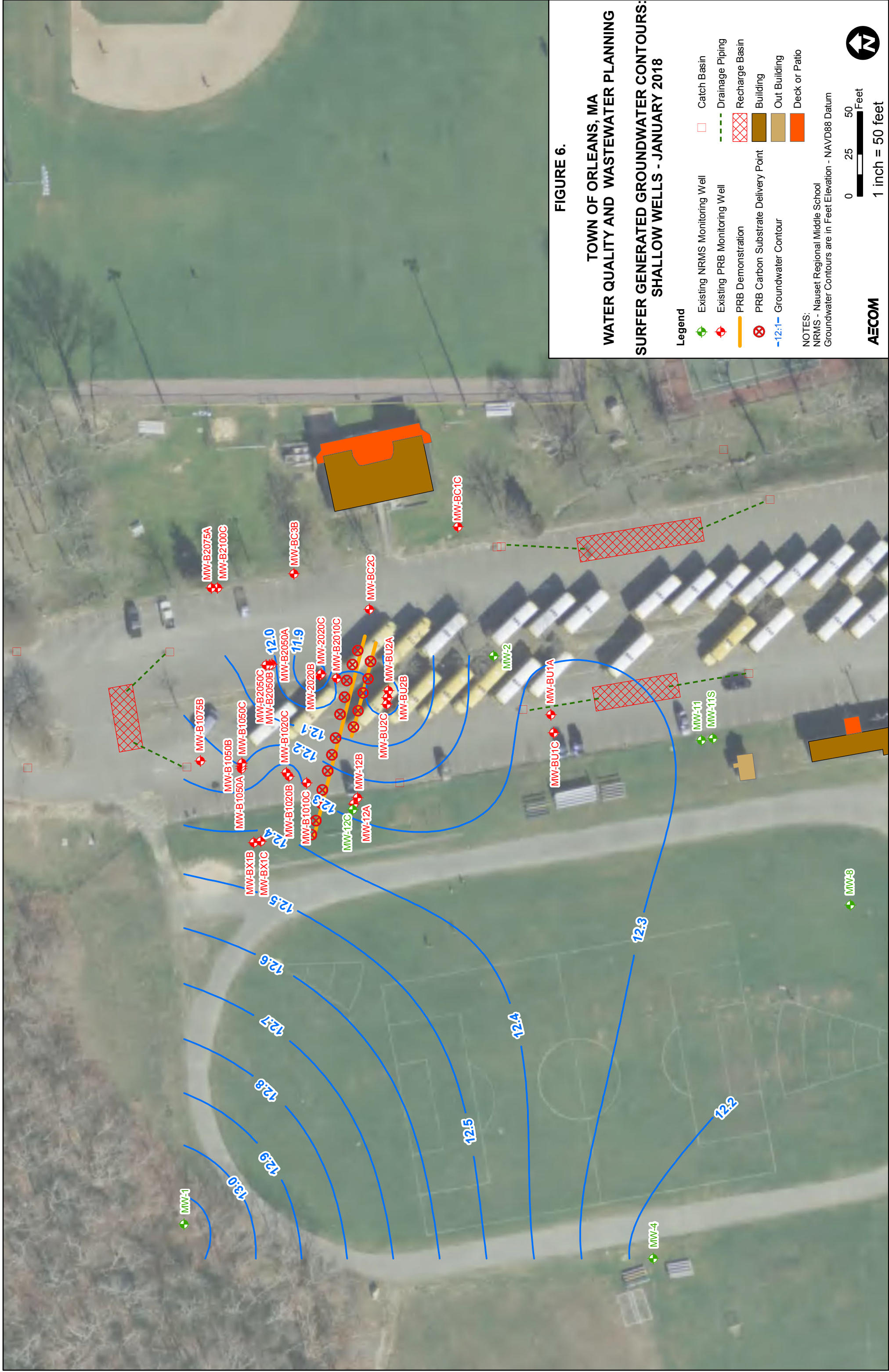


FIGURE 6.
TOWN OF ORLEANS, MA
WATER QUALITY AND WASTEWATER PLANNING
SURFER GENERATED GROUNDWATER CONTOURS -
SHALLOW WELLS - JANUARY 2018

- Legend**
- + Existing NRMS Monitoring Well
 - + Existing PRB Monitoring Well
 - + PRB Demonstration
 - ⊗ PRB Carbon Substrate Delivery Point
 - 12:1- Groundwater Contour
 - Catch Basin
 - Drainage Piping
 - Recharge Basin
 - Building
 - Out Building
 - Deck or Patio

NOTES:
 NRMS - Nauset Regional Middle School
 Groundwater Contours are in Feet Elevation - NAVD88 Datum

AECOM

0 25 50 Feet
 1 inch = 50 feet



FIGURE 8.

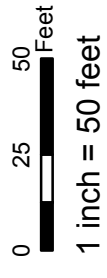
**TOWN OF ORLEANS, MA
WATER QUALITY AND WASTEWATER PLANNING**

**SURFER GENERATED GROUNDWATER
CONTOURS: DEEP WELLS - JANUARY 2018**

Legend

- + Existing NRMS Monitoring Well
- + Existing PRB Monitoring Well
- + PRB Demonstration
- + PRB Carbon Substrate Delivery Point
- Groundwater Contour
- Catch Basin
- Drainage Piping
- Recharge Basin
- Building
- Out Building
- Deck or Patio

NOTES:
NRMS - Nauset Regional Middle School
Groundwater Contours are in Feet Elevation - NAVD88 Datum



AECOM

