

1. Title

Study on Groundwater Quality Parameter Variation Due to Temperature Change in Calibration Solution and Instrumentation

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4. Abstract

Measurement of groundwater quality parameters is essential for environmental professionals to evaluate subsurface geochemical conditions. These parameters may be used to determine the direction of site remediation approach, thus they must be accurately measured. It has been shown that there is some variation in measured groundwater quality parameters when the temperature of the calibration fluids do not correspond to the temperature of the groundwater to be collected. However, the amount of the variance is not reflected in current regulations or field operation manuals. Regulatory agencies (such as the New Jersey Department of Environmental Protection (NJDEP)) have taken a conservative stance on these differences, requiring that groundwater quality instruments must be calibrated in the field with fluids at the same temperature as the groundwater to be analyzed. This study was attempted to quantify

these variations, and to determine if the time and effort required by regulatory agencies in instrumentation calibration are necessary for effectively making site decisions and determine a remediation strategy.

This study found that there was little difference in a subset of the control groundwater parameters measured by the laboratory (pH, specific conductivity, and redox potential), and those measured by groundwater quality instruments calibrated at different temperatures. Dissolved oxygen and turbidity were measured by the laboratory and groundwater quality instruments during the study, but the results were such that they were used in conclusion analysis. Based upon these results, it may be possible to forgo both the field calibration of groundwater quality equipment (office calibration may be acceptable) and the keeping of calibration fluids at the same temperature as the groundwater to be sampled.

5. Introduction

In New Jersey, groundwater sampling procedures have been carefully described and regulated by the NJDEP. The NJDEP's (NJDEP, Field Sampling Procedures Manual, 2005) designates which type of equipment may be used, what order samples should be collected in, and how/when to properly calibrate groundwater quality instrumentation. The Field Sampling Procedures Manual (FSPM) states that a groundwater quality instrument must be calibrated "in the field prior to the day's events." (NJDEP104). The NJDEP FSPM goes on to state that calibration solutions must be kept to the same temperature as the groundwater to be sampled, the flow-through cell must also be kept at the same temperature as the groundwater to be sampled, and that conductivity, dissolved oxygen, and pH are temperature-dependent.

Due to the duality of the environmental industry (between science and business), following these directions to the letter is all but impossible for field personnel to accomplish. Groundwater sampling events are frequently one-day or budget-limited events that must be completed within the time allotted. If one was to calibrate his/her instrumentation in the manner prescribed by the NJDEP, the work would not be done. Setting aside the business aspect, unless there had been sampling events completed at that same site at the same time of year and conditions how an individual would know what temperature the groundwater will be upon sampling. Also, the equipment used to sample monitoring wells has the likelihood of changing groundwater temperature (sometimes drastically depending on the type of pump used). If this temperature is difficult to predict, how a field technician can pre-chill (or heat) the calibration solutions and flow-through cell. Lastly, the NJDEP assumes that all personnel within the environmental industry are technically proficient and have had the same level of training to recognize the need to calibrate their equipment in the prescribed fashion. In direct contrast, there is a wide range of training and capabilities in personnel even from within the same company. While there are commercially available training courses in groundwater sampling, it is much more likely that an individual learns the techniques from a colleague. This colleague must be technically proficient and there must be enough training time available to satisfy the needs of the trainee (for which there frequently is not).

There has been some specific scientific information obtained on the subject by research. In this case, it has mostly been completed by the manufacturers of groundwater quality instruments

and probes. There have also been inquiries into this subject by the United States Environmental Protection Agency, and the NJDEP. In order to better understand the data involved with the research, it will be necessary to understand the specific groundwater quality parameters being measured. From there it will be necessary to understand how the instrumentation measures these parameters (ex. direct measurement versus calculated). The research being proposed is a temperature condition and groundwater quality instrumentation study in real-world conditions. This research will help environmental professionals to better understand the importance of proper instrument calibration, if any variance from the prescribed calibration method is scientifically acceptable, and to develop a connection between the data being obtained and the business being conducted.

The questions being addressed with this research are the following: does the temperature of a calibration solution and/or of a groundwater quality instrument affect measured groundwater quality parameters. If such an effect exists, then how it can be quantified. Given a set of temperature conditions what confidence level may an environmental professional have in the measured parameters?

This research will advance groundwater quality science in a practical way. If the hypotheses are confirmed, there may be a wider range of temperatures in which groundwater instruments may be calibrated and then confidently used. The amount of time and labor costs saved by calibrating prior to sampling (possibly at room temperature) would be noteworthy. While there

have been many studies regarding the accuracy of ground water quality probes, there have not been practical experiments conducted regarding these probes and temperature changes.

6. Materials and Methods

Groundwater Samples

A single groundwater sample was used in this study. Groundwater was collected from an uncontaminated monitoring well at an environmental site located in Somerville, NJ. The groundwater sample was collected via NJDEP-approved groundwater sampling methodology (NJDEP, Field Sampling Procedures Manual, 2005), and stored at 4°C. Prior to the study, the sample was sent to Integrated Analytical Laboratories, Inc. (IAL) for baseline laboratory analysis. IAL was given a representative portion of the groundwater sample, having well mixed the sampled groundwater due to the amount collected. IAL analyzed the sample for: specific conductance, pH, total dissolved oxygen (DO), turbidity, and oxidation-reduction potential (ORP). These results were used as the controlled results of the groundwater quality parameters for the collected groundwater, as IAL used properly calibrated laboratory grade equipment in a controlled environment to analyze the samples. Standard laboratory methods were used in the analysis of the above parameters.

Groundwater Quality Instrumentation

Three groundwater quality instruments were used in this study. Each instrument was cleaned, fitted with similar groundwater parameter probes (pH, turbidity, conductivity, temperature, ORP, and DO), and properly calibrated (NJDEP, Field Sampling Procedures Manual, 2005) prior

to use. The three instruments included in this study were: YSI 6820, Horiba U-52, and In-Situ TROLL 9500. The instruments were clean and calibrated prior to parameter measurements on every sample. Instruments were deployed in a single location throughout the study.

The groundwater quality instruments used in this study properly calibrated according to manufacturer recommendations and NJDEP standards prior to usage. Calibration fluids were dedicated to each instrument. The calibration fluids were placed into each of the three temperature study zones (basement, bedroom, and garage) along with collected groundwater samples. Prior to sample readings, each instrument was calibrated with fluids from one temperature zone. Documentation of the calibration of each instrument using fluids from each temperature zone is included with this study as Appendix 1.

Temperature Experiments

The collected groundwater sample was split into three 500 mL plastic sample containers. Each sample container and calibration fluids were placed in different temperature zones of the testing area (Garage, Basement, and Bedroom) to simulate different work environments. By placing the calibration fluids and samples in different temperatures, one may evaluate the effect each temperature has on instrument calibration and groundwater parameter readings. Three rounds of testing were completed on the groundwater samples according to the temperature zone of the corresponding calibration fluids. Groundwater quality instruments were calibrated with solutions from one of the three temperature zones for each testing round. The temperature of the samples and the calibration fluids were verified with a calibration-

certified thermometer. Following calibration, groundwater samples from each of the three temperature zones were tested in each instrument. Samples were shaken nominally prior to testing to simulate sampling turbidity conditions. Initial groundwater quality readings were collected at time zero, followed by three additional sampling points at five minute intervals. The parameters collected included: pH, specific conductivity, turbidity, ORP, temperature, and DO. Following their usage for each temperature zone, groundwater quality instruments, their probes, and sampling vessels were cleaned with DI water. All samples were analyzed over a 15 minute time period.

Data Analysis

Data from the individual temperature zones and different temperature calibration fluids were compared against one another on a per instrument basis. The data from each instrument for each testing round was then compared against one another. The data from each testing round and instrument was compared to the results provided by IAL. All data analysis was completed using Microsoft Excel 2013 for Windows. All data provided below is listed as the initial groundwater quality reading followed by the last reading for the indicated sample.

7. Results

The results discussed below indicate the initial reading measured by the instrument and the last reading in the sample cycle. Full data tables for all collected parameters are included as Tables 1 through 3. Charts of each instrument and certain groundwater quality parameters as compared to time are included as Figures 1 through 9.

Basement calibration

The initial basement sample temperature was 18.4 degree Celsius (°C). The pH (standard units) of the basement sample was found to be: 5.75 to 7.03 (Horiba), 7.07 to 7.17 (YSI), and 7.29 (In-Situ). The specific conductivity ($\mu\text{S}/\text{cm}$) of the basement sample was found to be: 3,430 (Horiba), 3,430 to 3,402 (YSI), and 3,347 to 3,348 (In-Situ). The redox potential (millivolts (mV)) of the basement sample was found to be: 311 to 239 (Horiba), 218 to 249 (YSI), and 279 (In-Situ). The dissolved oxygen (milligrams per Liter (mg/L)) of the basement sample was found to be: 7.38 to 5.55 (Horiba), 9.64 to 9.52 (YSI), and 8.63 (In-Situ). The turbidity (nephelometric turbidity units (NTU)) of the basement sample was found to be: 183.0 to 140.0 (Horiba), 241.5 to 193.5 (YSI), and 56.6 to 49.1 (In-Situ). The temperature (°C) of the basement sample was found to be: 17.09 to 17.13 (Horiba), 17.46 to 17.25 (YSI), and 17.20 to 17.27 (In-Situ).

The initial bedroom sample temperature was 17.8°C. The pH (standard units) of the bedroom sample was found to be: 6.88 to 7.34 (Horiba), 7.19 to 7.32 (YSI), and 7.36 to 7.43 (In-Situ). The specific conductivity ($\mu\text{S}/\text{cm}$) of the bedroom sample was found to be: 3,450 to 3,480 (Horiba), 3,358 to 3,427 (YSI), and 3300 to 3,377 (In-Situ). The redox potential (mV) of the bedroom sample was found to be: 271 to 238 (Horiba), 230 to 236 (YSI), and 280 to 274 (In-Situ). The dissolved oxygen (mg/L) of the bedroom sample was found to be: 10.04 to 6.01 (Horiba), 10.35 to 10.07 (YSI), and 10.83 to 9.75 (In-Situ). The turbidity (NTU) of the bedroom sample was found to be: 512 to 251 (Horiba), 552 to 447 (YSI), and 231 to 195 (In-Situ). The temperature

(°C) of the bedroom sample was found to be: 16.64 to 16.67 (Horiba), 17.39 (YSI), and 17.48 to 17.35 (In-Situ).

The initial garage sample temperature was 7.4°C. The pH (standard units) of the garage sample was found to be: 7.45 to 7.30 (Horiba), 7.34 to 7.30 (YSI), and 7.43 to 7.46 (In-Situ). The specific conductivity ($\mu\text{S}/\text{cm}$) of the garage sample was found to be: 3,260 to 3,440 (Horiba), 3,395 to 3,398 (YSI), and 3,359 to 3,342 (In-Situ). The redox potential (mV) of the garage sample was found to be: 241 to 239 (Horiba), 232 to 255 (YSI), and 265 to 269 (In-Situ). The dissolved oxygen (mg/L) of the garage sample was found to be: 14.04 to 7.36 (Horiba), 12.20 to 11.43 (YSI), and 14.24 to 11.64 (In-Situ). The turbidity (NTU) of the garage sample was found to be: 0.0 to 800.0 (Horiba), 557.0 to 533.7 (YSI), and 840.6 to 630.8 (In-Situ). The temperature (°C) of the garage sample was found to be: 9.90 to 10.41 (Horiba), 12.35 to 13.47 (YSI), and 10.61 to 13.50 (In-Situ).

Table 1. Basement calibration - groundwater quality monitoring results

SAMPLE TEMPERATURE ZONE	EQUIPMENT NAME	TIME (minutes)	pH (standard units)		SPECIFIC CONDUCTIVITY (µS/cm)		REDOX POTENTIAL (mV)		DISSOLVED OXYGEN (mg/L)		TURBIDITY (NTU)		TEMPERATURE (degrees C)	
			READING	CHANGE	READING	CHANGE	READING	CHANGE	READING	CHANGE	READING	CHANGE	READING	CHANGE
Basement	Horiba	0	5.75	NA	3,430	NA	311	NA	7.38	NA	183	NA	17.09	NA
		5	6.76	1.01	3,420	-10	260	-51	5.91	-1.47	166	-17	17.31	0.22
		10	6.94	0.18	3,430	10	247	-13	5.54	-0.37	147	-19	17.21	-0.10
		15	7.03	0.09	3,430	0.00	239	-8	5.55	0.01	140	-7	17.13	-0.08
Basement	YSI	0	7.07	NA	3,430	NA	218.4	NA	9.64	NA	241.5	NA	17.46	NA
		5	7.04	-0.03	3,421	-9	231.0	12.6	9.56	-0.08	214.1	-27.4	17.25	-0.21
		10	7.12	0.08	3,407	-14	242.7	11.7	9.51	-0.05	243.1	29.0	17.28	0.03
		15	7.17	0.05	3,402	-5	249.3	6.6	9.52	0.01	193.5	-49.6	17.25	-0.03
Basement	In-Situ	0	7.29	NA	3,347.07	NA	279	NA	8.63	NA	56.6	NA	17.20	NA
		5	7.29	0.00	3,348.40	1.33	279	0.00	8.67	0.04	52.8	-3.8	17.22	0.02
		10	7.29	0.00	3,348.12	-0.28	279	0.00	8.64	-0.03	49.6	-3.2	17.27	0.05
		15	7.29	0.00	3,348.08	-0.04	279	0.00	8.63	-0.01	49.1	-0.5	17.27	0.00
Bedroom	Horiba	0	6.88	NA	3,450	NA	271	NA	10.04	NA	512	NA	16.64	NA
		5	7.26	0.38	3,480	30	249	-22	6.52	-3.52	332	-180	16.65	0.01
		10	7.33	0.07	3,480	0	293	44	6.20	-0.32	296	-36	16.65	0.00
		15	7.34	0.01	3,480	0	238	-55	6.01	-0.19	251	-45	16.67	0.02
Bedroom	YSI	0	7.19	NA	3,358	NA	229.5	NA	10.35	NA	552.0	NA	17.39	NA
		5	7.27	0.08	3,429	71	231.3	1.8	10.10	-0.25	502.3	-49.7	17.41	0.02
		10	7.30	0.03	3,431	2	233.6	2.3	10.09	-0.01	501.0	-1.3	17.40	-0.01
		15	7.32	0.02	3,427	-4	235.9	2.3	10.07	-0.02	447.3	-53.7	17.39	-0.01
Bedroom	In-Situ	0	7.36	NA	3,299.80	NA	280	NA	10.83	NA	230.8	NA	17.48	NA
		5	7.42	0.06	3,378.94	79.14	277	-3	10.25	-0.58	212.8	-18	17.34	-0.14
		10	7.43	0.01	3,376.11	-2.83	276	-1	9.98	-0.27	201.8	-11	17.35	0.01
		15	7.43	0.00	3,376.70	0.59	274	-2	9.75	-0.23	194.6	-7.2	17.35	0.00
Garage	Horiba	0	7.45	NA	3,260	NA	241	NA	14.04	NA	0	NA	9.90	NA
		5	7.82	0.37	3,340	80	240	-1	7.81	-6.23	800	800	10.04	0.14
		10	7.31	-0.51	3,420	80	240	0	7.51	-0.30	800	0	10.22	0.18
		15	7.30	-0.01	3,440	20	239	-1	7.36	-0.15	800	0	10.41	0.19
Garage	YSI	0	7.34	NA	3,395	NA	232.0	NA	12.20	NA	557	NA	12.35	NA
		5	7.26	-0.08	3,394	-1	247.5	15.5	11.48	-0.72	569.5	12.5	12.91	0.56
		10	7.27	0.01	3,393	-1	252.7	5.2	11.43	-0.05	564.3	-5.2	13.22	0.31
		15	7.30	0.03	3,398	5	254.8	2.1	11.43	0.00	533.7	-30.6	13.47	0.25
Garage	In-Situ	0	7.43	NA	3,359.35	NA	265	NA	14.24	NA	840.6	NA	10.61	NA
		5	7.46	0.03	3,331.86	-27.49	267	2	11.60	-2.64	685.6	-155.0	12.47	1.86
		10	7.46	0.00	3,335.95	4.09	268	1	11.56	-0.04	697.5	11.9	13.14	0.67
		15	7.46	0.00	3,341.61	5.66	269	1	11.64	0.08	630.8	-66.7	13.50	0.36

Notes: C - celsius, mg/L - milligrams per Liter, mV - milliVolt, NA - not applicable, NTU - nephelometric turbidity units, µS/cm - microSiemens per centimeter

Bedroom calibration

The initial basement sample temperature was 18.8°C. The pH (standard units) of the basement sample was found to be: 5.75 to 7.05 (Horiba), 7.11 (YSI), and 7.17 to 7.27 (In-Situ). The specific conductivity ($\mu\text{S}/\text{cm}$) of the basement sample was found to be: 3,470 to 3,480 (Horiba), 3,470 to 3,450 (YSI), and 3,388 to 3,389 (In-Situ). The redox potential (mV) of the basement sample was found to be: 350 to 274 (Horiba), 219 to 248 (YSI), and 268 to 289 (In-Situ). The dissolved oxygen (mg/L) of the basement sample was found to be: 8.22 to 5.64 (Horiba), 9.70 to 9.41 (YSI), and 8.58 to 8.12 (In-Situ). The turbidity (NTU) of the basement sample was found to be: 237.0 to 199.0 (Horiba), 231.1 to 197.1 (YSI), and 311.1 to 211.4 (In-Situ). The temperature (°C) of the basement sample was found to be: 18.11 to 17.51 (Horiba), 17.74 to 17.71 (YSI), and 18.67 to 18.21 (In-Situ).

The initial bedroom sample temperature was 17.9°C. The pH (standard units) of the bedroom sample was found to be: 6.97 to 7.37 (Horiba), 7.19 to 7.37 (YSI), and 7.35 to 7.42 (In-Situ). The specific conductivity ($\mu\text{S}/\text{cm}$) of the bedroom sample was found to be: 3,460 to 3,480 (Horiba), 3,345 to 3,498 (YSI), and 3,357 to 3,399 (In-Situ). The redox potential (mV) of the bedroom sample was found to be: 265 to 238 (Horiba), 238 to 245 (YSI), and 289 to 279 (In-Situ). The dissolved oxygen (mg/L) of the bedroom sample was found to be: 9.54 to 7.22 (Horiba), 10.21 to 9.87 (YSI), and 10.56 to 8.23 (In-Situ). The turbidity (NTU) of the bedroom sample was found to be: 676.0 to 267.0 (Horiba), 578.9 to 512.1 (YSI), and 239.3 to 178.2 (In-Situ). The temperature (°C) of the bedroom sample was found to be: 16.79 (Horiba), 17.41 to 17.42 (YSI), and 17.87 to 17.53 (In-Situ).

The initial garage sample temperature was 8.1°C. The pH (standard units) of the garage sample was found to be: 7.41 to 7.31 (Horiba), 7.38 to 7.34 (YSI), and 7.37 to 7.45 (In-Situ). The specific conductivity ($\mu\text{S}/\text{cm}$) of the garage sample was found to be: 3,229 to 3,430 (Horiba), 3,458 to 3,461 (YSI), and 3,349 to 3,359 (In-Situ). The redox potential (mV) of the garage sample was found to be: 248 to 239 (Horiba), 235 to 297 (YSI), and 289 to 275 (In-Situ). The dissolved oxygen (mg/L) of the garage sample was found to be: 14.31 to 7.12 (Horiba), 12.12 to 11.66 (YSI), and 13.12 to 10.31 (In-Situ). The turbidity (NTU) of the garage sample was found to be: 800.0 (Horiba), 783.5 to 589.3 (YSI), and 931.9 to 790.1 (In-Situ). The temperature (°C) of the garage sample was found to be: 10.83 to 11.73 (Horiba), 11.21 to 12.78 (YSI), and 11.32 to 13.52 (In-Situ).

Table 2. Bedroom calibration - groundwater quality monitoring results

SAMPLE TEMPERATURE ZONE	EQUIPMENT NAME	TIME (minutes)	pH (standard units)		SPECIFIC CONDUCTIVITY (µS/cm)		REDOX POTENTIAL (mV)		DISSOLVED OXYGEN (mg/L)		TURBIDITY (NTU)		TEMPERATURE (degrees C)	
			READING	CHANGE	READING	CHANGE	READING	CHANGE	READING	CHANGE	READING	CHANGE	READING	CHANGE
Basement	Horiba	0	5.75	NA	3,470	NA	350	NA	8.22	NA	237	NA	18.11	NA
		5	6.95	1.20	3,480	10	280	-70	5.66	-2.56	223	-14	17.54	-0.57
		10	7.01	0.06	3,480	0	275	-5	5.67	0.01	201	-22	17.54	0.00
		15	7.05	0.04	3,480	0	274	-1	5.64	-0.03	199	-2	17.51	-0.03
Basement	YSI	0	7.11	NA	3,470	NA	218.7	NA	9.70	NA	231.1	NA	17.74	NA
		5	7.10	-0.01	3,440	-30	235.6	16.9	9.65	-0.05	210.5	-20.6	17.71	-0.03
		10	7.09	-0.01	3,450	10	241.1	5.5	9.44	-0.21	199.9	-10.6	17.71	0.00
		15	7.11	0.02	3,450	0	247.6	6.5	9.41	-0.03	197.1	-2.8	17.71	0.00
Basement	In-Situ	0	7.11	NA	3,387.50	NA	268	NA	8.58	NA	311.1	NA	18.67	NA
		5	7.24	0.13	3,401.40	13.90	278	10	8.42	-0.16	297.2	-13.9	18.23	-0.44
		10	7.25	0.01	3,378.30	-23.10	285	7	8.31	-0.11	267.5	-29.7	18.21	-0.02
		15	7.27	0.02	3,389.45	11.15	289	4	8.12	-0.19	211.4	-56.1	18.21	0.00
Bedroom	Horiba	0	6.97	NA	3,460	NA	265	NA	9.54	NA	676	NA	16.79	NA
		5	7.31	0.34	3,470	10	249	-16	7.34	-2.20	432	-244	16.87	0.08
		10	7.34	0.03	3,480	10	278	29	7.23	-0.11	346	-86	16.85	-0.02
		15	7.37	0.03	3,480	0	238	-40	7.22	-0.01	267	-79	16.79	-0.06
Bedroom	YSI	0	7.19	NA	3,345	NA	238.1	NA	10.21	NA	578.9	NA	17.41	NA
		5	7.32	0.13	3,478	133	238.9	0.8	10.00	-0.21	567.3	-11.6	17.47	0.06
		10	7.32	0.00	3,489	11	241.1	2.2	9.93	-0.07	543.2	-24.1	17.45	-0.02
		15	7.37	0.05	3,498	9	245.2	4.1	9.87	-0.06	512.1	-31.1	17.42	-0.03
Bedroom	In-Situ	0	7.35	NA	3,357.10	NA	289	NA	10.56	NA	239.3	NA	17.87	NA
		5	7.41	0.06	3,414.23	57.13	284	-5	9.75	-0.81	211.2	-28.1	17.69	-0.18
		10	7.42	0.01	3,445.34	31.11	281	-3	8.42	-1.33	192.6	-18.6	17.63	-0.06
		15	7.42	0.00	3,398.93	-46.41	279	-2	8.23	-0.19	178.2	-14.4	17.53	-0.10
Garage	Horiba	0	7.41	NA	3,229	NA	248	NA	14.31	NA	800	NA	10.83	NA
		5	7.64	0.23	3,370	141	243	-5	7.51	-6.80	800	0	11.35	0.52
		10	7.31	-0.33	3,415	45	240	-3	7.23	-0.28	800	0	11.70	0.35
		15	7.31	0.00	3,430	15	239	-1	7.12	-0.11	800	0	11.73	0.03
Garage	YSI	0	7.38	NA	3,458	NA	235.2	NA	12.12	NA	783.5	NA	11.21	NA
		5	7.27	-0.11	3,465	7	248.5	13.3	11.58	-0.54	642.4	-141.1	12.67	1.46
		10	7.31	0.04	3,463	-2	269.8	21.3	11.48	-0.10	612.9	-29.5	12.89	0.22
		15	7.34	0.03	3,461	-2	296.5	26.7	11.66	0.18	589.3	-23.6	12.78	-0.11
Garage	In-Situ	0	7.37	NA	3,349.12	NA	289	NA	13.12	NA	931.9	NA	11.32	NA
		5	7.44	0.07	3,345.30	-3.82	272	-17	10.15	-2.97	765.2	-166.7	12.49	1.17
		10	7.45	0.01	3,354.80	9.50	272	0	10.12	-0.03	789.1	23.9	13.13	0.64
		15	7.45	0.00	3,359.40	4.60	275	3	10.31	0.19	790.1	1.0	13.52	0.39

Notes: C - celsius, mg/L - milligrams per Liter, mV - millivolt, NA - not applicable, NTU - nephelometric turbidity units, µS/cm - microSiemens per centimeter

Garage calibration

The initial basement sample temperature was 20.9°C. The pH (standard units) of the basement sample was found to be: 5.76 to 7.16 (Horiba), 7.71 to 7.32 (YSI), and 6.76 to 7.26 (In-Situ). The specific conductivity ($\mu\text{S}/\text{cm}$) of the basement sample was found to be: 3,490 to 3,510 (Horiba), 3,431 to 3,479 (YSI), and 3,407 to 3,431 (In-Situ). The redox potential (mV) of the basement sample was found to be: 416 to 265 (Horiba), 219 to 250 (YSI), and 260 to 297 (In-Situ). The dissolved oxygen (mg/L) of the basement sample was found to be: 9.20 to 5.35 (Horiba), 9.72 to 9.25 (YSI), and 8.47 to 7.88 (In-Situ). The turbidity (NTU) of the basement sample was found to be: 427.0 to 205.0 (Horiba), 193.9 to 183.2 (YSI), and 913.6 to 585.0 (In-Situ). The temperature (°C) of the basement sample was found to be: 19.06 to 18.29 (Horiba), 18.24 to 17.80 (YSI), and 19.89 to 19.29 (In-Situ).

The initial bedroom sample temperature was 17.6°C. The pH (standard units) of the bedroom sample was found to be: 7.16 to 7.38 (Horiba), 7.29 to 7.45 (YSI), and 7.34 to 7.31 (In-Situ). The specific conductivity ($\mu\text{S}/\text{cm}$) of the bedroom sample was found to be: 3,470 (Horiba), 3,317 to 3,521 (YSI), and 3,385 to 3,453 (In-Situ). The redox potential (mV) of the bedroom sample was found to be: 260 to 234 (Horiba), 243 to 252 (YSI), and 291 to 281 (In-Situ). The dissolved oxygen (mg/L) of the bedroom sample was found to be: 8.74 to 8.53 (Horiba), 10.02 to 9.75 (YSI), and 9.09 to 7.78 (In-Situ). The turbidity (NTU) of the bedroom sample was found to be: 800.0 to 275.0 (Horiba), 631.5 to 492.5 (YSI), and 176.5 to 165.5 (In-Situ). The temperature (°C) of the bedroom sample was found to be: 17.04 to 16.86 (Horiba), 17.46 to 17.47 (YSI), and 18.00 to 18.14 (In-Situ).

The initial garage sample temperature was 9.32°C. The pH (standard units) of the garage sample was found to be: 7.33 (Horiba), 7.41 to 7.36 (YSI), and 7.27 to 7.43 (In-Situ). The specific conductivity ($\mu\text{S}/\text{cm}$) of the garage sample was found to be: 3,320 to 3,440 (Horiba), 3,505 to 3,535 (YSI), and 3,338 to 3,367 (In-Situ). The redox potential (mV) of the garage sample was found to be: 254 to 239 (Horiba), 238 to 276 (YSI), and 290 to 289 (In-Situ). The dissolved oxygen (mg/L) of the garage sample was found to be: 14.71 to 6.33 (Horiba), 11.99 to 11.81 (YSI), and 11.33 to 9.31 (In-Situ). The turbidity (NTU) of the garage sample was found to be: 16.9 to 791.0 (Horiba), 978.4 to 694.3 (YSI), and 1,309.7 to 941.5 (In-Situ). The temperature (°C) of the garage sample was found to be: 11.73 to 12.45 (Horiba), 10.56 to 11.82 (YSI), and 11.65 to 13.62 (In-Situ).

Table 3. Garage calibration - groundwater quality monitoring results

SAMPLE TEMPERATURE ZONE	EQUIPMENT NAME	TIME (minutes)	pH (standard units)		SPECIFIC CONDUCTIVITY (µS/cm)		REDOX POTENTIAL (mV)		DISSOLVED OXYGEN (mg/L)		TURBIDITY (NTU)		TEMPERATURE (degrees C)	
			READING	CHANGE	READING	CHANGE	READING	CHANGE	READING	CHANGE	READING	CHANGE	READING	CHANGE
Basement	Horiba	0	5.76	NA	3,490	NA	416	NA	9.20	NA	427	NA	19.06	NA
		5	7.12	1.36	3,510	20	265	-151	5.13	-4.07	426	-1	18.87	-0.19
		10	7.10	-0.02	3,500	-10	264	-1	5.24	0.11	302	-124	18.53	-0.34
		15	7.16	0.06	3,510	10	265	1	5.35	0.11	205	-97	18.29	-0.24
Basement	YSI	0	7.71	NA	3,431	NA	219.3	NA	9.72	NA	193.9	NA	18.24	NA
		5	7.34	-0.37	3,470	39	238.8	19.5	9.23	-0.49	191.5	-2.4	17.92	-0.32
		10	7.32	-0.02	3,477	7	244.9	6.1	9.25	0.02	187.0	-4.5	17.85	-0.07
		15	7.32	0.00	3,479	2	249.9	5	9.25	0	183.2	-3.8	17.8	-0.05
Basement	In-Situ	0	6.76	NA	3,406.95	NA	260	NA	8.47	NA	913.6	NA	19.89	NA
		5	7.21	0.45	3,413.54	6.59	282	22	8.05	-0.42	768.7	-144.9	19.63	-0.26
		10	7.24	0.03	3,395.62	-17.92	292	10	8.01	-0.04	676.5	-92.2	19.43	-0.20
		15	7.26	0.02	3,430.58	34.96	297	5	7.88	-0.13	585	-91.5	19.29	-0.14
Bedroom	Horiba	0	7.16	NA	3,470	NA	260	NA	8.74	NA	800	NA	17.04	NA
		5	7.32	0.16	3,470	0	248	-12	8.62	-0.12	688	-112	16.97	-0.07
		10	7.35	0.03	3,470	0	243	-5	8.56	-0.06	525	-163	16.93	-0.04
		15	7.38	0.03	3,470	0	234	-9	8.53	-0.03	275	-250	16.86	-0.07
Bedroom	YSI	0	7.29	NA	3,317	NA	243	NA	10.02	NA	631.5	NA	17.46	NA
		5	7.4	0.11	3,517	200	243.7	0.7	9.77	-0.25	596	-35.5	17.48	0.02
		10	7.44	0.04	3,520	3	247.5	3.8	9.76	-0.01	560.1	-35.9	17.47	-0.01
		15	7.45	0.01	3,521	1	251.6	4.1	9.75	-0.01	492.5	-67.6	17.47	0.00
Bedroom	In-Situ	0	7.34	NA	3,385.40	NA	291	NA	9.09	NA	176.5	NA	18	NA
		5	7.4	0.06	3,449.32	63.92	286	-5	8.26	-0.83	174.2	-2.3	18.1	0.10
		10	7.41	0.01	3,452.28	2.96	283	-3	7.91	-0.35	169.2	-5.0	18.11	0.01
		15	7.41	0.00	3,453.30	1.02	281	-2	7.78	-0.13	165.5	-3.7	18.14	0.03
Garage	Horiba	0	7.33	NA	3,320	NA	254	NA	14.71	NA	16.9	NA	11.73	NA
		5	7.21	-0.12	3,380	60	244	-10	7.15	-7.56	800	783.1	12.03	0.30
		10	7.32	0.11	3,410	30	241	-3	6.53	-0.62	800	0	12.26	0.23
		15	7.33	0.01	3,440	30	239	-2	6.33	-0.2	791	-9	12.45	0.19
Garage	YSI	0	7.41	NA	3,505	NA	237.9	NA	11.99	NA	978.4	NA	10.56	NA
		5	7.32	-0.09	3,523	18	266.8	28.9	11.66	-0.33	878.1	-100.3	11.18	0.62
		10	7.34	0.02	3,529	6	272.9	6.1	11.53	-0.13	773.4	-104.7	11.54	0.36
		15	7.36	0.02	3,535	6	275.5	2.6	11.81	0.28	694.3	-79.1	11.82	0.28
Garage	In-Situ	0	7.27	NA	3,338.15	NA	290	NA	11.33	NA	1309.7	NA	11.65	NA
		5	7.42	0.15	3,354.20	16.05	287	-3	9.65	-1.68	1221	-88.7	12.56	0.91
		10	7.42	0.00	3,364.51	10.31	288	1	9.45	-0.2	1072.9	-148.1	13.12	0.56
		15	7.43	0.01	3,367.20	2.69	289	1	9.31	-0.14	941.5	-131.4	13.62	0.50

Notes: C - celsius, mg/L - milligrams per Liter, mV - millivolt, NA - not applicable, NTU - nephelometric turbidity units, µS/cm - microSiemens per centimeter

A portion of the studied groundwater sample was sent to IAL for laboratory analysis to be used as a control set of groundwater quality parameters. The full analytical data report is included with this study as Appendix 2. The measured pH (standard units) of the sample was 7.13. The measured specific conductivity ($\mu\text{S}/\text{cm}$) of the sample was 4,000. The measured redox potential (mV) of the sample was 222. The measured dissolved oxygen (mg/L) of the sample was 8.8. The measured turbidity (NTU) of the sample was 24.6. While sample temperature is an important parameter to consider when measuring the other parameters above, it was not measured due to the temperature variability introduced by sample storage, transport, and analysis at the laboratory.

The measured pH from IAL of the groundwater sample was 7.13 standard units. The range of pHs (based upon the final study reading) from each temperature zone calibration, sample temperature zone, and instrument were: 7.03 to 7.46 (basement calibration), 7.05 to 7.45 (bedroom calibration), and 7.16 to 7.45 (garage calibration). The measured pH of all samples within the study was between 1.4% lower and 4.6% higher than the pH of the groundwater measured at the laboratory. Figures comparing all pHs at each temperature zone are included as Figures 1, 4 and 7.

Figure 1. Basement calibration - instrument pH comparison

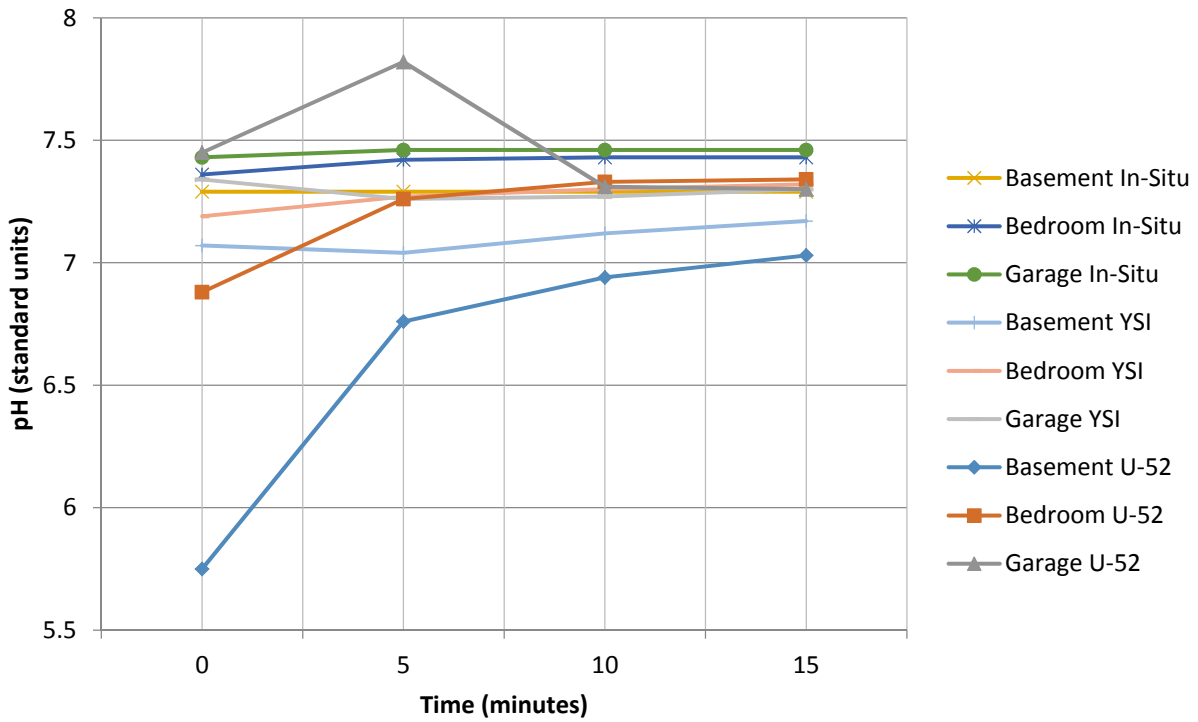


Figure 4. Bedroom calibration - instrument pH comparison

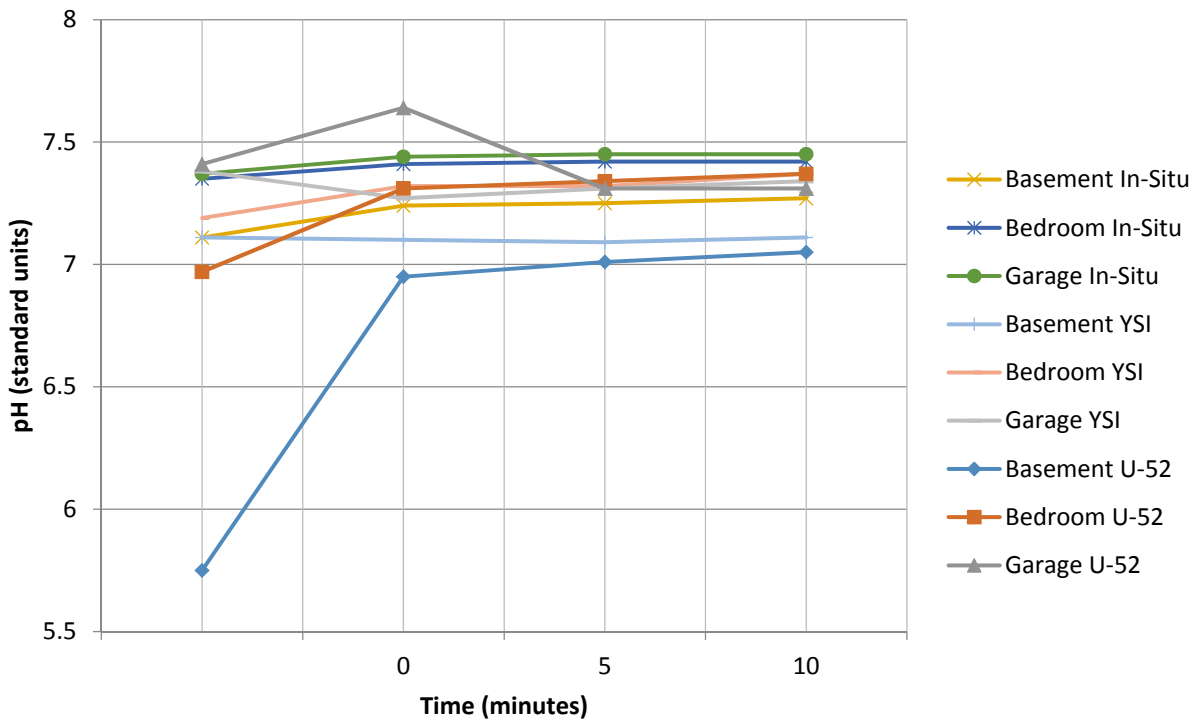
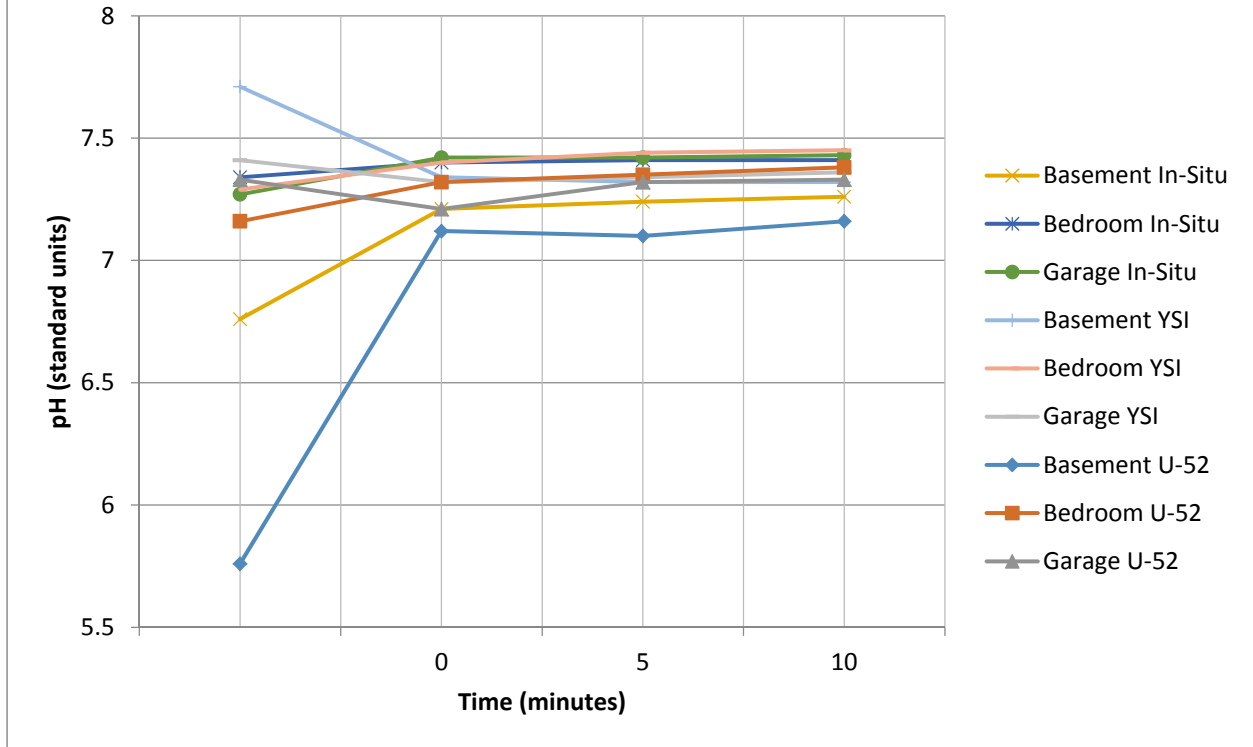


Figure 7. Garage calibration - instrument pH comparison



When the instruments were calibrated by the garage temperature zone calibration fluids and they measured the garage temperature zone sample, the final pH results were 7.33, 7.38, and 7.43. When the instruments measured the pH of samples from the other two temperature zones the final results were between 7.16 and 7.45.

The range of pHs measured (based upon the final study reading) by the Horiba U-52 were: 7.03 to 7.34 (basement calibration), 7.05 to 7.37 (bedroom calibration), and 7.16 to 7.38 (garage calibration). The mean of the measured pHs by the Horiba was 7.25. The mean pH from the Horiba was 1.7% higher than the laboratory measured pH.

The range of pHs measured (based upon the final study reading) by the YSI 6820 were: 7.17 to 7.32 (basement calibration), 7.11 to 7.37 (bedroom calibration), and 7.32 to 7.45 (garage calibration). The mean of the measured pHs by the YSI was 7.30. The mean pH from the YSI was 2.45% higher than the laboratory measured pH.

The range of pHs measured (based upon the final study reading) by the In-Situ LEVELTROLL were: 7.29 to 7.46 (basement calibration), 7.11 to 7.37 (bedroom calibration), and 7.26 to 7.43 (garage calibration). The mean of the measured pHs by the In-Situ was 7.34. The mean pH from the In-Situ was 3.0% higher than the laboratory measured pH.

The measured specific conductivity from IAL of the groundwater sample was 4,000 $\mu\text{S}/\text{cm}$. The range of specific conductivities (based upon the final study reading) from each temperature zone calibration, sample temperature zone, and instrument were: 3,342 to 3,480 (basement calibration), 3,359 to 3,498 (bedroom calibration), and 3,367 to 3,535 (garage calibration). The measured specific conductivity of all samples within the study was between 11.6% and 16.5% lower than the specific conductivity of the groundwater measured at the laboratory. Figures comparing all specific conductivities at each temperature zone are included as Figures 2, 5, and 8.

Figure 2. Basement calibration - instrument specific conductivity comparison

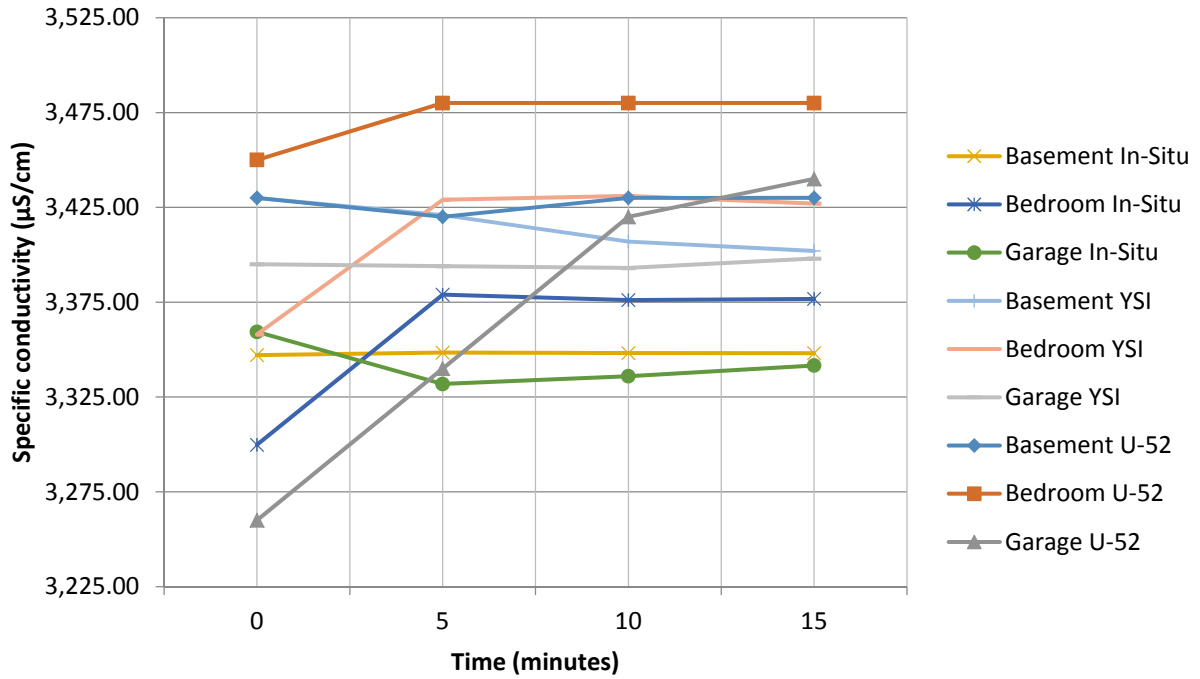


Figure 5. Bedroom calibration - instrument specific conductivity comparison

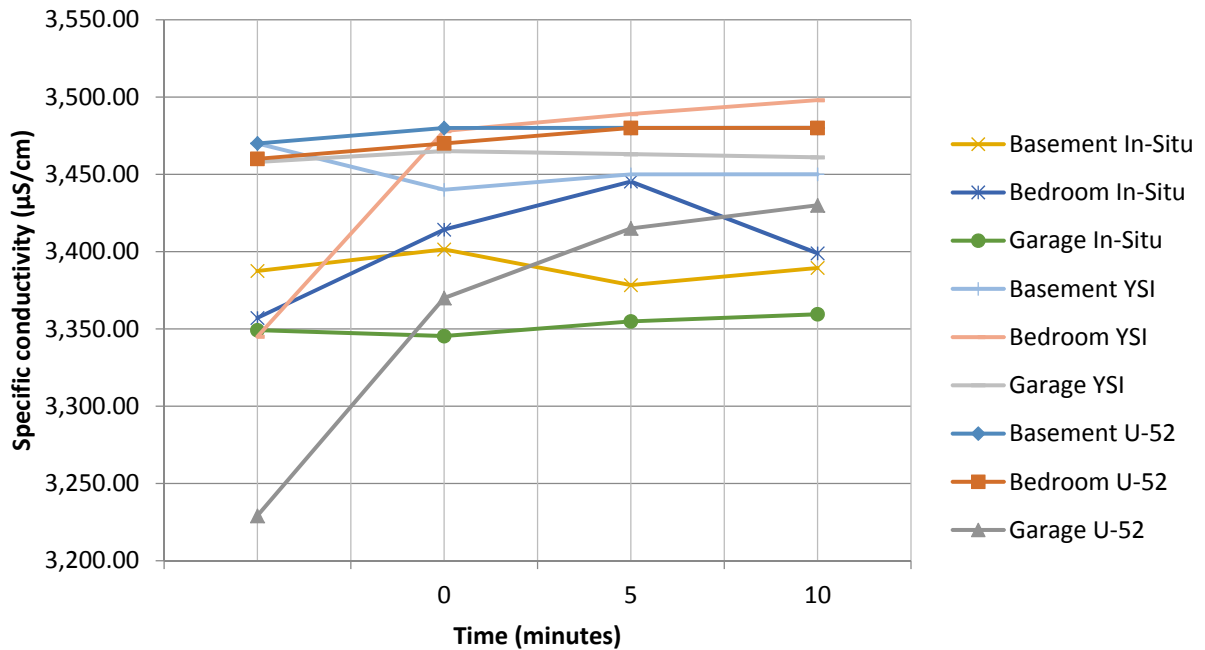
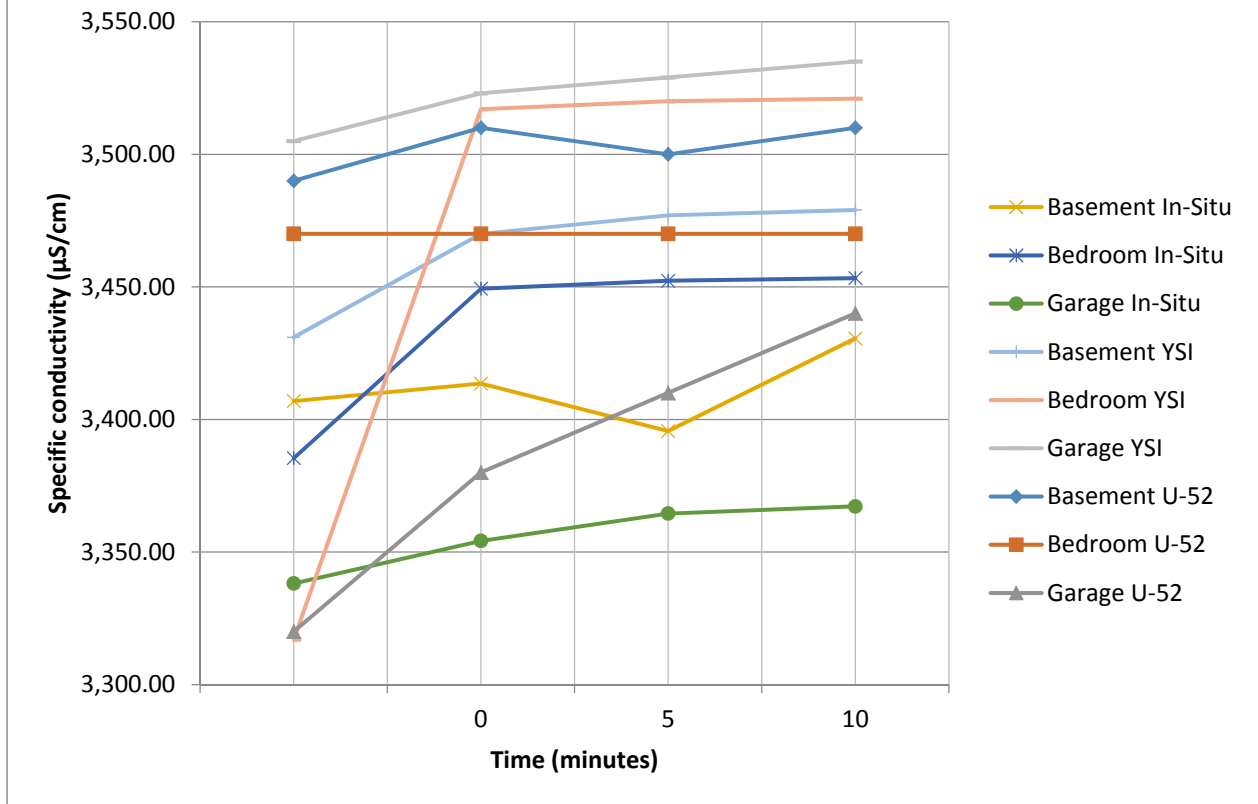


Figure 8. Garage calibration - instrument specific conductivity comparison



When the instruments were calibrated by the basement temperature zone calibration fluids and they measured the basement temperature zone sample, the final specific conductivity results were 3,348, 3,402, and 3,430. When these instruments measured the specific conductivity of samples from the other two temperature zones the final results were between 3,342 and 3,480.

When the instruments were calibrated by the bedroom temperature zone calibration fluids and they measured the bedroom temperature zone sample, the final specific conductivity results were 3,399, 3,450, and 3,498. When these instruments measured the specific conductivity of samples from the other two temperature zones the final results were between 3,359 and 3,480.

When the instruments were calibrated by the garage temperature zone calibration fluids and they measured the garage temperature zone sample, the final specific conductivity results were 3,367, 3,440, and 3,535. When the instruments measured the specific conductivity of samples from the other two temperature zones the final results were between 3,431 and 3,521.

The range of specific conductivities measured (based upon the final study reading) by the Horiba U-52 were: 3,430 to 3,480 (basement calibration), 3,430 to 3,480 (bedroom calibration), and 3,440 to 3,510 (garage calibration). The mean of the measured specific conductivities by the Horiba was 3,462. The mean specific conductivity from the Horiba was 13.4% lower than the laboratory measured specific conductivity.

The range of specific conductivities measured (based upon the final study reading) by the YSI 6820 were: 3,398 to 3,427 (basement calibration), 3,450 to 3,498 (bedroom calibration), and 3,479 to 3,535 (garage calibration). The mean of the measured specific conductivities by the YSI was 3,463. The mean specific conductivity from the YSI was 13.4% lower than the laboratory measured specific conductivity.

The range of specific conductivities measured (based upon the final study reading) by the In-Situ LEVELTROLL were: 3,342 to 3,377 (basement calibration), 3,359 to 3,399 (bedroom calibration), and 3,367 to 3,453 (garage calibration). The mean of the measured specific

conductivities by the In-Situ was 3,385. The mean specific conductivity from the In-Situ was 15.4% lower than the laboratory measured specific conductivity.

The measured redox potential from IAL of the groundwater sample was 222 mV. The range of redox potentials (based upon the final study reading) from each temperature zone calibration, sample temperature zone, and instrument were: 236 to 279 (basement calibration), 239 to 297 (bedroom calibration), and 234 to 297 (garage calibration). The measured redox potential of all samples within the study was between 5.4% and 33.8% higher than the redox potential of the groundwater measured at the laboratory. Figures comparing all redox potentials at each temperature zone are included as Figures 3, 6, and 9.

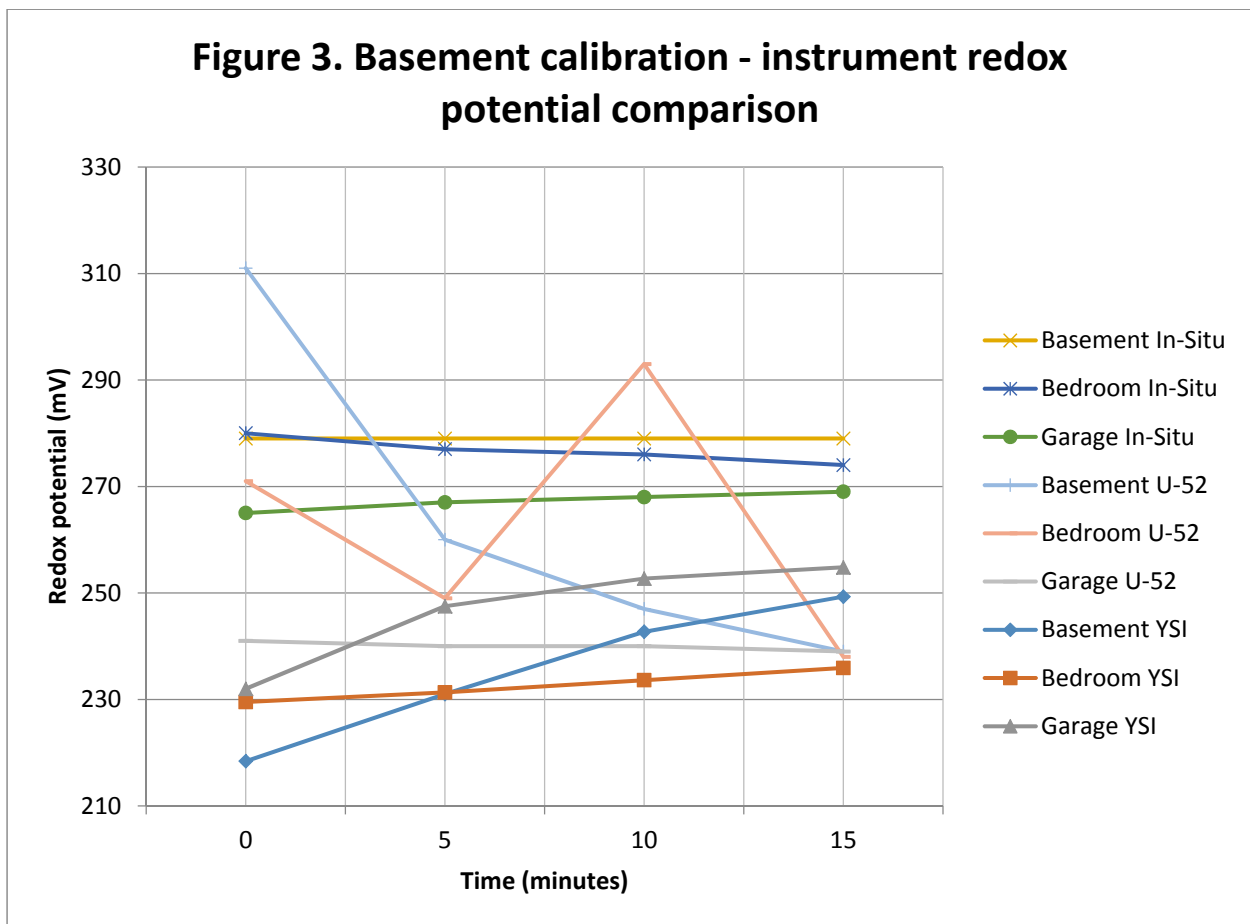


Figure 6. Bedroom calibration - instrument redox potential comparison

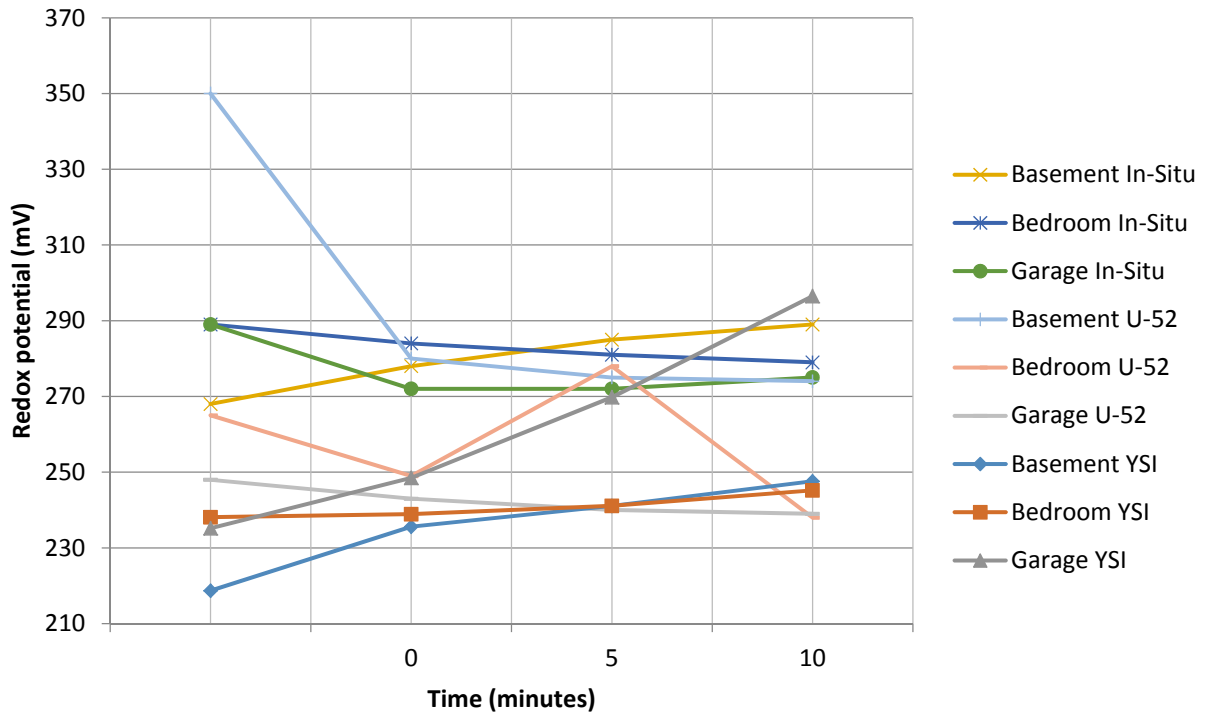
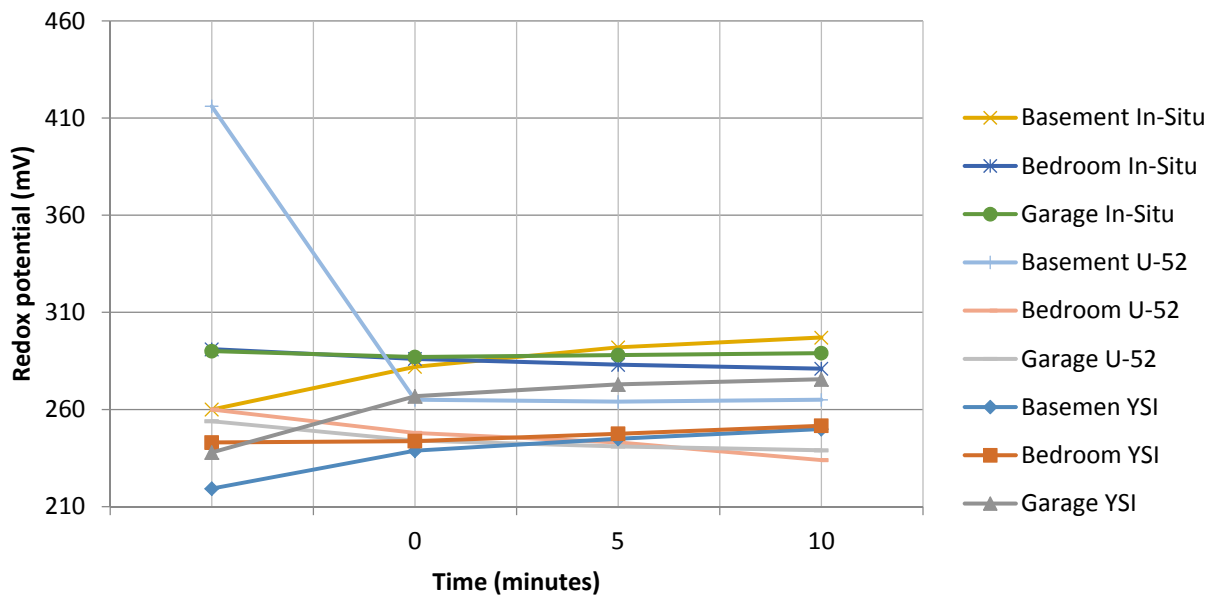


Figure 9. Garage calibration - instrument redox potential comparison



When the instruments were calibrated by the basement temperature zone calibration fluids and they measured the basement temperature zone sample, the final redox potential results were 239, 249, and 279. When these instruments measured the redox potential of samples from the other two temperature zones the final results were between 236 and 274.

When the instruments were calibrated by the bedroom temperature zone calibration fluids and they measured the bedroom temperature zone sample, the final redox potential results were 238, 245, and 279. When these instruments measured the redox potential of samples from the other two temperature zones the final results were between 239 and 297.

When the instruments were calibrated by the garage temperature zone calibration fluids and they measured the garage temperature zone sample, the final redox potential results were 239, 276, and 289. When the instruments measured the redox potential of samples from the other two temperature zones the final results were between 234 and 297.

The range of redox potentials measured (based upon the final study reading) by the Horiba U-52 were: 238 to 239 (basement calibration), 239 to 274 (bedroom calibration), and 234 to 265 (garage calibration). The mean of the measured redox potentials by the Horiba was 245. The mean redox potential from the Horiba was 10.4% higher than the laboratory measured redox potential.

The range of redox potentials measured (based upon the final study reading) by the YSI 6820 were: 236 to 255 (basement calibration), 245 to 297 (bedroom calibration), and 250 to 276 (garage calibration). The mean of the measured redox potentials by the YSI was 256. The mean redox potential from the YSI was 15.4% higher than the laboratory measured redox potential.

The range of redox potentials measured (based upon the final study reading) by the In-Situ LEVELTROLL were: 269 to 279 (basement calibration), 275 to 289 (bedroom calibration), 281 to 297 (garage calibration). The mean of the measured redox potentials by the In-Situ was 281. The mean redox potential from the In-Situ was 26.7% higher than the laboratory measured redox potential.

The measured dissolved oxygen from IAL of the groundwater sample was 8.80 mg/L. The range of dissolved oxygen (based upon the final study reading) from each temperature zone calibration, sample temperature zone, and instrument were: 5.55 to 11.64 (basement calibration), 5.64 to 11.66 (bedroom calibration), and 5.55 to 11.64 (garage calibration). The measured dissolved oxygen of all samples within the study was between 63% lower and 32.3% higher than the dissolved oxygen of the groundwater measured at the laboratory.

When the instruments were calibrated by the basement temperature zone calibration fluids and they measured the basement temperature zone sample, the final dissolved oxygen results were 5.55, 8.63, and 9.52. When these instruments measured the dissolved oxygen of samples from the other two temperature zones the final results were between 6.01 and 11.64.

When the instruments were calibrated by the bedroom temperature zone calibration fluids and they measured the bedroom temperature zone sample, the final dissolved oxygen results were 7.22, 8.23, and 9.87. When these instruments measured the dissolved oxygen of samples from the other two temperature zones the final results were between 5.64 and 11.66.

When the instruments were calibrated by the garage temperature zone calibration fluids and they measured the garage temperature zone sample, the final dissolved oxygen results were 6.33, 9.31, and 11.81. When the instruments measured the dissolved oxygen of samples from the other two temperature zones the final results were between 5.35 and 9.75.

The range of dissolved oxygen measured (based upon the final study reading) by the Horiba U-52 were: 5.55 to 7.36 (basement calibration), 5.64 to 7.22 (bedroom calibration), and 5.35 to 8.53 (garage calibration). The mean of the measured dissolved oxygen by the Horiba was 6.57. The mean dissolved oxygen from the Horiba was 25.3% lower than the laboratory measured dissolved oxygen.

The range of dissolved oxygen measured (based upon the final study reading) by the YSI 6820 were: 9.52 to 11.43 (basement calibration), 9.41 to 11.66 (bedroom calibration), and 9.25 to 11.81 (garage calibration). The mean of the measured dissolved oxygen by the YSI was 10.30. The mean dissolved oxygen from the YSI was 17.13% higher than the laboratory measured dissolved oxygen.

The range of dissolved oxygen measured (based upon the final study reading) by the In-Situ LEVELTROLL were: 8.63 to 11.64 (basement calibration), 8.13 to 10.31 (bedroom calibration), 7.78 to 9.31 (garage calibration). The mean of the measured dissolved oxygen by the In-Situ was 9.07. The mean dissolved oxygen from the In-Situ was 3.09% higher than the laboratory measured dissolved oxygen.

The measured turbidity from IAL of the groundwater sample was 24.6 NTU. The range of turbidity (based upon the final study reading) from each temperature zone calibration, sample temperature zone, and instrument were: 49.1 to 800.0 (basement calibration), 178.2 to 800.0 (bedroom calibration), and 165.5 to 941.5 (garage calibration). The measured turbidity of all samples within the study was between 99.59% and 3,727.24% higher than the turbidity of the groundwater measured at the laboratory.

When the instruments were calibrated by the basement temperature zone calibration fluids and they measured the basement temperature zone sample, the final turbidity results were 49.1, 140.0, and 193.5. When these instruments measured the turbidity of samples from the other two temperature zones the final results were between 194.6 and 800.0.

When the instruments were calibrated by the bedroom temperature zone calibration fluids and they measured the bedroom temperature zone sample, the final turbidity results were 178.2,

267.0, and 512.1. When these instruments measured the turbidity of samples from the other two temperature zones the final results were between 197.1 and 800.0.

When the instruments were calibrated by the garage temperature zone calibration fluids and they measured the garage temperature zone sample, the final turbidity results were 694.3, 791.0, and 941.5. When the instruments measured the turbidity of samples from the other two temperature zones the final results were between 165.5 and 585.0.

The range of turbidity measured (based upon the final study reading) by the Horiba U-52 were: 140.0 to 800.0 (basement calibration), 199.0 to 800.0 (bedroom calibration), and 205.0 to 791.0 (garage calibration). The mean of the measured turbidity by the Horiba was 414.2. The mean turbidity from the Horiba was 1,583.8% higher than the laboratory measured turbidity.

The range of turbidity measured (based upon the final study reading) by the YSI 6820 were: 193.5 to 533.7 (basement calibration), 197.1 to 589.3 (bedroom calibration), and 165.5 to 941.5 (garage calibration). The mean of the measured turbidity by the YSI was 427.0. The mean turbidity from the YSI was 1,635.8% higher than the laboratory measured turbidity.

The range of turbidity measured (based upon the final study reading) by the In-Situ LEVELTROLL were: 194.6 to 630.8 (basement calibration), 178.2 to 790.1 (bedroom calibration), 165.5 to 941.5 (garage calibration). The mean of the measured turbidity by the In-Situ was 416.2. The mean turbidity from the In-Situ was 26.7% higher than the laboratory measured turbidity.

8. Discussion

This study focused on temperature changes in relation to groundwater quality instrument calibration fluids and the groundwater samples that are measured following calibration. While six groundwater quality parameters (pH, specific conductivity, redox potential, dissolved oxygen, turbidity, and temperature) were measured during instrument calibration and the study itself, only three groundwater quality parameters (pH, specific conductivity, and redox potential) may be used to evaluate if temperature conditions had an effect on the quality of the data collected. These parameters are the most likely of the parameters measured to have remained unchanged from the time of collection to the study time frame. The other three groundwater quality parameters (dissolved oxygen, turbidity, and temperature) all may have been compromised in various ways prior to their analysis for the study.

There were a wide range of measured values for all parameters during the study, but most of these readings occurred at the zero minute sampling time. This initial sampling point may not necessarily reflect the true reading for that groundwater sample as the groundwater quality instruments have lag time in between when the probes enter the fluid and when the measurements settle. Also, these initial reading were subject to the largest amount of turbidity due to sample mixing. Turbidity measurements of 0 or 800 in certain instruments (such as the Horiba) reflect a parameter value that exceeds the probe's measurable concentration range.

The level of dissolved oxygen in the collected groundwater sample changed measurably from the time of collection, to the time of laboratory analysis, to its eventual usage in the study. Samples were stored in 500 mL plastic containers, which are not air-tight storage vessels. Thus oxygen levels within the containers likely equalized with storage environments and may not correspond to the concentration measured by IAL.

While the total volume of groundwater collected was mixed and distributed to storage containers evenly, the turbidity of the groundwater in each container may not have been equal. This may be due to the amount of material in or not in solution in the original sample, or from the material already in each container from the sampling event. Sampling containers were thoroughly mixed prior to measurement with the groundwater quality instruments, but that might not have been the procedure completed by the lab. Also, there was some lag time in between when a sample was mixed and when it was placed into a sampling vessel for measurement. A quantity of material in the sample may have come out of solution prior to measurement, thus disrupting the results.

The temperature of the groundwater sample was not measured by IAL as the parameter may have easily varied due to storage conditions, transport conditions, and analysis conditions. The temperature of the calibration fluids and the groundwater samples at each temperature zone were monitored using a properly calibrated temperature sensor, but this was completed to ensure that each was at similar temperatures prior to usage. There may have been some variation between the calibration fluids and groundwater samples due to inherent lag time that

occurred in between calibration and sampling. The fluids and/or samples may have cooled or warmed (depending on their initial temperature) due to the temperature of the sampling area (which was kept consistent for the entirety of the study).

In terms of measured pH, there was a little difference between the readings measured by IAL and those measured at various temperatures by the groundwater quality instruments in the study. The lowest temperature calibration fluids reflected neither the lowest or highest pH values, but the highest temperature calibration fluids did exhibit the lowest pH values. The measured pH values from samples at the same temperature as the calibration fluids used to calibrate the groundwater quality instruments were not more accurate than those measured in samples from other temperature zones. For this study, there did not seem to be a connection between calibration fluid temperature and measured pH. In theory, there should be a direct correlation between calibration fluid temperature and measured pH.

Out of the three groundwater quality instruments used in this study, the Horiba U-52 measured pH more consistent with the value obtained by IAL. The YSI and In-Situ instruments had mean pH values higher in percentage above the laboratory-obtained value than the Horiba, but not by more than a few percent. This result may be due to: differences in pH probe quality, calibration fluid quality, slight pH variations between the 500 mL sample containers, turbidity variations between containers, or the Horiba may better compensate for variations in calibration fluid temperature.

In terms of measured specific conductivity, there was over a 10 percent difference between the concentration measured by IAL and those measured at various temperatures by the groundwater quality instruments in the study. Neither the lowest or highest temperature calibration fluids reflected extreme specific conductivity values in the study. The measured specific conductivity values from samples at the same temperature as the calibration fluids used to calibrate the groundwater quality instruments were not more accurate than those measured in samples from other temperature zones. For this study, there did not seem to be a connection between calibration fluid temperature and measured specific conductivity. In theory, there should be a direct correlation between calibration fluid temperature and measured specific conductivity.

Out of the three groundwater quality instruments used in this study, the Horiba U-52 and YSI 6820 measured specific conductivity more consistent with the value obtained by IAL. The In-Situ instrument had a mean specific conductivity value higher in percentage above the laboratory-obtained value than the other two groundwater quality instruments, but not by more than a few percent. This result may be due to: differences in specific conductivity probe quality, calibration fluid quality, slight specific conductivity variations between the 500 mL sample containers, turbidity variations between containers, or the Horiba/YSI may better compensate for variations in calibration fluid temperature.

In terms of measured redox potential, there was over between a 5.4 and 33.8 percent difference between the concentration measured by IAL and those measured at various

temperatures by the groundwater quality instruments in the study. Neither the lowest or highest temperature calibration fluids reflected extreme redox potential values in the study. The measured redox potential values from samples at the same temperature as the calibration fluids used to calibrate the groundwater quality instruments were not more accurate than those measured in samples from other temperature zones. For this study, there did not seem to be a connection between calibration fluid temperature and measured redox potential.

Out of the three groundwater quality instruments used in this study, the Horiba U-52 measured redox potential more consistent with the value obtained by IAL. The YSI and In-Situ instruments had mean redox potential values higher in percentage above the laboratory-obtained value than the other two groundwater quality instruments. The YSI had an approximate five percent higher mean than the Horiba. The In-Situ instrument had a mean 15 percent greater than the Horiba value. This result may be due to: differences in redox potential probe quality, calibration fluid quality, slight redox potential variations between the 500 mL sample containers, turbidity variations between containers, or the Horiba may better compensate for variations in calibration fluid temperature.

9. Conclusions

The results from this study show that there is some variation in measured groundwater quality parameters when instrumentation is calibrated at different temperatures, but the differences are not overwhelming (besides those variations addressed in the adobe section for the dissolved oxygen, temperature, and turbidity parameters). It is possible that the quality of

groundwater quality instruments has improved to a point where their internal computers effectively compensate for these temperature differences. While the NJDEP does specify that groundwater quality instruments must be calibrated in the field with fluids of the same temperature as the groundwater to be measured, this study shows that this requirement may not be critical to project success. Accounting for differences in groundwater quality instrumentation, differences in temperature between calibration fluids and sampled groundwater, quality of field personnel training, variances in field calibration and/or sampling procedures, etc. there might not be a need to maintain this requirement as stated. This conclusion does not extend to the dissolved oxygen and turbidity parameters, as their varied results within the study should not be used for interpretation.

The parameters measured in this study are essential in making remediation decisions for a project, but the discrepancy between the true parameter values and those seemingly altered due to the above may be negligible to the point of becoming a nonfactor. For example, if the results of this study showed that the true pH of a groundwater sample to be acidic but the measured value classified the sample as alkaline in nature then the temperature difference would be a quantified problem. Instead, this study displayed minimal differences between true and measured groundwater quality parameter values. If there is little difference in values obtained no matter the temperature of the calibration fluids (or groundwater temperature), then it may be possible to save an effort by calibrating groundwater quality instruments in the office prior to going out into the field. This would save time, money, and effort for both the field personnel and the environmental company in general.

A secondary conclusion of this study is that the Horiba U-52 handled the temperature changes with its calibration fluid better than the other two instruments in the study. The Horiba consistently measured each parameter at a value closer to the laboratory-obtained values. In comparison with the YSI, this result may be due to the Horiba only having one calibration fluid (containing all parameters to be calibrated) varying temperature whereas the YSI has separate calibration fluids for each parameter. In comparison with the In-Situ, this result may be due to a quality difference between the instrument probes. As YSI-brand groundwater quality instruments have a reputation in the environmental industry as being the most accurate and reliable, the results of this study stand as a contradiction to that assumption.

10. Acknowledgment

This study was generously supported by Integrated Analytical Laboratories (Randolph, NJ), US Environmental (Hamilton, NJ), colleagues at Peak Environmental and Shaw Environmental, and the University of Florida Soil and Water Science Department.

11. References

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Appendix 1

Field Instrument and Calibration Data Sheet

Site: <u>Basement calibration - Insitu</u>
Field Personnel: <u>quick cal temp = 16.8 c</u>
Date: _____ Start Time: _____ Stop: _____

Meter (make/model)	Probe
DO _____	_____
pH _____	_____
Spec. Cond. _____	_____
ORP _____	_____
Turbidity _____	_____

Dissolved Oxygen	Turbidity	ORP
	Standard Reading	
Water Temp <u>17.3909</u>	<u>D.I. Water</u> _____	Standard Temp. <u>16.9548</u>
Baro. Pres. <u>30.1169 hg</u>	_____	Standard Conc. <u>236.218</u>
Saturation _____	_____	Initial Reading <u>209.465</u>
Init. Mtr. Rd. <u>9.65055 mg/l</u>	_____	Meter reset to <u>236.218</u>
Mtr. reset to <u>9.65055</u>	_____	
O₂ Satur. % _____	_____	

Specific Conductance					
	Conc.	Initial Reading	Reset to	Temperature	Lot # and Exp. Date
Standard #1	<u>7980 ug/cm</u>	<u>7980</u>	<u>7980</u>	<u>16.9548</u>	_____
Standard #2	_____	_____	_____	_____	_____
Standard #3	_____	_____	_____	_____	_____
Standard #4	_____	_____	_____	_____	_____

pH Calibration					
Buffer	Temperature	Initial Reading	mV	Meter Reset To	Lot # and Exp. Date
4	_____	_____	_____	_____	_____
7	<u>16.9548</u>	<u>7.00</u>	<u>-23.8659</u>	<u>7.00</u>	_____
10	_____	_____	_____	_____	_____

Field Instrument and Calibration Data Sheet

Site: Basement calibration - Horiba U-52	
Field Personnel: autocal temp = 16.9 c	
Date: _____	Start Time: _____ Stop: _____

Meter (make/model)	Probe
DO _____	_____
pH _____	_____
Spec. Cond. _____	_____
ORP _____	_____
Turbidity _____	_____

Dissolved Oxygen	Turbidity	ORP
	Standard Reading	
Water Temp _____	D.I. Water _____	Standard Temp. _____
Baro. Pres. _____	ac 0.0	Standard Conc. _____
Saturation _____	_____	Initial Reading _____
Init. Mtr. Rd. 10.52	_____	Meter reset to _____
Mtr. reset to _____	_____	
O ₂ Satur. % _____	_____	

Specific Conductance					
	Conc.	Initial Reading	Reset to	Temperature	Lot # and Exp. Date
Standard #1	4.49	4.49	_____	_____	_____
Standard #2	_____	_____	_____	_____	_____
Standard #3	_____	_____	_____	_____	_____
Standard #4	_____	_____	_____	_____	_____

pH Calibration					
Buffer	Temperature	Initial Reading	mV	Meter Reset To	Lot # and Exp. Date
4	_____	3.98	_____	_____	_____
7	_____	_____	_____	_____	_____
10	_____	_____	_____	_____	_____

Field Instrument and Calibration Data Sheet

Site: <u>Basement calibration - YSI 6820</u>		
Field Personnel: _____		
Date: _____	Start Time: _____	Stop: _____

Meter (make/model)	Probe
DO _____	_____
pH _____	_____
Spec. Cond. _____	_____
ORP _____	_____
Turbidity _____	_____

Dissolved Oxygen	Turbidity	ORP
	Standard Reading	
Water Temp <u>16.9</u>	<u>D.I. Water</u> <u>1.9</u>	Standard Temp. <u>13.48</u>
Baro. Pres. <u>775.5</u>	_____	Standard Conc. <u>244</u>
Saturation _____	_____	Initial Reading <u>247.7</u>
Init. Mtr. Rd. <u>10.43</u>	_____	Meter reset to <u>244.0</u>
Mtr. reset to <u>10.12</u>	_____	
O₂ Satur. % <u>105.1</u>	_____	

Specific Conductance					
	Conc.	Initial Reading	Reset to	Temperature	Lot # and Exp. Date
Standard #1	<u>1000 ug/cm</u>	<u>990</u>	<u>1000</u>	<u>17.06</u>	_____
Standard #2	_____	_____	_____	_____	_____
Standard #3	_____	_____	_____	_____	_____
Standard #4	_____	_____	_____	_____	_____

pH Calibration					
Buffer	Temperature	Initial Reading	mV	Meter Reset To	Lot # and Exp. Date
4	<u>16.87</u>	<u>3.99</u>	<u>228.9</u>	<u>4.00</u>	_____
7	<u>16.88</u>	<u>6.97</u>	<u>161.3</u>	<u>7.00</u>	_____
10	<u>16.89</u>	<u>10.02</u>	<u>131.7</u>	<u>10.0</u>	_____

Field Instrument and Calibration Data Sheet

Site: <u>Garage calibration - Insitu</u>		
Field Personnel: <u>qc initial = 13.8 c</u>		
Date: _____	Start Time: _____	Stop: _____

Meter (make/model)	Probe
DO _____	_____
pH _____	_____
Spec. Cond. _____	_____
ORP _____	_____
Turbidity _____	_____

Dissolved Oxygen	Turbidity	ORP
	Standard Reading	
Water Temp <u>15.5194</u>	<u>D.I. Water</u> _____	Standard Temp. <u>15.5194</u>
Baro. Pres. <u>30.2555</u>	_____	Standard Conc. <u>238.43</u>
Saturation _____	_____	Initial Reading <u>208.606</u>
Init. Mtr. Rd. <u>9.61725</u>	_____	Meter reset to <u>238.43</u>
Mtr. reset to <u>9.61725</u>	_____	
O₂ Satur. % _____	_____	

Specific Conductance				
Conc.	Initial Reading	Reset to	Temperature	Lot # and Exp. Date
Standard #1 <u>7980</u>	<u>7980</u>	<u>7980</u>	<u>15.5194</u>	_____
Standard #2 _____	_____	_____	_____	_____
Standard #3 _____	_____	_____	_____	_____
Standard #4 _____	_____	_____	_____	_____

pH Calibration					
Buffer	Temperature	Initial Reading	mV	Meter Reset To	Lot # and Exp. Date
4	_____	_____	_____	_____	_____
7	<u>15.5194</u>	<u>7</u>	<u>-26.581</u>	<u>7</u>	_____
10	_____	_____	_____	_____	_____

Field Instrument and Calibration Data Sheet

Site: Garage calibration - Horiba U-52	
Field Personnel: ac initial temp = 14.3	
Date: _____	Start Time: _____ Stop: _____

Meter (make/model)	Probe
DO _____	_____
pH _____	_____
Spec. Cond. _____	_____
ORP _____	_____
Turbidity _____	_____

Dissolved Oxygen	Turbidity	ORP
	Standard Reading	
Water Temp _____	D.I. Water _____	Standard Temp. _____
Baro. Pres. _____	0.0	Standard Conc. _____
Saturation _____	_____	Initial Reading _____
Init. Mtr. Rd. 10.68	_____	Meter reset to _____
Mtr. reset to _____	_____	
O ₂ Satur. % _____	_____	

Specific Conductance					
	Conc.	Initial Reading	Reset to	Temperature	Lot # and Exp. Date
Standard	#1	4.52	_____	_____	_____
Standard	#2	_____	_____	_____	_____
Standard #3	_____	_____	_____	_____	_____
Standard #4	_____	_____	_____	_____	_____

pH Calibration					
Buffer	Temperature	Initial Reading	mV	Meter Reset To	Lot # and Exp. Date
4	_____	3.96	_____	_____	_____
7	_____	_____	_____	_____	_____
10	_____	_____	_____	_____	_____

Field Instrument and Calibration Data Sheet

Site: Garage calibration - YSI 6820		
Field Personnel: _____		
Date: _____	Start Time: _____	Stop: _____

Meter (make/model)	Probe
DO _____	_____
pH _____	_____
Spec. Cond. _____	_____
ORP _____	_____
Turbidity _____	_____

Dissolved Oxygen	Turbidity	ORP
	Standard Reading	
Water Temp <u>14.71</u>	<u>D.I. Water</u> <u>0.3</u>	Standard Temp. <u>14.40</u>
Baro. Pres. <u>776.7</u>	_____	Standard Conc. <u>244</u>
Saturation _____	_____	Initial Reading <u>245.3</u>
Init. Mtr. Rd. <u>10.19</u>	_____	Meter reset to <u>244</u>
Mtr. reset to <u>10.06</u>	_____	
O ₂ Satur. % <u>103.4</u>	_____	

Specific Conductance					
	Conc.	Initial Reading	Reset to	Temperature	Lot # and Exp. Date
Standard #1	<u>1000</u>	<u>953</u>	<u>1000</u>	<u>15.06</u>	_____
Standard #2	_____	_____	_____	_____	_____
Standard #3	_____	_____	_____	_____	_____
Standard #4	_____	_____	_____	_____	_____

pH Calibration					
Buffer	Temperature	Initial Reading	mV	Meter Reset To	Lot # and Exp. Date
4	<u>15.21</u>	<u>4.32</u>	<u>292.0</u>	<u>4.00</u>	_____
7	<u>14.65</u>	<u>6.99</u>	<u>240.1</u>	<u>7.00</u>	_____
10	<u>15.41</u>	<u>10.04</u>	<u>198.8</u>	<u>10.01</u>	_____

Appendix 2

ANALYTICAL DATA REPORT

for

Peak Environmental Inc.

74 Main Street

2nd Floor

Woodbridge, NJ 07095

Project Name: KRPS

Lab Case Number: E13-01769

RL = REPORTING LIMIT

MDL = METHOD DETECTION LIMIT

General Analytical

Lab ID: 01769-001

Client ID: KRPS-1

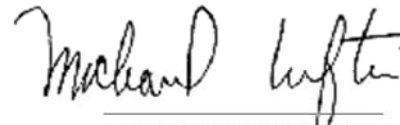
Percent Moisture: 100

Date Sampled: 2/28/2013

Time Sampled: 12:00

Parameter	Result	RL	MDL	Matrix-Units	Date Analyzed
Specific Conductance	4000	2.00	2.00	Aqueous- μ S/cm @ 25°C	3/4/2013 11:00
pH/Corrosivity	7.13	NA	NA	Aqueous-SU	3/4/2013 11:10
Total Dissolved Oxygen	8800	100	100	Aqueous- μ g/L	3/1/2013 16:00
Turbidity	24.6	0.100	0.080	Aqueous-NTU	3/1/2013 17:00
Oxidation-Reduction Potential	222	NA	NA	Aqueous-mV	3/4/2013 11:45

These data have been reviewed and accepted by:



Michael H. Leftin, Ph.D

Laboratory Director