WRIGHT-PIERCE
Engineering a Better Environment

MEMORANDUM DRAFT

TO:	Art Ditto, Rye Water District Arik Jones, Rye Water District	DATE:	March 15, 2019
FROM:	Greg Smith, Rick Davee, Chris Berg, Lauren Thistle	PROJECT NO.:	14207A
SUBJECT:	Cedar Run Well Cleaning and Organics Evaluation		

This memo summarizes activities completed during the 2019 packer testing and cleaning of the Cedar Run Well in Rye, NH. The Cedar Run Well, displayed on Figure 1, currently serves as one of the drinking supply wells for the Town of Rye. Original safe yield of the well is reported to be 350 gpm. Well diameter and depth are 10 inches and 437 feet, respectively. Evaluation of water quality issues in the distribution system led Rye Water District (RWD) to believe the Cedar Run well is the source of metals and organics in the water system.

An assessment was done on the Cedar Run Well including downhole video to asses the well seal, borehole, and water bearing fractures. Rehabilitation of the well was conducted including pre and post cleaning performance tests, chemical treatment, surging/redevelopment, and pump repairs. The goal of this assessment was to determine which fracture zones were producing the elevated concentrations of metals, and whether modifications to the Cedar Run Well could mitigate degrading water quality.

Down-Hole Well Assessment

The Cedar Run Well pump was removed and cleaned by Dennis L. Maher Company. Pump repairs were completed, and the pump was installed back into the well. Fracture depths and widths below top of casing (TOC) were recorded using a WellVu submersible video camera. Based on observations during the well assessment, it was concluded that the main water bearing fracture zones were between 170 and 240 feet below TOC. Isolated small fracture zones were observed from 314 to 388 feet below TOC that were generally 0.5 feet in width or smaller. The integrity of the well seal between the casing and bedrock was also assessed. The seal was observed at a depth of 154 feet below TOC and was observed to be intact with no obvious cracks or indication of leaks.

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Well Cleaning

Rehabilitation of Cedar Run Well

The well cleaning followed a multi-step treatment process designed specifically for the Cedar Run Well which included the use of mechanical and chemical treatments. The mechanical cleaning process included pump and surge techniques to redevelop the well. The well was mechanically pumped and surged for 40 hours. Chemical treatments included injections of muriatic acid, NuWell 310, and chlorine. The starting specific capacity of the well was approximately 9.3 gallons per minute per foot of drawdown (gpm/ft). Following well rehabilitation, the specific capacity increased by approximately 0.8 gpm/ft. The final specific capacity was 10.1 gpm/ft during the final test.

Video inspection of the Cedar Run well was conducted before the well cleaning. Well video will be sent electronically to RWD. Pre-cleaning inspection showed significant iron bacteria growth within the well bore from 170 to 240 feet.

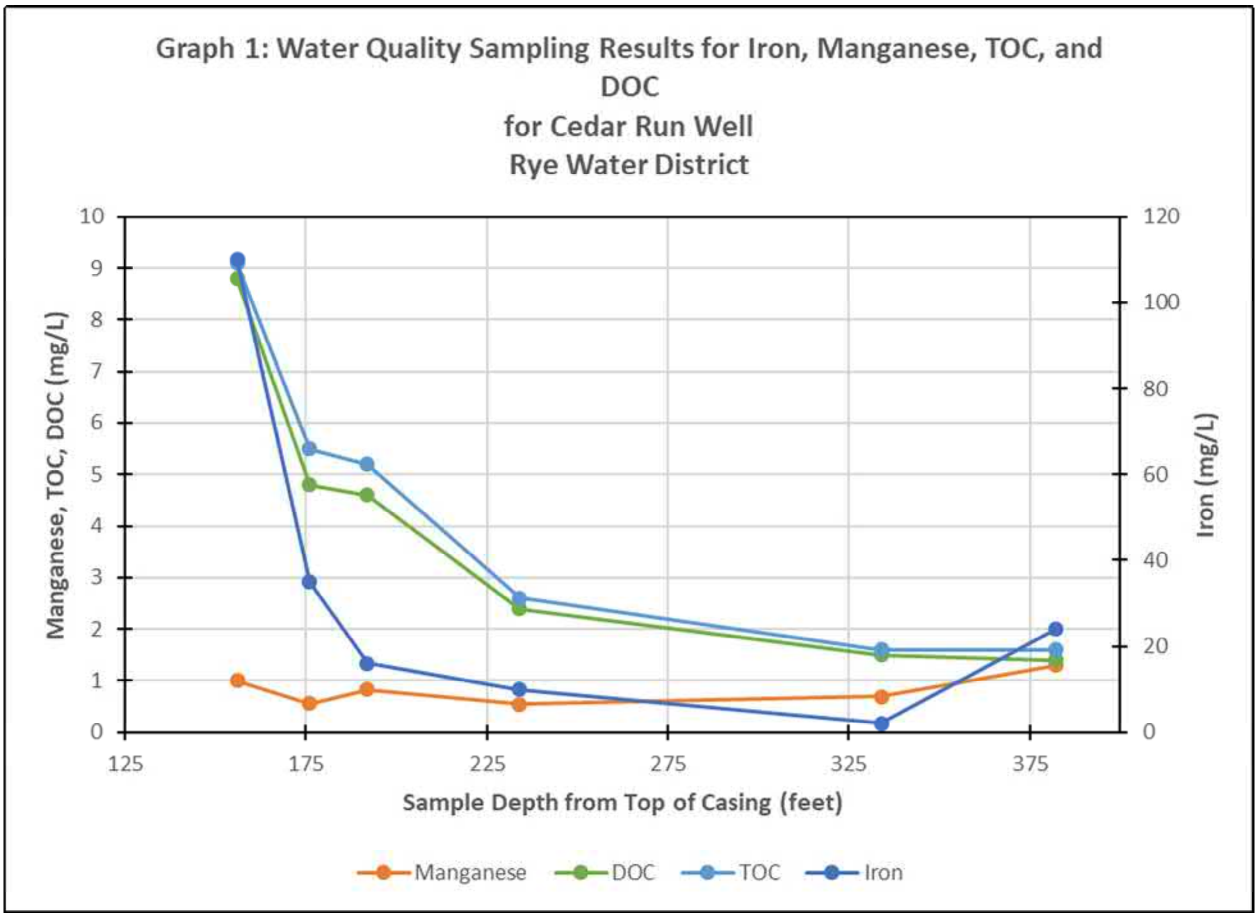
Packer Sampling

Water sampling for iron and manganese concentrations in isolated fracture zones was performed using a packer sampling method from February 5 to February 6, 2019. Smith Pump Company, Inc. of Hooksett, New Hampshire supplied a packer sampling setup that consisted of two packers spaced approximately ten feet apart. The packers were placed above and below the sample zone to isolate fracture zones. Water was then pumped to the surface for a minimum of three times the volume within the packers to minimize the influence of turbidity on analytical results. Six water samples were submitted to Eastern Analytical, Inc. of Concord, New Hampshire for water quality analysis. Laboratory results are attached. Packer sampling results are summarized in Table 1.

Table 1
Packer Sampling Summary

Depth (below TOC)	Iron (mg/L)	Manganese (mg/L)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Total Organic Carbon (mg/L)	Dissolved Organic Carbon (mg/L)	pH
151-161 (End casing)	110	1.0	18	<1	9.1	8.8	3.76
171-181	35	0.56	29	60	5.5	4.8	6.17
187-197	16	0.83	35	57	5.2	4.6	6.14
229-239	10	0.54	48	98	2.6	2.4	6.47
329-339	20	0.70	45	76	1.6	1.5	6.46
377-387	24	1.3	62	55	1.6	1.4	6.13

TOC = top of casing
Mg/l = milligrams per liter



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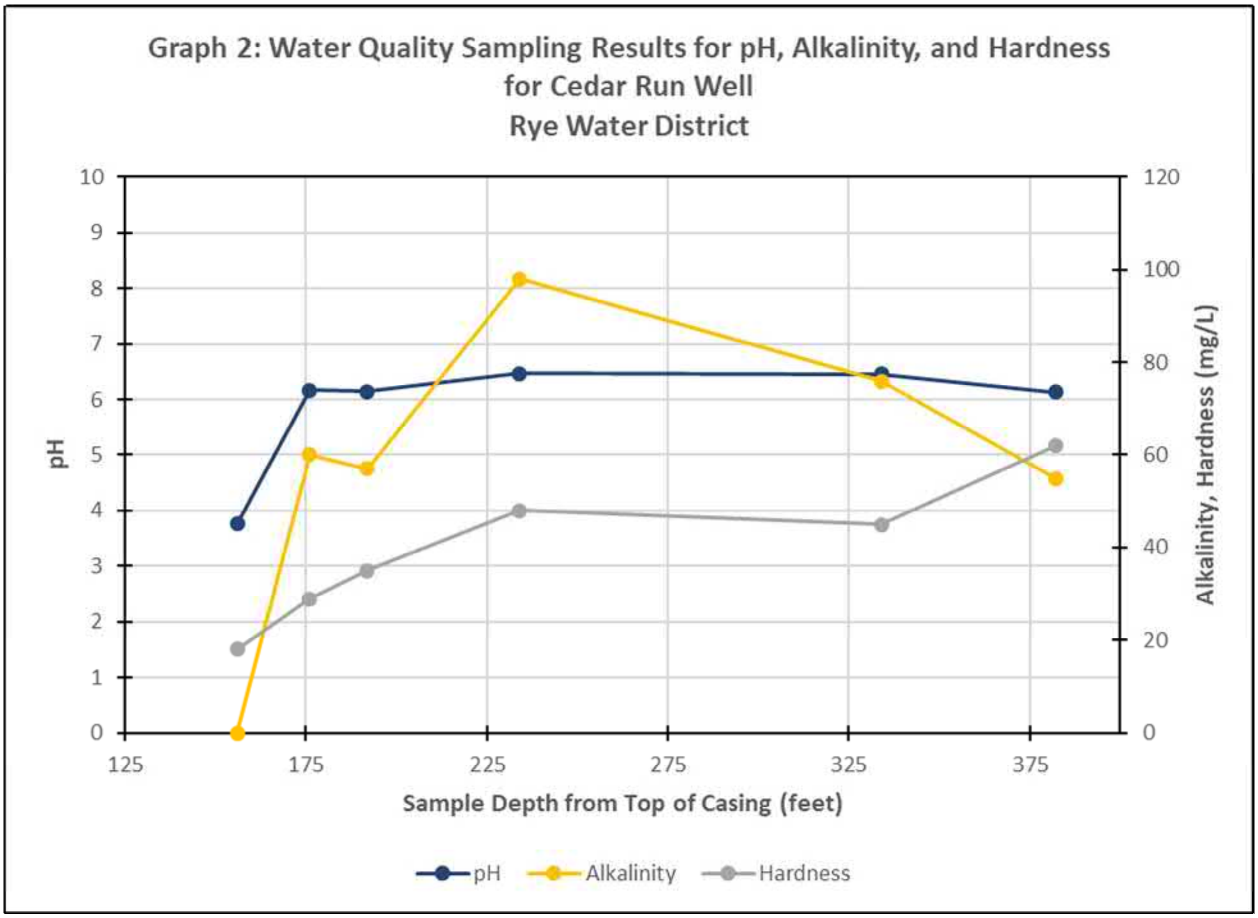
Graph 1 shows concentrations of manganese, iron, total organic carbon, and dissolved organic carbon in milligrams per liter (mg/L) at decreasing well depths. The shallowest sample taken at the end of the casing from 151-161 feet shows the highest concentration of total organic carbon, dissolved organic carbon, and iron. pH for this sample is very low at 3.76. Total organic carbon and dissolved organic carbon remain high for samples at 171-181 feet and 187-197 feet and decrease with depth. Iron generally decreases with depth in the well until the deepest sample from 377-387 feet which has a slightly higher concentration of iron. Manganese is consistent throughout the depth of the well and is highest for the shallowest sample from 151-161 feet and for the deepest sample from 377-387 feet.



Graph 2 shows sample concentrations for hardness and alkalinity in mg/L and pH at decreasing well depths. pH is very low for the shallowest sample at the end of the casing from 151-161 feet at 3.76. All other pH samples are between 6.13-6.47 and are within the normal range for groundwater. Alkalinity and hardness are lowest for the shallowest sample at the end of casing from 151-161 feet. Hardness mostly increases with depth. Alkalinity increases with depth until 229-239 feet, then decreases with depth. The maximum alkalinity and hardness are 98 mg/L and 62 mg/L respectively. These overall low concentrations of alkalinity and hardness are good water quality especially from a bedrock well for these parameters.

Results and Recommendations

Field water quality testing and laboratory results indicate decreasing total organic carbon and dissolved organic carbon with well depth. There is elevated iron and manganese from all zones similar to that of the overall water quality of the well. Iron is highest in shallow zones from 151-181 feet. Manganese concentrations were generally consistent across well depths. Alkalinity and hardness are found at relatively low levels across well depths. Elevated organics are due to the migration of surface water from nearby surface water bodies, most likely from the east. However, given the complex nature of bedrock aquifers, it is nearly impossible to determine the origin of the organics given the available data. Poor water quality at the bottom of the well casing indicates a well seal integrity issue. Since poor water quality is found to most likely be entering the well through shallow fracture zones, modifications to the Cedar Run Well could have a beneficial effect on water quality. Wright-Pierce has identified several potential courses of action based on the findings of this study.

Over-drilling the casing and extending the casing depth deeper is a potential option, however given the depth that the casing is set into rock, this is an extremely risky approach with a high risk of rendering the well unusable. This approach is not recommended.

The installation of a Jaswell type seal to isolate zones of poor water quality could be installed. WP is currently looking into the feasibility and costs for this approach. Generally, the idea of this seal is to isolate fractures with poor water quality. This would likely require sealing off the entire high yielding fracture zone from the bottom of the casing to approximately 240 feet below ground. A shorter seal could be installed, however, it is likely that the fractures in this zone are all hydraulically connected and the poor water quality would rapidly migrate to lower portions of this zone under pumping conditions. Sealing off the main fracture zone would result in a significant reduction in well yield and would rely entirely on two small deeper fracture zones. The yield of the well with a Jaswell seal is nearly impossible to determine, however given the fracture distribution the well would likely yield between 50 to 100 gpm or possibly less.

A potential option for retaining well yield while improving water quality is exploring the Cedar Run Well site vicinity for a suitable location for a replacement well. Geophysical exploration using electrical resistivity surveys can provide data on bedrock geology and fracture geometry at the site. When these wells were originally sited, they were drilled directly over a lineament, thus the shallow fractures. If the structure is dipping (angled), the high-yield fractures can be intersected at greater depths and any shallow fractures cased off, resulting in a preferential draw of water from the deeper fractured bedrock aquifer. Furthermore, there is potential that the well could be sighted farther from surface water bodies (sources of organics and water chemistry that mobilizes iron) further improving and potentially resulting in sustainable water quality in the well.

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In accordance with New Hampshire Department of Environmental Services (NHDES) Env-Wq 403.36, a new well installed to replace or back-up an existing well that operates and impacts water users and water resources in substantially the same manner as the well that is being replaced is considered a replacement well and requires much less permitting compared to a new source. The area surrounding the existing Cedar Run Well is undeveloped but has multiple property owners (Figure 2). The new well site would need to have control through easement or ownership of a 400 foot radius surrounding the replacement well site.

Another potential option is the possibility of a multi-well type approach. This would require a replacement well downgradient from the wetlands that intersects deeper fractures to serve as a water supply well. The existing Cedar Run Well could act as an interception well and would be run to waste. This would remove the poor water quality entering the fractures from the pond and wetland area to the east-northeast. This would require some additional permitting and vetting with NHDES but offers a potential longer-term solution. It is likely that this option would be difficult to permit and could potentially meet significant pushback by NHDES. However, we do recommend that RWD consider all options

The success rate increases with each option, as does cost and complexity. However, new sources are costly to develop, and it would be a significant savings if the well could be salvaged.

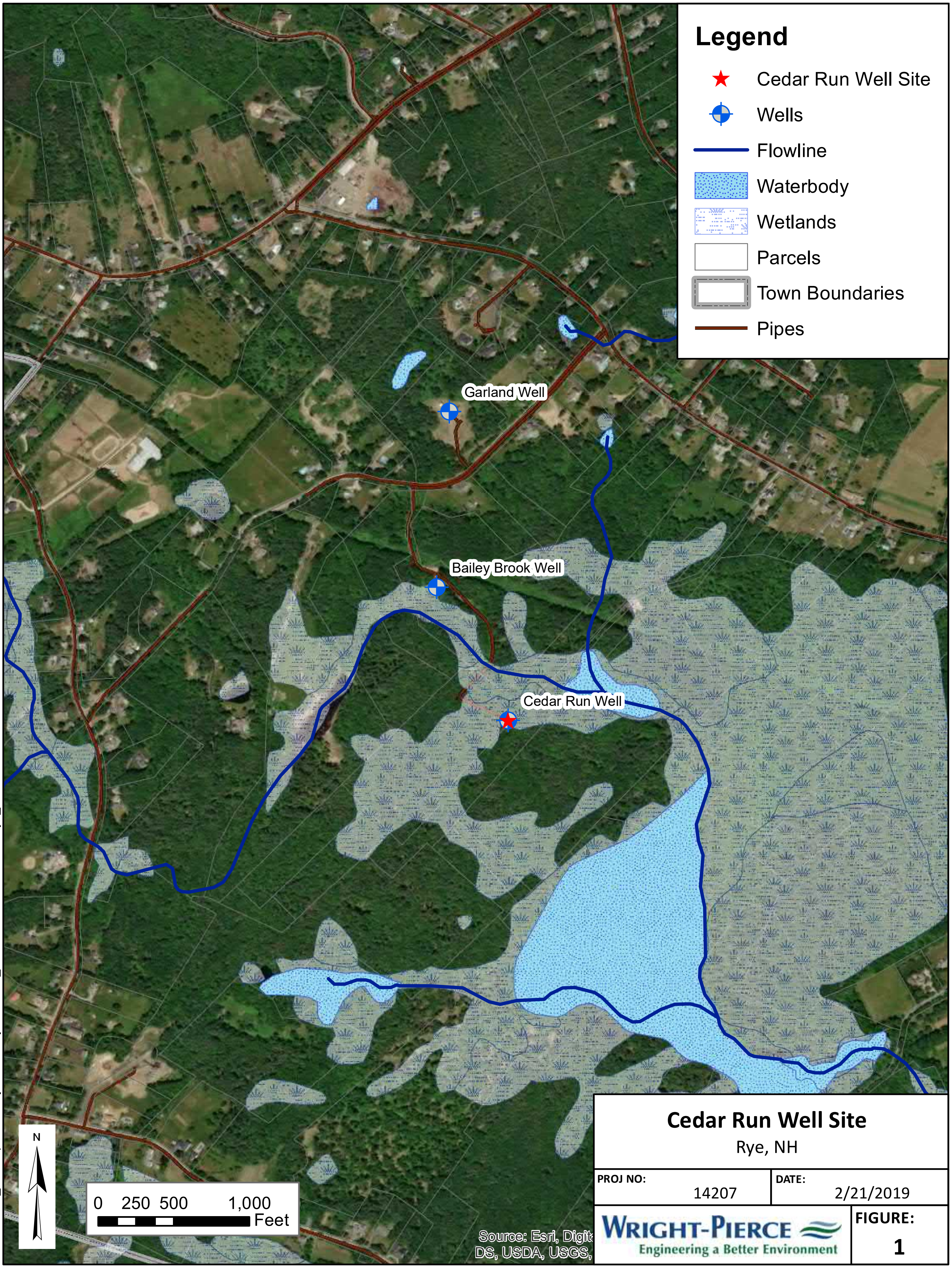
Thank you and please don't hesitate to call me with any questions.

Sincerely,
WRIGHT-PIERCE

Greg Smith

Christopher Berg, P.E.
Project Manager

Greg Smith, PG, CG
Lead Hydrogeologist



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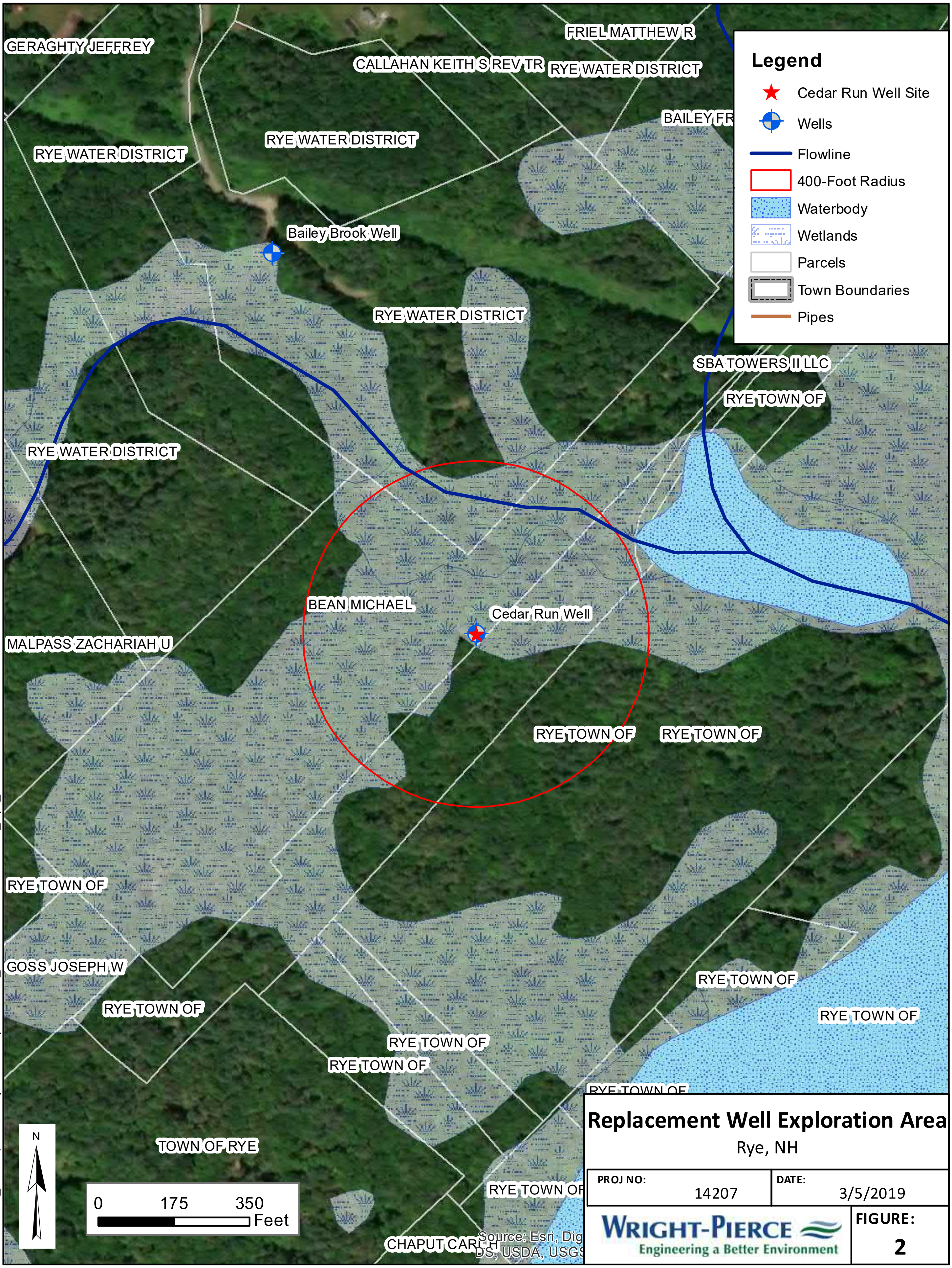

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Eastern Analytical, Inc.

professional laboratory and drilling services

Greg Smith
Wright-Pierce (NH)
230 Commerce Way, Suite 302
Portsmouth , NH 03801

Subject: Laboratory Report

Eastern Analytical, Inc. ID:	191828
Client Identification:	Cedar Run Well | 14207A
Date Received:	2/6/2019

Dear Mr. Smith :

Enclosed please find the laboratory report for the above identified project. All analyses were performed in accordance with our QA/QC Program. Unless otherwise stated, holding times, preservation techniques, container types, and sample conditions adhered to EPA Protocol. Samples which were collected by Eastern Analytical, Inc. (EAI) were collected in accordance with approved EPA procedures. Eastern Analytical, Inc. certifies that the enclosed test results meet all requirements of NELAP and other applicable state certifications. Please refer to our website at www.easternanalytical.com for a copy of our NELAP certificate and accredited parameters.

The following standard abbreviations and conventions apply to all EAI reports:

Solid samples are reported on a dry weight basis, unless otherwise noted
< : "less than" followed by the reporting limit
> : "greater than" followed by the reporting limit
%R : % Recovery

Eastern Analytical Inc. maintains certification in the following states: Connecticut (PH-0492), Maine (NH005), Massachusetts (M-NH005), New Hampshire/NELAP (1012), Rhode Island (269), Vermont (VT1012) and New York (12072).

The following information is contained within this report: Sample Conditions summary, Analytical Results/Data, Quality Control data (if requested) and copies of the Chain of Custody. This report may not be reproduced except in full, without the the written approval of the laboratory.

If you have any questions regarding the results contained within, please feel free to directly contact me or the chemist(s) who performed the testing in question. Unless otherwise requested, we will dispose of the sample (s) 30 days from the sample receipt date.

We appreciate this opportunity to be of service and look forward to your continued patronage.

Sincerely,

Lorraine Olashaw

Lorraine Olashaw, Lab Director

2-14-19
Date

4
\# of pages (excluding cover letter)

SAMPLE CONDITIONS PAGE

EAI ID#: **191828**

Client: **Wright-Pierce (NH)**

Client Designation: **Cedar Run Well | 14207A**

Temperature upon receipt (°C): 3.3 **Received on ice or cold packs (Yes/No): Y**

Acceptable temperature range (°C): 0-6

Lab ID	Sample ID	Date Received	Date Sampled	Sample Matrix	% Dry Weight	Exceptions/Comments (other than thermal preservation)
191828.01	156ft	2/6/19	2/6/19	aqueous		Adheres to Sample Acceptance Policy
191828.02	176ft	2/6/19	2/6/19	aqueous		Adheres to Sample Acceptance Policy
191828.03	192ft	2/6/19	2/6/19	aqueous		Adheres to Sample Acceptance Policy
191828.04	234ft	2/6/19	2/6/19	aqueous		Adheres to Sample Acceptance Policy
191828.05	334ft	2/6/19	2/6/19	aqueous		Adheres to Sample Acceptance Policy
191828.06	382ft	2/6/19	2/6/19	aqueous		Adheres to Sample Acceptance Policy

Samples were properly preserved and the pH measured when applicable unless otherwise noted. Analysis of solids for pH, Flashpoint, Ignitability, Paint Filter, Corrosivity, Conductivity and Specific Gravity are reported on an "as received" basis.
Immediate analyses, pH, Total Residual Chlorine, Dissolved Oxygen and Sulfite, performed at the laboratory were run outside of the recommended 15 minute hold time.

All results contained in this report relate only to the above listed samples.

References include:

1) EPA 600/4-79-020, 1983
2) Standard Methods for Examination of Water and Wastewater, 20th, 21st, 22nd & 23rd Edition or noted Revision year.
3) Test Methods for Evaluating Solid Waste SW 846 3rd Edition including updates IVA and IVB
4) Hach Water Analysis Handbook, 4th edition, 1992

LABORATORY REPORT

EAI ID#: **191828**

Client: **Wright-Pierce (NH)**

Client Designation: **Cedar Run Well | 14207A**

Sample ID:	156ft	176ft	192ft	234ft		Analysis			
Lab Sample ID:	191828.01	191828.02	191828.03	191828.04					
Matrix:	aqueous	aqueous	aqueous	aqueous					
Date Sampled:	2/6/19	2/6/19	2/6/19	2/6/19					
Date Received:	2/6/19	2/6/19	2/6/19	2/6/19	**Units**	**Date**	**Time**	**Method**	**Analyst**
Alkalinity Total (CaCO3)	< 1	**60**	**57**	**98**	mg/L	02/07/19	8:49	2320B-11	ATA
TOC	**9.1**	**5.5**	**5.2**	**2.6**	mg/L	02/11/19	12:30	5310C-00	LO
Dissolved Organic Carbon	**8.8**	**4.8**	**4.6**	**2.4**	mg/L	02/11/19	12:17	5310C-00	LO
pH	**3.76**	**6.17**	**6.14**	**6.47**	SU	02/06/19	15:30	4500H+B-11	KL

Sample ID:	334ft	382ft		Analysis			
Lab Sample ID:	191828.05	191828.06					
Matrix:	aqueous	aqueous					
Date Sampled:	2/6/19	2/6/19					
Date Received:	2/6/19	2/6/19	**Units**	**Date**	**Time**	**Method**	**Analyst**
Alkalinity Total (CaCO3)	**76**	**55**	mg/L	02/07/19	8:49	2320B-11	ATA
TOC	**1.6**	**1.6**	mg/L	02/11/19	14:05	5310C-00	LO
Dissolved Organic Carbon	**1.5**	**1.4**	mg/L	02/11/19	15:25	5310C-00	LO
pH	**6.46**	**6.13**	SU	02/06/19	15:40	4500H+B-11	KL

LABORATORY REPORT

EAI ID#: **191828**

Client: **Wright-Pierce (NH)**

Client Designation: **Cedar Run Well | 14207A**

Sample ID:	156ft	176ft	192ft	234ft					
Lab Sample ID:	191828.01	191828.02	191828.03	191828.04					
Matrix:	aqueous	aqueous	aqueous	aqueous					
Date Sampled:	2/6/19	2/6/19	2/6/19	2/6/19	**Analytical Matrix**	**Units**	**Date of Analysis**	**Method**	**Analyst**
Date Received:	2/6/19	2/6/19	2/6/19	2/6/19					
Iron	**110**	**35**	16	**10**	AqTot	mg/L	2/8/19	200.8	DS
Manganese	**1.0**	**0.56**	**0.83**	**0.54**	AqTot	mg/L	2/8/19	200.8	DS
Total Hardness (as CaCO3)	**18**	**29**	**35**	**48**	AqTot	mg/L	2/8/19	200.8	DS

Sample ID:	334ft	382ft					
Lab Sample ID:	191828.05	191828.06					
Matrix:	aqueous	aqueous					
Date Sampled:	2/6/19	2/6/19	**Analytical Matrix**	**Units**	**Date of Analysis**	**Method**	**Analyst**
Date Received:	2/6/19	2/6/19					
Iron	**20**	**24**	AqTot	mg/L	2/8/19	200.8	DS
Manganese	**0.70**	**1.3**	AqTot	mg/L	2/8/19	200.8	DS
Total Hardness (as CaCO3)	**45**	**62**	AqTot	mg/L	2/8/19	200.8	DS

CHAIN-OF-CUSTODY RECORD

191828

BOLD FIELDS REQUIRED. PLEASE CIRCLE REQUESTED ANALYSIS.

Sample I.D.	Sampling Date/Time *If Composite, Indicate Both Start & Finish Date/Time	Matrix (see below)	Grab/*Composite	VOC: 524.2 / 524.2 BTEX / 524.2 MTBE only	VOC: 8260 624 VTICs / 1,4 Dioxane	VOC: 8021 BTEX HALOS	VOC: 8015 GRO MAVPH	SVOC: 8270 625 SVTICs EDB DBCP / ABN A BN PAH	SVOC: TPH8100 L1 L2	SVOC: 8015 DRO MAEPH	SVOC: PEST 608 PCB 608 / PEST 8081 PCB 8082	SVOC: Oil & Grease 1664 TPH 1664	TCLP: TCLP 1311 ABN Metals / VOC Pest Herb	Metals: Dissolved Metals (List Below)	Metals: Total Metals (List Below)	Inorganics: TS TSS TDS Spec. Con.	Inorganics: Br Cl F SO_4 / NO_2 NO_3 NO_3NO_2	Inorganics: BOD CBOD T. Alk.	Inorganics: TKN NH_3 T. Phos. O. Phos.	Inorganics: pH T. Res. Chlorine	Inorganics: COD Phenols TOC DOC	Inorganics: Total Cyanide ~~Total Sulfide~~	Inorganics: Reactive Cyanide Reactive Sulfide / Flashpoint Ignitability	Micro: Total Coliform E. Coli / Fecal Coliform	Micro: Enterococci / Heterotrophic Plate Count	Other: Hardness $CaCO_3$	Other	Other	# of Containers	Notes MeOH Vial #
156ft	2-6-19 8:15	GW	G												X			X		X	X	~~X~~				X			5	
176ft	2-6-19 9:00	GW	G												X			X		X	X	~~X~~				X			5	
192ft	2-6-19 9:30	GW	G												X			X		X	X	~~X~~				X			5	
234ft	2-6-19 10:15	GW	G												X			X		X	X	~~X~~				X			5	
334ft	2-6-19 11:00	GW	G												X			X		X	X	~~X~~				X			5	
382ft	2-6-19 11:30	GW	G												X			X		X	X	~~X~~				X			5	

Matrix: A-Air; S-Soil; GW-Ground Water; SW-Surface Water; DW-Drinking Water; WW-Waste Water

Preservative: H-HCL; N-HNO_3; S-H_2SO_4; Na-NaOH; M-MEOH

Project Manager: Greg Smith
Company: Wright-Pierce
Address: 250 Commercial St. Suite 4014
City: Manchester **State:** NH **Zip:**
Phone: 978-758-3516 **Ext.:**
Fax:
E-mail: lauren.thistle@wright-pierce.com
Site Name: Cedar Run Well
Project #: 14207A
State: NH MA ME VT **Other:**
Regulatory Program: NPDES: RGP POTW Stormwater or GWP, Oil Fund, Brownfield or Other: NA
Quote #: 1014791 **PO #:**

Date Needed: NA (Standard)

QA/QC Reporting Level NA
A B C
OR
MA MCP

Reporting Options
Prelims: Yes or No

Electronic Options
E-Mail PDF Equis Excel

Temp. 3.3 °C
Ice? Yes No

Metals: 8 RCRA 13 PP Fe, Mn Pb, Cu
Other Metals:
Samples Field Filtered? ☐ Yes ☑ No
Notes: (ie: Special Detection Limits, Billing Info, If Different)

Sampler(s): Lauren Thistle
Lauren Thistle

Relinquished By:	Date:	Time:	Received By:
Lauren Thistle	2-6-19	1350	[signature]

Site History:
Suspected Contamination:
Field Readings:

4