Milestone Report for

WIPP Water Qualities Collected From 2019 to 2020

Milestone Report for Groundwater Sampling

Task Number 4.4.2.3.1

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1. Introduction

The purpose of this milestone report is to document recent water quality analyses collected from monitoring wells in the Waste Isolation Pilot Plant (WIPP), well monitoring network. This work falls under TP 03-01 Rev.3 (Schuhen, 2010) and is in alignment with the 5-year plan presented in 2016 (Thomas et al, 2016). The milestone report Bowman, 2019 documented chemistry analysis for the first two years (2017 and 2018) of a 4-year study. This report documents the last two years (2019 and 2020) of data from that study. Newly collected data will be presented along with a side by side comparison to previous years passive sampling water quality analyses and historical conventional pumping analyses. The 2017-2018 report presented data comparing recent data to historical data. This milestone report expands on the previous report by presenting the current 2019-2020 data and comparing it to the previous two years as well as historical data. This analysis documents the maximum and lowest reported analyte level along with the recorded and mean average of all the samples from both the current and historical data. This comparison will allow the WIPP program to better characterize short-term changes in the water chemistry of the WIPP monitoring well network. These data can also be used to examine the long-term changes in the water chemistry profiles for the wells of interest. This milestone report will also be used to evaluate and validate a new sampling method (snap-sampling) which is a specific objective detailed in the present 5-year plan (Thomas et al., 2016).

Water quality sampling of the WIPP well monitoring network has historically served two purposes, these purposes being 1) investigation of groundwater geochemistry and, 2) an indicator of the degree of removal of non-native water emplaced during well construction activities. Historical water quality samples discussed in this report (i.e. those not captured with the Snap-Sampler®) were collected from the produced water of pumping tests or purges at the end of each well's testing/development. These samples were collected after 3 wellbore volumes were evacuated from the well, per EPA guidelines (Wilde et al., 1998). Samples collected from 2017-2020 were retrieved using the passive snap-sampling system which requires no pumping of the well. All water samples discussed in this report were collected from the Culebra Dolomite Member (Culebra) of the Rustler Formation (Figure 1).

The collections and analyses of more recent samples were performed in accordance with Sandia National Laboratories (SNL) Activity Specific Procedure SP 12-36, Rev.0, *Use and Maintenance of the Snap-Sampler Brand Passive Water Sampling System.* Hall Environmental Analysis Laboratory (HEAL) was used to analyze water chemistry for the samples collected from 2017-2020. A description of HEAL laboratory procedures and standards are detailed in each analytical report (e.g. EPA method 300.0, SM2510B, etc.).

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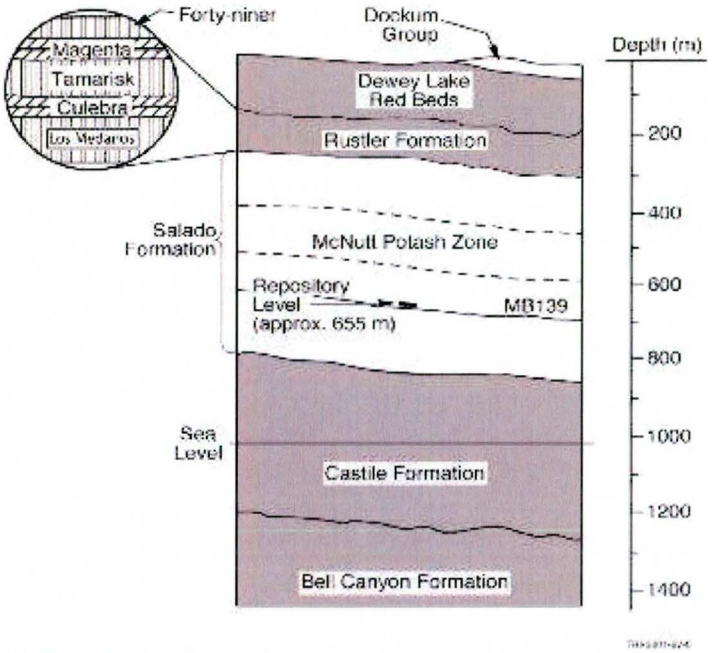

Figure 1. WIPP Geologic Stratigraphy. (Appendix TFIELDS 2014)

2. Sampling Procedures and Analysis

Water quality sample collection has historically been conducted during well development and/or pumping tests for wells in the WIPP Culebra while obtaining aquifer properties and well performance data. Samples were collected at the end of the development event and then sent to an offsite laboratory (HEAL and International Technology Analytical Services (IT)) for analysis. Test Plan (TP) 03-01 (Schuhen, 2010) directed that all new wells should be tested by pumping to allow water samples representative of the completion formation to be collected. This approach provided the program with base-line water quality chemistry profiles for each well but was reliant on scheduling during the pumping of a well, requiring additional staff and equipment to collect.

The Snap-Sampler ® system is a passive water quality collection system that can be deployed in the well column at a specific depth, with no pumping required. This system was used to acquire water quality samples for sampling years 2017 - 2020. The Snap-Sampler® consists of open-ended sampling containers held in an actuated housing that allows for the deployment of the containers in a fixed-open state for controlled closure of submerged sample containers by delivering an air pulse through a ¼" poly air-line from the surface. The Snap-Sampler® can be deployed at any depth, however for this study, the sampler capture depth was deployed in the mid-formation of each well as this water is most likely to be the most representative sample of formation water unaffected by well casing residence affects.

During deployment of the Snap-Sampler®, vertical mixing of the water column in each wellbore will occur. In order to obtain samples representative of formation water, a residence time of 24 hours, prior to capturing water samples, is allowed for disturbed water to equilibrate. In other words, the sampler is deployed and allowed to sit in the well column for an adequate residence time, so the well can return to an un-mixed state before samples are captured. In some cases, the wells are in high-traffic areas (i.e. near a highway, near an oil pad, etc.) and are subject to

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vandalism and theft. In these locations, sampler residence time was reduced to 1 hour. The residence time used for each well is listed in Table 1.

Table 1: Residence Times for the Snap-Sampler® in WIPP wells

Well	Residence Time (hr)	Well	Residence Time (hr)	Well	Residence Time (hr)	Well	Residence Time (hr)
AEC-7R	24	**H-11b4R**	24	**SNL-5**	24	**SNL-16**	1
H-2b2	24	**H-12R**	24	**SNL-8**	1	**SNL-17**	1
H-4bR	24	**H-17**	24	**SNL-9**	1	**SNL-18**	24
H-5b	24	**H-19b0**	24	**SNL-10**	24	**SNL-19**	1
H-6bR	24	**SNL-1**	1	**SNL-12**	1	**WIPP-11**	24
H-7b1	24	**SNL-2**	1	**SNL-13**	1	**WIPP-13**	24
H-9bR	24	**SNL-3**	1	**SNL-14**	24	**WIPP-19**	24

All samples collected from 2017 – 2020 via the Snap-Sampler® method were collected in compliance with American Society for Testing and Materials (ASTM) Standard D7929-14 (2014), the guideline for passive sampling, and TP 03-01 (Schuhen, 2010). TP 03-01 describes procedures and plans for well testing and sample collection for SNL WIPP monitoring network. Snap-Sampler® collected aliquots were pulled to the surface and were placed in HEAL sample kits, then placed on ice until samples could be shipped in accordance with SNL WIPP Nuclear Waste Management Procedure (NP), NP 13-1 Rev.7, *Control of Samples and Standards*. A portion of the collected sample was also analyzed using the YSI multi-parameter sonde and the data was recorded in the associated SNs (WIPP Water Quality Monitoring series, (WWQM)) pursuant to Activity Specific Procedure (SP), SP 13-3 Rev. 3, *Field Water Quality Measurements*. The YSI Pro-Plus Handheld Multi-Parameter Sonde, SN #170109296 was calibrated as per Activity SP 12-15 Rev.2, *Calibration of Water Quality Measurement Instrumentation* prior to use. A post-calibration check was conducted after sampling activities to ensure probes were functioning within acceptance parameters after daily operations were complete. An additional sample was collected for use by SNL in-house, if necessary. The SNL sample was bottled without using preservatives and was also adequately sealed and stored in an iced cooler. The YSI sonde provided an immediate qualitative measurement of pH, conductivity, and specific conductance (SC). These values were recorded in the Scientific Notebook (SN) series, WWQM-1 and WWQM-2, and serve as a comparison and confirmation of HEAL laboratory collected analysis.

Collected samples were sent to HEAL, typically within 24 hours of retrieval in an iced chest. In cases where circumstances prevented immediate shipping, samples were refrigerated overnight. Any lapse in holding times for water samples, are documented on the respective HEAL reports. SNL samples were refrigerated and stored in the onsite lab as a precaution against unexpected or unrealistic HEAL lab results. In the event of unexpected or unrealistic results from the HEAL report, SNL would perform additional confirmation chemistry analysis. HEAL analyzed the water samples for the following properties/constituents:

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- pH
- Specific Conductance (Sp. Cond.)
- Total Dissolved Solids (TDS)
- Calcium (Ca^{2+})
- Magnesium (Mg^{2+})
- Sodium (Na^{+})
- Potassium (K^{+})
- Chlorine (Cl^{-})
- Bicarbonate (HCO_3^{-})
- Carbonate (CO_3^{-})
- Sulfate (SO_4^{2+})
- Fluoride (F^{-})
- Nitrate (NO^{3-})
- Nitrite (NO^{2-})

Figure 2 shows a location map of samples assessed in this study, both historical and in recent years (2017-2020). The figure designates which samples were collected with the passive collection device (Snap-Sampler®) as well as with more traditional methods.

All sampling procedures, YSI sonde pre and post-calibration checks, chains of custody (COCs), and HEAL reports from snap-sampling are detailed in the SN, WIPP Water Quality Monitoring-1 (WWQM-1) and WIPP Water Quality Monitoring-2 (WWQM-2) and their associated supplemental binders (WWQM-1 Supplemental Binder #1 and WWQM-1 Supplemental Binder #2). COCs and HEAL reports can be found in the WIPP Records Center and submitted in accordance with NP 17-1, *Records*.

Acceptance criteria for HEAL reports as well as SNL QA guidelines were followed (both EPA and Standard methods).

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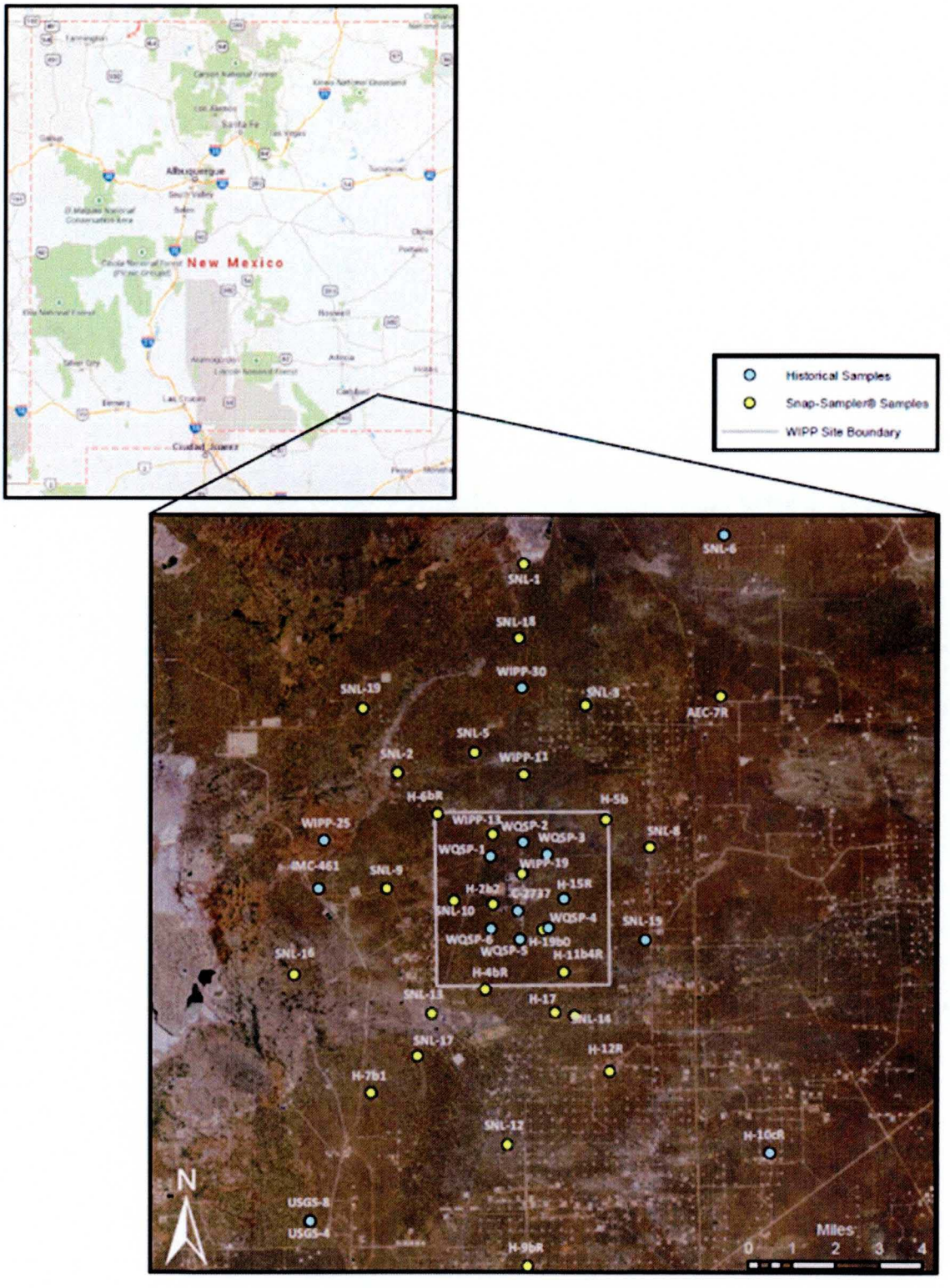

Figure 2. Location of the Culebra Wells Sampled for Water Quality (map generated for this study).

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3. Water Quality Parameters

The objectives of this milestone are to 1) document data collected using the Snap-Sampler® methodology from 2017-2020, 2) document historical water quality data gathered during the life of the monitoring program and compare those results to snap-sampled results in a single document. The following section describes the water quality results that were produced from historical sampling of Culebra wells and their analogous 2017-2020 snap-sampled counterparts.

Water quality data for sampled wells are presented and discussed on a well by well basis. Tables with well numbers present the results of each constituent for historical data as well as data collected from 2017-2020. The minimum, maximum and mean values are presented for each constituent for all years presented. Notable changes in constituents over time, data anomalies and recognized trends will be discussed beneath the table for each well. Historical data averages are not presented in this study, instead, the most recent historical value was selected and presented for comparison to the current study. Graphical (Piper diagrams) and spatial representations (contour maps) are presented in this report to provide the reader with a visual representation of the constituents with respect to concentrations, geographical location and analyte contours showing patterns and evolution of each of the water quality parameters.

In some wells, data could not be collected with the Snap-Sampler® apparatus, for various reasons including: Well casing diameter being too small, abandoned wells, etc. Additionally, several of the wells in the network that were sampled in years 2017-2019 were plugged before the 2020 sampling year. All of this information is documented in the respective tables and sections. Consequently, there are no 2020 results to report for wells H-7b1, H-17, H-5b, WIPP-19, and H-2b2. Existing water quality analysis results are reported for all monitoring wells, to provide a complete picture of the evolving water quality in the WIPP monitoring well network. These data represent the comprehensive available data for the WIPP monitoring network, to the authors present knowledge. Updates will be made in future milestones if new data is found or generated.

Water quality analysis result accuracy is subject to both constituents holding time constraints and lab efficiency. The accuracy of the reported values is quantified in each individual water quality HEAL report with notations of extended residence time (when applicable) and charge balance. Data in the following Tables represent the respective accuracies of the methods and laboratory facility, as documented in the official well data report, submitted to records. Where applicable, percent deviation was calculated between reported values using the following equation:

$$\%\ Deviation\ = \frac{x_{measured} - x_{true}}{x_{true}} * 100$$

All associated files used in the preparation of this report will be archived at:
/cvs/CVSLIB/WIPP_EXTERNAL/tp0301/waterqual2019_2020

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Well: AEC-7R

AEC-7R	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	3/11/2015	5/10/2017	6/20/2018	6/12/2019	6/24/2020				
pH (pH units)	7.41	7.06	7.11	6.93	7.17		6.93	7.41	7.14
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	180000	180000	190000	170000	170000		170000	190000	178000
CHARGE BALANCE ERROR (%)	NA	1	2	2	5		1	5	3
FLUORIDE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
CHLORIDE (mg/L)	58000	43000	49000	53000	46000		43000	58000	49800
BROMIDE (mg/L)	160.00	130.00	130.00	140.00	9.30		9.30	160.00	113.86
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	6600	6000	5900	6000	4700		4700	6600	5840
CALCIUM (mg/L)	1900	1500	1900	1800	1800		1500	1900	1780
MAGNESIUM (mg/L)	4700	3500	4300	4200	4400		3500	4700	4220
POTASSIUM (mg/L)	1900	1400	1800	1800	1800		1400	1900	1740
SODIUM (mg/L)	22000	21000	22000	25000	24000		21000	25000	22800
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	49.00	57.44	72.04	78.08	138.60		49.00	138.60	79.03
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	49.00	57.44	72.04	78.08	138.60		49.00	138.60	79.03
TDS (mg/L)	82500	91800	91900	91500	95600		82500	95600	90660

ND=Not Detected at the Reporting Limit
NA=Not Applicable, No Available Data

Well AEC-7R is a relatively low flow well and is cased with 8.6-inch fiber reinforced plastic (FRP). AEC-7R was constructed in 2013 and is located to the east of the WIPP Site. AEC7R well waters did not contain any detectable fluoride, nitrate/nitrite or phosphorus in any of the collected data. With the exception of sampling year 2017, calcium magnesium and potassium are comparatively stable, with little change in 2018-2020 compared to historic data (4, 9 and 5% difference respectively). Higher chloride readings were seen in the historic sample with a drop in 2017 and a steady rise through 2019, dropping again in the 2020 sample. Over-all change from historic compared to the 2020 chloride values show a decrease of 21%. Over-all the constituents in well AEC-7R have remained consistent from historical values measured in 2015 to the present 2020 data, with the majority of the fluctuations within the detection capabilities of HEAL instrumentation and certified EPA methods used for the analysis (e.g. EPA method 6010b within 10%, EPA method 300.0 within 10%). The most notable change in the data constituents is seen in total alkalinity, sulfate and bromide data. Total alkalinity has increased by 183% from 2015 (historic) to 2020 with the greatest increase occurring between 2019 and 2020 levels, while bromide levels for 2020 showed a significant decrease (94% from historic to current) with the greatest difference recorded between 2019 and 2020. Sulfate also decreased by 29% from 2015 to 2020. AEC-7R was acidized on 4/16/2014 to facilitate break down of the clay seen in the well. The treatment was combined with brushing to mix in the acid using formation water. Approximately 150 – 200 gallons of acid were added to the well along with 55 gallons of AEC-7R water and 100 gallons of non-native fresh water from the Capitan aquifer which could have contributed to the change in water chemistry. If this trend is real, it needs to be validated by at least another year of sampling data.

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Well: H-2b2

H-2b2	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	NA	9/7/2017	9/19/2018	9/5/2019	NA				
pH (pH units)	NA	9.19	9.43	9.28	NA		9.19	9.43	9.30
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	NA	24000	26000	21000	NA		21000	26000	23667
CHARGE BALANCE ERROR (%)	NA	7	3	5	NA		3	7	5
FLUORIDE (mg/L)	NA	ND	ND	ND	NA		ND	ND	ND
CHLORIDE (mg/L)	NA	6200	5600	5700	NA		5600	6200	5833
BROMIDE (mg/L)	NA	5.80	5.90	5.10	NA		5.10	5.90	5.60
NITRATE+ NITRITE (mg/L)	NA	ND	ND	ND	NA		ND	ND	ND
PHOSPHORUS (mg/L)	NA	ND	ND	ND	NA		ND	ND	ND
SULFATE (mg/L)	NA	3100	3100	3000	NA		3000	3100	3067
CALCIUM (mg/L)	NA	790	790	790	NA		790	790	790
MAGNESIUM (mg/L)	NA	140	120	120	NA		120	140	127
POTASSIUM (mg/L)	NA	120	100	110	NA		100	120	110
SODIUM (mg/L)	NA	3600	3600	3500	NA		3500	3600	3567
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	NA	ND	ND	ND	NA		ND	ND	ND
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	NA	46.48	36.80	48.40	NA		37	48	44
ALKALINITY as $CaCO_3$ Total (mg/L)	NA	53.40	51.36	52.52	NA		51.36	53.40	52.43
TDS (mg/L)	NA	14600	13100	13800	NA		13100	14600	13833

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well H-2b2 is a 5 ½-inch outside diameter (OD) steel cased, open-hole completion Culebra well west of the WIPP site. It was constructed in 1983 and was modified by adding a stainless-steel screen and packer assembly across the Culebra zone in 1984. H-2b2 was not sampled prior to 2017, therefore only comparisons that can be made are for the years 2017 – 2019. Magnesium levels showed no change from 2018 to 2019 samples. When compared to 2017 there was a 14% decrease in magnesium. Potassium levels show a decrease of 17% from year 2017 to 2018 with the levels rising slightly in 2019 from 100 mg/L in 2018 to 110 mg/L in 2019, an increase of 3%. Sodium levels drop slightly (3%) in 2019 when compared to 2017 and 2018 results. Although a decrease in total alkalinity was seen between 2017 and 2018 samples (20%), there was an increase noted in carbonate and total alkalinity. Carbonate shows a 30% increase from 2018 to 2019, but only a 4% increase when comparing 2017 to 2019. The TDS showed a change from year to year with the same trend as that of alkalinity. Well H-2b2 was plugged in April of 2020, consequently no water quality data was gathered for sampling year 2020.

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Well: H-4bR

H-4bR	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	8/13/2009	3/9/2017	3/28/2018	3/7/2019	3/5/2020				
pH (pH units)	7.76	7.82	7.81	7.87	7.73		7.73	7.87	7.80
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	24000	30000	25000	25000	25000		24000	30000	25800
CHARGE BALANCE ERROR (%)	NA	0	4	6	0		0	6	3
FLUORIDE (mg/L)	2.90	ND	ND	ND	1.10		1.10	2.90	2.00
CHLORIDE (mg/L)	6100	5700	6200	5700	5200		5200	6200	5780
BROMIDE (mg/L)	24.00	41.00	25.00	20.00	24.00		20.00	41.00	26.80
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	4500	4400	4500	4600	4000		4000	4600	4400
CALCIUM (mg/L)	660	710	730	690	720		660	730	702
MAGNESIUM (mg/L)	280	320	300	260	280		260	320	288
POTASSIUM (mg/L)	130	130	130	130	120		120	130	128
SODIUM (mg/L)	3800	4400	4200	3900	3900		3800	4400	4040
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	54.00	72.48	70.16	58.04	56.36		54.00	72.48	62.21
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	54.00	72.48	70.16	58.04	56.36		54.00	72.48	62.21
TDS (mg/L)	14900	16500	15600	15700	15900		14900	16500	15720

ND=Not Detected at the Reporting Limit
NA=Not Applicable, No Available Data

Well H-4bR is a 5 ½-inch OD, Fiber Reinforced Plastic (FRP) -cased well located southwest of the WIPP site and was constructed in 2009 as a replacement for H-4b.For well H-4bR minimal change in Bromide was documented with the exception of the sampling in 2017. Bromide values in 2017 increased from the average bromide in other years by 76%. This increase coincided with an increase in sodium, which would indicate the bromide is in the form of NaBr. In 2017 sodium increased by 11% from the average of other years of collected data. Sulfate in the 2020 showed an 11% decrease from the average of previous years. The sulfate changed from a high of 4600 mg/L in 2019 to a low of 4000 mg/L in 2020 resulting in a 13 % change with the average modern samples compare to historic showing. Chloride data showed fluctuations from 2017-2020 with the average being 7% different from the historical measured sample in 2009. Sodium, bicarbonate and total alkalinity show an increase from historical (2009) to 2017, however levels of these constituents gradually decrease from 2017-2020, with the values in 2020 reflecting the original value measured in 2009. From 2009 to 2017 alkalinity increased by 34% when compared to the historical value. The 2017 – 2020 TDS readings compared to historical display a trend increase in TDS with a difference of 11% from 2009 to 2017. Subsequent year samples are elevated from 2009 but decrease by an average of 5% from 2017 to 2020.

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Well: H-5b

H-5b	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	12/10/2008	9/7/2017	9/19/2018	8/16/2019	NA				
pH (pH units)	7.07	6.84	7.81	7.90	NA		6.84	7.90	7.41
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	124000	290000	290000	290000	NA		124000.00	290000	248500
CHARGE BALANCE ERROR (%)	NA	2	9	6	NA		2	9	6
FLUORIDE (mg/L)	ND	ND	ND	ND	NA		ND	ND	ND
CHLORIDE (mg/L)	85700	88000	97000	93000	NA		85700	97000	90925
BROMIDE (mg/L)	70.30	41.00	67.00	50.00	NA		41.00	70.30	57.08
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	NA		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	NA		ND	ND	ND
SULFATE (mg/L)	9160	8000	8500	6500	NA		6500.00	9160	8040
CALCIUM (mg/L)	1630	1500	1600	1700	NA		1500.00	1700	1608
MAGNESIUM (mg/L)	2060	2000	2100	2000	NA		2000.00	2100	2040
POTASSIUM (mg/L)	1190	1100	1100	1100	NA		1100.00	1190	1123
SODIUM (mg/L)	47300	57000	50000	50000	NA		47300.00	57000	51075
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	31.10	ND	49.00	51.28	NA		31.10	51.28	43.79
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	25.04	ND	ND	NA		25.04	25.04	25.04
ALKALINITY as $CaCO_3$ Total (mg/L)	31.10	38.76	49.00	51.28	NA		31.10	51.28	42.54
TDS (mg/L)	156000	155000	155000	159000	NA		155000.00	159000	156250

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well H-5b is a 5 ½-inch steel-cased well, open-hole completion constructed in 1978 and is located northeast of the WIPP site. Well H-5b increased in pH from 6.84 in 2017 to 7.90 in 2019, this was an increase of 12% from the historical value of 7.07. Chloride had a historical value of 85,700 mg/L and increased in 2018 to 97,000 mg/L, which is an increase of 12%, however reduced in 2019 to 93,000 mg/L. Bromide fluctuated from historical values from 70.30 mg/L to 2019 of a value of 50.00 mg/L, which is a decrease of 29%. Sulfates values decreased from 2008 (9,160 mg/L) to 6500 mg/L in 2019, resulting in a decrease of 29%. Calcium fluctuated through the years (including historical) with an average of 1608 mg/L. Total alkalinity gradually increased by 65% from 2008 to 2019. Well H-5b was plugged in September of 2019, consequently no sample data was collected for 2020. Replacement well H-5bR was drilled to replace the H-5b in the same month. A conventional water quality sample will be obtained from H-5bR once the well is fully developed. This will provide a more recent chemistry profile for baseline comparison for the formation in this area so that comparisons can be made with future passive sampling results from this area of the formation.

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Well: H-6bR

H-6bR	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	12/10/2008	8/9/2017	8/8/2018	8/7/2019	9/23/2020				
pH (pH units)	7.73	8.75	9.01	8.81	8.95		7.73	9.01	8.65
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	91000	110000	110000	110000	110000		91000	110000	106200
CHARGE BALANCE ERROR (%)	NA	7	0	4	6		0	7	4
FLUORIDE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
CHLORIDE (mg/L)	32000	25000	28000	33000	27000		25000	33000	29000
BROMIDE (mg/L)	36.00	26.00	30.00	23.00	29.00		23.00	36.00	28.80
NITRATE+ NITRITE (mg/L)	ND	ND	78.00	ND	ND		78	78	78
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	4000	3400	3100	3100	3000		3000	4000	3320
CALCIUM (mg/L)	2000	2400	2600	2400	2400		2000	2600	2360
MAGNESIUM (mg/L)	950	830	780	730	780		730	950	814
POTASSIUM (mg/L)	350	340	360	340	370		340	370	352
SODIUM (mg/L)	17000	16000	15000	17000	17000		15000	17000	16400
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	77.00	ND	ND	ND	ND		77.00	77.00	77.00
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	25.04	36.17	24.72	33.04		25	36	30
ALKALINITY as $CaCO_3$ Total (mg/L)	77.00	38.76	41.52	36.04	40.76		36.04	77.00	46.82
TDS (mg/L)	54000	60000	64800	63500	55600		54000	64800	59580

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well H-6bR is a 5 ½-inch FRP-cased well, constructed in 2008 and is located northwest of the WIPP site. H-6bR pH values increased from 7.73 in 2008 to 8.95 in 2020. The average of 2017 – 2020 as compared to historical sample increased in pH value by 15%. Since the historical sample in 2008, average total alkalinity from 2017-2020 has decreased by 49%. In addition, there was a shift in the form of $CaCO_3$ from bicarbonate in 2008 to carbonate in 2017-2020, which is the reason for the shift in pH to a higher pH in 2020. Sulfates in H-6bR experienced a steady decline over the sampling years with the historical value in 2008 being 4000 mg/L and the lowest recorded in 2020 of 3000 mg/L resulting in a change of 25% decrease. Both chloride and bromide values decreased from 2008 to 2020, by 16% and 19% respectively. In 2018 nitrate + nitrite was measured at 78 mg/L with all other sampling years being Non-Detectable (ND). Due to the large discrepancies between years, it is possible that the data for nitrate-nitrite in 2018 is in error. Calcium values increased by 23% when comparing the 2008 value to the average of 2017-2020. Sodium decreased slightly (average of 9%) in 2017 and 2018 but increased back to the historical value of 170,000 mg/L in 2020.

Information Only

Well: H-7b1

H-7b1	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	11/9/1990	7/12/2017	7/25/2018	7/23/2019	NA				
pH (pH units)	7.14	7.45	7.42	7.54	NA		7.14	7.54	7.39
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	3760	4900	4200	3900	NA		3760	4900	4190
CHARGE BALANCE ERROR (%)	NA	4	0	3	NA		0	4	2
FLUORIDE (mg/L)	1.50	1.60	1.40	1.20	NA		1.20	1.60	1.43
CHLORIDE (mg/L)	280	630	350	290	NA		280	630	388
BROMIDE (mg/L)	ND	ND	ND	ND	NA		ND	ND	ND
NITRATE+ NITRITE (mg/L)	ND	2.70	2.10	1.70	NA		1.70	2.70	2.17
PHOSPHORUS (mg/L)	ND	ND	ND	ND	NA		ND	ND	ND
SULFATE (mg/L)	2100	2200	1800	1800	NA		1800	2200	1975
CALCIUM (mg/L)	670	610	570	600	NA		570	670	613
MAGNESIUM (mg/L)	140	160	130	140	NA		130	160	143
POTASSIUM (mg/L)	ND	16	10	11	NA		10	16	12
SODIUM (mg/L)	100	410	230	210	NA		100	410	238
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	92.00	127.40	107.90	96.40	NA		92.00	127.40	105.93
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	NA		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	92.00	127.40	107.90	96.40	NA		92.00	127.40	105.93
TDS (mg/L)	NA	4240	3640	1720	NA		1720	4240	3200

ND=Not Detected at the Reporting Limit
NA=Not Applicable, No Available Data

Well H-7b1 is a 7-inch steel-cased open-hole completion well, constructed in 1979 and lies southwest of the WIPP site. pH for well H-7b1 showed a slight increase of 5% from 1990 (7.14) to 2019 (7.45). Well H-7b1 showed fluoride concentrations in all sample years averaging 1.43 mg/L. From 1990 to 2017, chloride concentration increased from 280 mg/L to 630 mg/L resulting in a 125% increase. However, concentrations decreased back to near historic levels in 2018 and 2019 with only a 4% difference between 1990 and 2019. Nitrate + Nitrite was present in 2017 – 2019 averaging 2.17 mg/L. Sulfate levels decreased in sampling years 2018 and 2019 by 14% from the 1990 value. Calcium fluctuated over sampling years with the highest level seen in the historical value and the lowest value seen in 2018 (570 mg/L). Over-all calcium decreased by 11% from 1990 to the average of 2017-2020. Magnesium values fluctuated through the sampling years with 2% change between the average of 2017-2020 and 1990. Potassium was not seen in historic sampling but showed concentrations averaging 12 mg/L in results from 2017-2019. Sodium concentration in 1990 was 100 mg/L while in 2017 the concentration had increased by 310% to 410 mg/L. In 2018 and 2019 however the average of sodium concentrations was 220 mg/L. Bicarbonate comprised the total alkalinity in H-7b1 for all sampling years and did not show drastic changes from 1990 to 2019, with an average total alkalinity for all years being 105.93 mg/L. No water quality data was collected in 2020 from well H-7b1 as it was plugged in April of 2020 before a sample was obtained.

Information Only

Well: H-9bR

H-9bR	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	8/20/2012	6/7/2017	5/23/2018	5/8/2019	5/28/2020				
pH (pH units)	7.68	7.87	7.45	7.41	7.82		7.41	7.87	7.65
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	3400	3700	3700	3600	3800		3400	3800	3640
CHARGE BALANCE ERROR (%)	NA	1	4	1	0		0	4	2
FLUORIDE (mg/L)	3.40	3.00	2.90	3.40	3.30		2.90	3.40	3.20
CHLORIDE (mg/L)	180	210	220	260	210		180	260	216
BROMIDE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	2000	1900	1700	2000	1900		1700	2000	1900
CALCIUM (mg/L)	610	580	570	610	550		550	610	584
MAGNESIUM (mg/L)	140	140	130	150	130		130	150	138
POTASSIUM (mg/L)	7.40	7.30	7.50	8.20	7.20		7.20	8.20	7.52
SODIUM (mg/L)	150	180	190	210	200		150	210	186
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	94.00	89.56	90.60	87.48	72.84		72.84	94.00	86.90
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	94.00	89.56	90.60	87.48	72.84		72.84	94.00	86.90
TDS (mg/L)	3380	3360	3440	3510	3480		3360	3510	3434

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well H-9bR is a relatively high-flow well drilled in the Culebra formation and constructed of 5 ½-inch FRP casing. The well was constructed in 2010 and is located south of the WIPP site. There were no notable changes in water chemistry for well H-9bR from 2012 to the average of 2017-2020. All changes between the historical values and averages of 2017-2020 were less than 10%, except for chloride and sodium. Chloride levels fluctuated slightly from year to year averaging 225 mg/L from 2017-2020, which is an increase of 25% from the historical 2012 value of 180 mg/L. Additionally, sodium values increased by 23% from the historical value of 150 mg/L to the average of 2017-2020 185 mg/L. One other interesting finding from this well was the presence of fluoride. Fluoride did not fluctuate greatly between sampling years but had an average of 3.20 mg/L from 2012-2020. Although well maintenance occurred at H-9bR prior to the 2020 sampling year, the constituent levels do not appear to have been impacted by the treatment and mechanical methods employed when comparing the 2020 (post maintenance) to 2019 (pre-maintenance).

Information Only

Well: H-11b4R

H-11b4R	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	6/14/2012	3/9/2017	3/28/2018	3/7/2019	3/5/2020				
pH (pH units)	7.24	7.33	7.42	7.47	7.42		7.24	7.47	7.38
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	180000	200000	200000	200000	200000		180000	200000	196000
CHARGE BALANCE ERROR (%)	NA	4	3	1	2		1	4	3
FLUORIDE (mg/L)	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00
CHLORIDE (mg/L)	65000	64000	63000	56000	57000		56000	65000	61000
BROMIDE (mg/L)	41	170	45	30	46		30	170	66
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	8400	7700	8200	6600	6700		6600	8400	7520
CALCIUM (mg/L)	1800	1800	1800	1800	1800		1800	1800	1800
MAGNESIUM (mg/L)	1500	1300	1300	1200	1300		1200	1500	1320
POTASSIUM (mg/L)	940	710	770	720	720		710	940	772
SODIUM (mg/L)	42000	37000	37000	34000	37000		34000	42000	37400
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	42.00	91.28	89.72	105.20	85.24		42.00	105.20	82.69
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	42.00	91.28	89.72	105.20	85.24		42.00	105.20	82.69
TDS (mg/L)	112000	113000	114000	114000	108000		108000	114000	112200

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well H-11b4R is a 5 ½-inch FRP-cased well, constructed in 2011 and is located southeast of the WIPP site. H-11b4R did not show notable differences in chemistry concentrations (<10%) when comparing 2012 data to the average of 2017-2020 for pH, chloride, and calcium. Bromide levels in 2017 showed a notable spike, increasing by 315%, when compared to the 2012 value of 41 mg/L. However, bromide concentration decreases again from 2018-2020 with an average being 40.33 mg/L and only 2% difference from the 2012 historical value. Sulfate concentrations decreased by 21% for 2019-2020 when compared to the historical value in 2012. Sodium concentrations decreased by 12% from the historical value in 2012 to the average of 2017-2020. Total alkalinity increased by 122% when comparing the average of 2017-2020 to the measured historical value in 2012. TDS showed very little change across most sampling years, but had a notable decrease in 2020, of 4% when compared to the historical value measured in 2012.

Information Only

Well: H-12R

H-12R	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	4/22/2015	5/10/2017	5/23/2018	5/8/2019	5/20/2020				
pH (pH units)	7.59	7.34	7.39	7.33	7.80		7.33	7.80	7.49
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	290000	410000	370000	340000	250000		250000	410000	332000
CHARGE BALANCE ERROR (%)	NA	7	5	8	7		5	8	7
FLUORIDE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
CHLORIDE (mg/L)	94000	118000	110000	97000	92000		92000	118000	102200
BROMIDE (mg/L)	99	75	63	46	58		46	99	68
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	7700	9400	8300	6300	7800		6300	9400	7900
CALCIUM (mg/L)	1600	1200	1100	1300	1600		1100	1600	1360
MAGNESIUM (mg/L)	1700	1100	1100	1300	1600		1100	1700	1360
POTASSIUM (mg/L)	1100	1100	1400	1400	1000		1000	1400	1200
SODIUM (mg/L)	51000	66000	63000	73000	50000		50000	73000	60600
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	61.80	47.36	47.48	46.24	77.28		46.24	77.28	56.03
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	61.80	47.36	47.48	46.24	77.28		46.24	77.28	56.03
TDS (mg/L)	151000	225000	204000	208000	137000		137000	225000	185000

ND=Not Detected at the Reporting Limit
NA=Not Applicable, No Available Data

H-12R is a 5 ½-inch OD FRP cased well completed in 2014 located south of the WIPP site. There were no notable differences (2%) in pH values from 2017-2020 average from the historical value of 7.59. Chloride concentration displayed minimal fluctuation from 2015 to 2020 with the average of 2017-2020 value being 11% different than the 2015 value. Bromide concentrations decreased from the historical value of 99 mg/L to an average of 68 mg/L for 2017-2020, resulting in a decrease of 24%. Calcium concentrations decreased by 33% in 2017-2019 and then increased back to the historical value of 1600 mg/L in 2020. Magnesium was very similar in trend to that of calcium across sampling years, with the highest level being the historical value of 1700 mg/L but ending in year 2020 with only a 6% decrease. Sodium concentrations increased from 2017-2019 by 32% from the historical value of 51,000 mg/L, however decreased by 32% from 2019 to 2020, returning the concentration to very near the historical value in 2015. Alkalinity decreased in concentration from historical to 2019 by 31% but increased in 2020 by 25% compared to the historical value.

Information Only

Well: H-17

H-17	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	10/27/1987	9/7/2017	9/19/2018	9/5/2019	NA				
pH (pH units)	6.64	6.00	6.29	6.04	NA		6.00	6.64	6.24
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	224000	360000	350000	350000	NA		224000	360000	321000
CHARGE BALANCE ERROR (%)	NA	1	3	5	NA		1	5	3
FLUORIDE (mg/L)	1.30	ND	ND	ND	NA		1.30	1.30	1.30
CHLORIDE (mg/L)	87300	110000	120000	120000	NA		87300	120000	109325
BROMIDE (mg/L)	75.00	27.00	56.00	40.00	NA		27.00	75.00	49.50
NITRATE+ NITRITE (mg/L)	ND	ND	ND	140.00	NA		140	140	140
PHOSPHORUS (mg/L)	ND	ND	ND	ND	NA		ND	ND	ND
SULFATE (mg/L)	7000	6500	7600	7300	NA		6500	7600	7100
CALCIUM (mg/L)	1500	1700	1800	1800	NA		1500	1800	1700
MAGNESIUM (mg/L)	1700	1200	1400	1400	NA		1200	1700	1425
POTASSIUM (mg/L)	1400	940	980	1000	NA		940	1400	1080
SODIUM (mg/L)	54700	68000	71000	69000	NA		54700	71000	65675
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	43.00	ND	ND	ND	NA		43.00	43.00	43.00
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	NA		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	43.00	ND	ND	ND	NA		43.00	43.00	43.00
TDS (mg/L)	NA	194000	182000	202000	NA		182000	202000	192667

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well H-17 is a 7-inch steel-cased, open-hole completion well, constructed in 1987 and is located southeast of the WIPP site. There was one historical sampling year for well H-17, which was in 1987. There were no notable differences in average of 2017-2019 from historical data, 1987 for pH and sulfate (<10%). Chloride concentration increased from the historical value in 1987 from, 87,300 mg/L to the average of 2017-2019 of 116,667 mg/L concentrations which is an increase of 34%. Bromide concentrations decreased from 1987 from 75 mg/L to 27 mg/L in 2017, a decrease of 64%. However, bromide concentrations increased in 2018-2019 from 2017 by 78% to an average of 48 mg/L. Nitrate + nitrate was detected in the 2019 sample at 140 mg/L, however, was not detected in all other years of sampling. Calcium, magnesium, potassium, and sodium all increased from the historical value in 1987 to the average value from 2017-2020, respectively, by 18, 22, 30 and 27%. The well was plugged on April 23rd 2020, before the well was scheduled to be sampled.

Information Only

Well: H-19b0

H-19b0	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	8/31/2006	5/10/2017	5/23/2018	5/8/2019	5/20/2020				
pH (pH units)	7.42	8.18	9.38	9.01	9.42		7.42	9.42	8.68
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	170000	190000	180000	170000	170000		170000	190000	176000
CHARGE BALANCE ERROR (%)	NA	8	5	ND	6		5	8	6
FLUORIDE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
CHLORIDE (mg/L)	47000	47000	51000	54000	61000		47000	61000	52000
BROMIDE (mg/L)	50	37	36	29	35		29	50	37
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	4800	6100	5500	5400	6200		4800	6200	5600
CALCIUM (mg/L)	1600	1400	1600	1700	1700		1400	1700	1600
MAGNESIUM (mg/L)	1100	950	1000	1100	1100		950	1100	1050
POTASSIUM (mg/L)	680	560	690	710	730		560	730	674
SODIUM (mg/L)	27000	25000	28000	33000	33000		25000	33000	29200
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	46.00	74.08	ND	30.08	ND		30.08	74.08	50.05
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	114.20	120.00	121.90		114.20	121.90	118.70
ALKALINITY as $CaCO_3$ Total (mg/L)	46.00	74.08	140.00	150.10	142.70		46.00	150.10	110.58
TDS (mg/L)	90000	97700	93200	93500	64300[1]		90000	97700	93600

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

[1]Data Point for the 2020 TDS Analysis was in Error (See HEAL Laboratories Email Acknowledgement a the end of the References)

Well H-19b0 is a 9-inch FRP-cased well, with a 7 3/4-inch open-hole interval, constructed in 1995 as a replacement for well H-19b1 and is located southeast of the WIPP site. There was a significant shift in pH (27% increase) in this well from the historical value to 2020. Chloride concentrations also showed steady increases across sampling years with 2020 results having increased 30% compared to the historical data (2006). Average bromide levels in this well for 2017-2020 showed a decrease of 32% compared to historical. Sulfate concentrations increased from 2006 to 2020 by 29%. Calcium, magnesium, and potassium concentrations did not have notable changes with all changes being less than 10% difference from 2006. Sodium concentrations increased by 22% from 2006 to 2020. Total alkalinity average of 2017-2020 increased significantly (175%) from the historical value. Historical alkalinity was bicarbonate dominate but switched entirely to carbonate dominate by sampling year 2020. TDS did not significantly change but the data point for 2020 TDS was not accepted due to a noted lab analysis error. Overall, very little decrease was seen in the other constituents in 2020, indicating the TDS value for 2020 is an error.

Information Only

Well: SNL-1

SNL-1	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	6/15/2016	8/8/2017	8/7/2018	8/7/2019	8/26/2020				
pH (pH units)	7.47	7.10	7.29	7.48	7.49		7.10	7.49	7.37
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	67000	70000	68000	61000	76000		61000	76000	68400
CHARGE BALANCE ERROR (%)	2	2	1	4	3		1	4	2
FLUORIDE (mg/L)	ND	ND	ND	ND	1.00		1.00	1.00	1.00
CHLORIDE (mg/L)	17000	17000	16000	20000	17000		16000	20000	17400
BROMIDE (mg/L)	12.00	12.00	19.00	6.90	12.00		6.90	19.00	12.38
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	2.30		2.30	2.30	2.30
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	3200	4200	3600	3900	4200		3200	4200	3820
CALCIUM (mg/L)	1600	1400	1400	1400	1400		1400	1600	1440
MAGNESIUM (mg/L)	630	590	560	590	600		560	630	594
POTASSIUM (mg/L)	280	260	260	240	260		240	280	260
SODIUM (mg/L)	9900	9800	9100	11000	11000		9100	11000	10160
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	145.10	137.00	106.20	103.80	125.60		103.80	145.10	123.54
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	145.10	137.00	106.20	103.80	125.60		103.80	145.10	123.54
TDS (mg/L)	37100	36600	36800	38100	33800		33800	38100	36480

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well SNL-1 is a 5-inch FRP-cased well, constructed in 2004 and is located north of the WIPP site. There were no notable changes in parameters for pH, chloride, bromide, magnesium, potassium or TDS, with all differences being less than 10% different from the averages of 2017-2020 to the recorded values in 2016. Nitrate + nitrite was detected only in the final year (2020) of sampling at 2 mg/L. Sulfate levels rose and on average increased by 24% when comparing 2017-2020 average to historical. Average total alkalinity for 2017-2020 compared to the historical value in 2016 resulted in a decrease of 19%.

Information Only

Well: SNL-2

SNL-2	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	1/24/2005	7/11/2017	7/24/2018	7/10/2019	7/22/2020				
pH (pH units)	7.01	7.30	7.41	7.09	7.35		7.01	7.41	7.23
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	22000	30000	15000	17000	18000		15000	30000	20400
CHARGE BALANCE ERROR (%)	NA	2	1	2	5		1	5	3
FLUORIDE (mg/L)	2.30	1.50	ND	1.40	1.10		1.10	2.30	1.58
CHLORIDE (mg/L)	3700	3700	3600	4000	3700		3600	4000	3740
BROMIDE (mg/L)	4.40	2.70	2.70	1.30	2.40		1.30	4.40	2.70
NITRATE+ NITRITE (mg/L)	4.30	ND	ND	ND	ND		4	4	4
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	2200	2200	2100	2300	2100		2100	2300	2180
CALCIUM (mg/L)	1100	900	870	930	940		870	1100	948
MAGNESIUM (mg/L)	380	270	250	280	270		250	380	290
POTASSIUM (mg/L)	46	41	39	41	41		39	46	42
SODIUM (mg/L)	1800	2100	2000	2000	2200		1800	2200	2020
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	310.00	167.50	156.60	152.30	155.80		152.30	310.00	188.44
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	310.00	167.50	156.60	152.30	155.80		152.30	310.00	188.44
TDS (mg/L)	9500	10600	9490	9540	10100		9490	10600	9846

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well SNL-2 is a 4.8-inch FRP-cased well, constructed in 2003 and is located northwest of the WIPP site. The historical value presented is from 2005 and there were no notable changes from the 2017-2020 average in pH, chloride, sulfate, or TDS. Bromide in well SNL-2 fluctuated with the highest reading recorded in the historical (4.4 mg/L) and the lowest recorded in sampling year 2019 (1.3 mg/L). Calcium decreased by 17% for the average of 2017-2020 vs. the 2005 historical value. Magnesium and potassium also decreased from the historical value by 30% and 12% respectively. Sodium levels averaged 2075 mg/L across snap-sampling years, however in 2020 had a 22% increase from 2005. Total alkalinity levels in modern samples averaged 155 mg/L resulting in a decrease of 49% compared to 2005.

Information Only

Well: SNL-3

SNL-3	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	4/16/2004	9/6/2017	9/5/2018	9/25/2019	8/25/2020				
pH (pH units)	7.41	7.84	7.49	7.54	7.37		7.37	7.84	7.53
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	140000	93000	86000	89000	96000		86000	140000	100800
CHARGE BALANCE ERROR (%)	NA	9	4	4	1		1	9	5
FLUORIDE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
CHLORIDE (mg/L)	26000	22000	23000	22000	25000		22000	26000	23600
BROMIDE (mg/L)	32.00	18.00	18.00	18.00	22.00		18.00	32.00	21.60
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND_1	ND		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	4700	4300	5000	4800	5000		4300	5000	4760
CALCIUM (mg/L)	1400	1600	1400	1400	1400		1400	1600	1440
MAGNESIUM (mg/L)	740	730	680	690	720		680	740	712
POTASSIUM (mg/L)	360	380	350	360	390		350	390	368
SODIUM (mg/L)	14000	16000	13000	15000	15000		13000	16000	14600
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	63.00	94.00	51.00	45.76	42.64		42.64	94.00	59.28
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	63.00	94.00	51.00	45.76	42.64		42.64	94.00	59.28
TDS (mg/L)	47000	51500	48100	40900	44100		40900	51500	46320

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

$_1$ The nitrate + nitrite HEAL analysis experienced an instrument malfunction for the 9/25/2019 sample. HEAL completed a separate analysis for nitrate + nitrite from a separate sample taken on 11/6/2019 and is represented in the table above.

Well SNL-3 is a 4.8-inch FRP-cased well, constructed in 2003 and is located northeast of the WIPP site. There were no notable differences from 2004 to the average of 2017-2020 for pH, sulfate, calcium, magnesium, potassium, sodium or TDS. All changes from historical to 2017-2020 averages were less than 10%. Chloride concentration decreased by 12% from 2004 to the average of 2017-2020. Bromide levels remained constant in sampling years 2017 – 2019 (18 mg/L) and increased slightly in 2020 (22 mg/L). Overall average of the modern samples showed a decrease of 41% for bromide compared to historical. Total alkalinity concentration showed mostly a decrease from historical to 2018-2020, with the exception of sampling year 2017 where an increase of 49% is seen. Average concentration of 2018-2020 to 2004 showed an over-all decrease in alkalinity of 26%.

Information Only

Well: SNL-5

SNL-5	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	7/24/2004	4/12/2017	4/25/2018	4/24/2019	5/28/2020				
pH (pH units)	7.46	7.42	7.94	7.28	7.44		7.28	7.94	7.51
SPEC COND (umhos/cm@25C)	19000	23000	22000	22000	26000		19000	26000.00	22400.00
Chg Bal Error (%)	0	3	3	3	7		0	7.00	3.20
FLUORIDE (mg/L)	1.50	0.00	0.00	0.00	0.00		0	1.50	0.30
CHLORIDE (mg/L)	7000	6400	5500	6800	6900		5500	7000.00	6520.00
BROMIDE (mg/L)	17.00	6.80	4.50	5.40	7.00		5	17.00	8.14
NITRATE+ NITRITE (mg/L)	0.62	0.00	0.00	0.00	0.00		0	0.62	0.12
PHOSPHORUS (mg/L)	0.00	0.00	0.00	0.00	0.00		0	0.00	0.00
SULFATE (mg/L)	1700	1500	1600	1800	1800		1500	1800.00	1680
CALCIUM (mg/L)	1400	1700	1400	1700	1400		1400	1700.00	1520
MAGNESIUM (mg/L)	510	490	460	460	450		450	510.00	474
POTASSIUM (mg/L)	67	62	73	66	68		62	73.00	67
SODIUM (mg/L)	1900	2300	2100	2100	2200		1900	2300.00	2120
ALKALINITY Bicarbonate (mg/L)	64.00	64.60	49.92	61.04	57.92		50	64.60	59
ALKALINITY Carbonate (mg/L)	0.00	0.00	0.00	0.00	0.00		0	0.00	0
ALKALINITY Total (mg/L)	64.00	64.60	49.92	61.04	57.92		50	64.60	59
TDS (mg/L)	13000	14800	13800	15900	15800		13000	15900.00	14660

Well SNL-5 is a 4.83-inch FRP-cased well, constructed in 2004 and is located north of the WIPP site. Fluoride was detected at 1.5 mg/L in the historical sample (2004), however was not detected in subsequent years. There were no notable differences (<10%) in averages of 2017-2020 compared to 2004 for pH, chloride, sulfate, magnesium, potassium, and alkalinity. Bromide levels decreased from historical with the average of modern samples showing an overall decrease of 65% compared to historical. Sodium levels for 2017-2020 samples show stability and average 2175 mg/L and an increase of 16% compared to historic.

Information Only

Well: SNL-8

SNL-8	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	8/2/2007	9/6/2017	9/5/2018	9/4/2019	9/23/2020				
pH (pH units)	7.26	7.61	7.65	7.68	7.35		7.26	7.68	7.51
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	280000	270000	250000	280000	270000		250000	280000	270000
CHARGE BALANCE ERROR (%)	NA	4	3	2	3		2	4	3
FLUORIDE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
CHLORIDE (mg/L)	77000	75000	84000	87000	81000		75000	87000	80800
BROMIDE (mg/L)	100.00	92.00	85.00	82.00	95.00		82.00	100.00	90.80
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	6400	5200	6600	7300	5800		5200	7300	6260
CALCIUM (mg/L)	2000	2000	1800	1800	1900		1800	2000	1900
MAGNESIUM (mg/L)	3100	2500	2600	2700	2800		2500	3100	2740
POTASSIUM (mg/L)	1500	1600	1500	1600	1500		1500	1600	1540
SODIUM (mg/L)	47000	48000	47000	49000	46000		46000	49000	47400
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	49.00	69.48	68.96	70.68	92.52		49.00	92.52	70.13
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	49.00	69.48	68.96	70.68	92.52		49.00	92.52	70.13
TDS (mg/L)	140000	139000	146000	139000	136000		136000	146000	140000

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well SNL-8 is a 5 ½-inch FRP-cased well, constructed in 2005 and is located east of the WIPP site. There were no notable differences between 2017-2020 averages and 2007 historical data for pH, chloride, bromide, sulfate, calcium, potassium, sodium or TDS. Magnesium average of 2017-2020 samples compared to historical shows a decrease of 15%. Total alkalinity increased from the average 2017-2020 value from historical by 54%. The 2020 total alkalinity value increased by 89% when compared to the historical 2007 concentration.

Information Only

Well: SNL-9

SNL-9	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	11/19/2004	6/7/2017	6/20/2018	6/12/2019	6/24/2020				
pH (pH units)	6.89	7.43	7.15	6.96	6.25		6.25	7.43	6.94
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	50000	52000	52000	41000	43000		41000	52000	47600
CHARGE BALANCE ERROR (%)	NA	4	3	2	6		2	6	4
FLUORIDE (mg/L)	2.50	ND	ND	ND	1.70		1.70	2.50	2.10
CHLORIDE (mg/L)	14000	16000	13000	13000	12000		12000	16000	13600
BROMIDE (mg/L)	16.00	24.00	58.00	10.00	9.40		9.40	58.00	23.48
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
PHOSPHORUS (mg/L)	ND	6.20	ND	ND	ND		6.20	6.20	6.20
SULFATE (mg/L)	1600	1600	1500	1700	1200		1200	1700	1520
CALCIUM (mg/L)	3100	3000	2900	2800	2800		2800	3100	2920
MAGNESIUM (mg/L)	810	820	700	760	760		700	820	770
POTASSIUM (mg/L)	44	39	46	44	45		39	46	44
SODIUM (mg/L)	4700	5300	5100	5000	4700		4700	5300	4960
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	140.00	74.56	36.28	38.72	27.56		27.56	140.00	63.42
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	140.00	74.56	36.28	38.72	27.56		27.56	140.00	63.42
TDS (mg/L)	25000	29100	27300	26800	24400		24400	29100	26520

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well SNL-9 is a 9 ½-inch FRP-cased well, constructed in 2003 and is located west of the WIPP site. There were no notable differences from 2017-2020 averages and 2004 historical data for pH, chloride, sulfate, calcium, magnesium, potassium sodium and TDS. Fluoride was detected in historical 2004 (2.5 mg/L) sample and the sample collected in 2020 (1.7 mg/L). Bromide concentrations fluctuated between sampling years with the highest recorded level in sampling year 2018 (58 mg/L) and the lowest reading in sampling year 2020 (9.4 mg/L). Over-all bromide concentrations decreased by 41% from 2004 to 2020. Phosphorous was detected in sampling year 2017 with no other detectable readings recorded in the remaining sampling years. Total alkalinity concentrations have decreased from 140 mg/L in 2004 to 27.56 mg/L in 2020, a total of an 80% decrease.

Information Only

Well: SNL-10

SNL-10	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	11/3/2006	6/7/2017	6/20/2018	6/12/2019	6/24/2020				
pH (pH units)	7.92	7.98	7.83	7.73	7.72		7.72	7.98	7.84
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	11000	13000	14000	13000	14000		11000	14000	13000
CHARGE BALANCE ERROR (%)	NA	2	4	5	3		2	5	4
FLUORIDE (mg/L)	2.70	0.95	2.50	1.60	1.40		0.95	2.70	1.83
CHLORIDE (mg/L)	1100	1300	1300	1600	1300		1100	1600	1320
BROMIDE (mg/L)	2.30	4.00	2.30	2.60	2.00		2.00	4.00	2.64
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	4400	4600	4500	4700	4200		4200	4700	4480
CALCIUM (mg/L)	500	480	550	480	500		480	550	502
MAGNESIUM (mg/L)	170	170	180	180	190		170	190	178
POTASSIUM (mg/L)	72	47	54	52	56		47	72	56
SODIUM (mg/L)	1900	2100	2300	2100	2100		1900	2300	2100
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	46.00	106.40	101.20	95.04	93.88		46.00	106.40	88.50
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	46.00	106.40	101.20	95.04	93.88		46.00	106.40	88.50
TDS (mg/L)	8500	9670	8350	9280	8930		8350	9670	8946

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well SNL-10 is a 5 ½-inch FRP-cased well, constructed in 2006 and is located west of the WIPP site. There were no notable changes in averages from 2017-2020 to 2006 for pH, sulfate, calcium, magnesium and TDS. This well had detectable levels of fluoride in all sampling years with averages between 2017 – 2020 showing a 40% decrease when compared to 2006. Chloride levels increase by 27% when comparing the average of 2017-2020 samples to 2006. Potassium concentrations decreased from 2006 to an average of 2017-2020 of 27%. Sodium concentrations increased by 13% from 2006 to the average of 2017-2020. Total alkalinity increased from 2006 by 116% to the average of 2017-2020.

Information Only

Well: SNL-12

SNL-12	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	8/14/2004	4/11/2017	5/28/2018	4/24/2019	5/27/2020				
pH (pH units)	7.90	7.66	7.90	7.68	7.70		7.66	7.90	7.77
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	5000	5100	5600	5300	5700		5000	5700	5340
CHARGE BALANCE ERROR (%)	NA	4	1	NA	1		1	4	2
FLUORIDE (mg/L)	3.30	3.10	2.10	3.00	3.20		2.10	3.30	2.94
CHLORIDE (mg/L)	740	670	910	810	770		670	910	780
BROMIDE (mg/L)	1.70	1.20	1.10	1.40	1.60		1.10	1.70	1.40
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	1900	1900	2100	2100	2100		1900	2100	2020
CALCIUM (mg/L)	610	660	690	670	620		610	690	650
MAGNESIUM (mg/L)	120	140	150	140	140		120	150	138
POTASSIUM (mg/L)	15	19	21	22	21		15	22	20
SODIUM (mg/L)	440	460	520	510	530		440	530	492
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	92.00	91.40	89.76	86.12	88.56		86.12	92.00	89.57
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	92.00	91.40	89.76	86.12	88.56		86.12	92.00	89.57
TDS (mg/L)	4200	4310	6500	4450	4550		4200	6500	4802

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well SNL-12 is a 4.8-inch FRP-cased well, constructed in 2003 and is located south of the WIPP site. There were not notable differences (<10%) from the averages of 2017-200 to 2004 for pH, chloride, sulfate, calcium, and total alkalinity. Fluoride readings throughout all sampling years with an average for 2017-2020 of 2.85 mg/L, a 14% decrease from the historical 2004 value. Bromide concentration decreased from 2004 by 22% from 1.7 mg/L to an average for 2017-2020 of 1.3 mg/L. Potassium concentrations increased by 38% from 2006 to the average for 2017-2020. The sodium concentrations in SNL-12 have increased from historical (440 mg/L) to 2020 (530 mg/L) by 20%. Sampling year 2018 readings (6500 mg/L) for TDS were the highest for all the sampling years but decreased near historical readings for sampling years 2019 and 2020. An overall increase of 18% is seen in TDS when comparing the average for 2017-2020 to historical.

Information Only

Well: SNL-13

SNL-13	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	7/17/2006	3/8/2017	3/28/2018	3/6/2019	3/5/2020				
pH (pH units)	8.49	8.31	8.23	8.27	8.36		8.23	8.49	8.33
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	40000	35000	32000	33000	33000		32000	40000	34600
CHARGE BALANCE ERROR (%)	NA	2	3	1	0		0	3	2
FLUORIDE (mg/L)	3.20	ND	ND	ND	ND		3.20	3.20	3.20
CHLORIDE (mg/L)	8500	8100	9000	8600	8700		8100	9000	8580
BROMIDE (mg/L)	31.00	39.00	19.00	14.00	20.00		14.00	39.00	24.60
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	3300	3400	3400	3600	3900		3300	3900	3520
CALCIUM (mg/L)	990	990	1000	980	1000		980	1000	992
MAGNESIUM (mg/L)	330	310	370	310	320		310	370	328
POTASSIUM (mg/L)	190	180	220	200	190		180	220	196
SODIUM (mg/L)	5200	5400	6000	5300	5600		5200	6000	5500
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	50.00	41.72	43.96	41.00	34.40		34.40	50.00	42.22
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	2.00	ND	ND	5.28		2.00	5.28	3.64
ALKALINITY as $CaCO_3$ Total (mg/L)	50.00	39.72	43.96	41.00	39.68		39.68	50.00	42.87
TDS (mg/L)	21000	22300	19800	19700	20300		19700	22300	20620

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well SNL-13 is a 5 ½-inch FRP-cased well, constructed in 2005 and located southwest of the WIPP site. There were no notable differences from the historical 2006 value from the average of 2017-2020 for pH, chloride, sulfate, calcium, magnesium, potassium, sodium, and TDS. Fluoride was detected in the 2006 sample at 3.2 mg/L but was not found in any of the later years of sampling. Bromide concentrations decreased over time from 2006 to the average of 2017-2020 by 26%. Total alkalinity concentration decreased from 2006 when compared to the average 2017-2020 by 18%.

Information Only

Well: SNL-14

SNL-14	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	8/21/2007	8/9/2017	8/8/2018	9/25/2019	8/26/2020				
pH (pH units)	7.41	7.40	7.39	7.30	7.44		7.30	7.44	7.39
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	130000	180000	160000	150000	160000		130000	180000	156000
CHARGE BALANCE ERROR (%)	NA	3	3	6	2		2	6	4
FLUORIDE (mg/L)	2.50	ND	ND	ND	ND		2.50	2.50	2.50
CHLORIDE (mg/L)	47000	43000	41000	39000	44000		39000	47000	42800
BROMIDE (mg/L)	40.00	39.00	37.00	30.00	40.00		30.00	40.00	37.20
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND_1	ND		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	6900	6200	5600	6100	6400		5600	6900	6240
CALCIUM (mg/L)	1500	1500	1500	1500	1500		1500	1500	1500
MAGNESIUM (mg/L)	1100	990	990	940	990		940	1100	1002
POTASSIUM (mg/L)	620	640	600	600	630		600	640	618
SODIUM (mg/L)	30000	29000	27000	28000	29000		27000	30000	28600
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	48.00	58.32	55.40	59.92	62.28		48.00	62.28	56.78
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	48.00	58.32	55.40	59.92	62.28		48.00	62.28	56.78
TDS (mg/L)	87000	86900	85100	82200	93300		82200	93300	86900

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

1 The nitrate + nitrite HEAL analysis experienced an instrument malfunction for the 9/25/2019 sample. HEAL completed a separate analysis for nitrate + nitrite from a separate sample taken on 11/6/2019.

Well SNL-14 is a 5.4-inch FRP-cased well, constructed in 2005 and is located south of the WIPP site There were no notable differences between 2007 historical data and the average of 2017-2020 for pH, bromide, calcium, potassium, sodium and TDS. Fluoride was not detected from 2017-2020 but was 2.5 mg/L in 2007. Chloride levels decreased by an average of 11% for the average of 2017-2020 samples compared to 2007. Sulfate also decreased from 2007 to the average of 2017-2020 by 12%. Total alkalinity concentrations increased from 2007 to the average of 2017-2020.

Information Only

Well: SNL-16

SNL-16	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	6/15/2016	8/8/2017	9/5/2018	8/7/2019	9/23/2020				
pH (pH units)	7.48	7.20	7.41	7.43	7.00		7.00	7.48	7.30
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	39000	39000	43000	41000	42000		39000	43000	40800
CHARGE BALANCE ERROR (%)	1	1	2	4	0		0	4	2
FLUORIDE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
CHLORIDE (mg/L)	11000	11000	12000	13000	12000		11000	13000	11800
BROMIDE (mg/L)	4.20	4.10	2.60	2.40	4.50		2.40	4.50	3.56
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	2300	2400	2300	2300	2400		2300	2400	2340
CALCIUM (mg/L)	1700	1700	1700	1800	1700		1700	1800	1720
MAGNESIUM (mg/L)	500	500	510	550	590		500	590	530
POTASSIUM (mg/L)	290	280	280	290	330		280	330	294
SODIUM (mg/L)	5400	5100	5500	5600	5800		5100	5800	5480
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	100.30	94.24	94.20	94.28	89.12		89.12	100.30	94.43
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	100.30	94.24	94.20	94.28	89.12		89.12	100.30	94.43
TDS (mg/L)	23000	24000	24100	26700	25400		23000	26700	24640

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well SNL-16 is a 5 ½-inch FRP-cased well, constructed in 2006 and is located southwest of the WIPP site in the Nash Draw geographic region. There were no notable differences (<10%) between the historical value from 2016 from the 2017-2020 average value for pH, chloride, sulfate, calcium, magnesium, potassium, sodium, alkalinity, and TDS. Bromide concentrations historical value was 4.2 mg/L and the average for 2017-2020 was 3.0 mg/L which is a decrease of 19%.

Information Only

Well: SNL-17

SNL-17	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	9/15/2006	3/8/2017	3/28/2018	3/6/2019	3/5/2020				
pH (pH units)	7.55	7.60	7.85	7.68	7.62		7.55	7.85	7.66
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	3500	3800	3600	3600	3400		3400	3800	3580
CHARGE BALANCE ERROR (%)	NA	2	1	2	2		1	2	2
FLUORIDE (mg/L)	1.30	0.94	0.62	ND	1.00		0.62	1.30	0.97
CHLORIDE (mg/L)	250	320	310	240	240		240	320	272
BROMIDE (mg/L)	ND	1.00	0.74	ND	ND		0.74	1.00	0.87
NITRATE+ NITRITE (mg/L)	2.80	2.10	2.40	2.70	2.80		2.10	2.80	2.56
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	1800	1800	1800	1800	2000		1800	2000	1840
CALCIUM (mg/L)	620	610	600	600	610		600	620	608
MAGNESIUM (mg/L)	150	150	140	150	150		140	150	148
POTASSIUM (mg/L)	5.30	6.40	7.40	5.50	5.50		5.30	7.40	6.02
SODIUM (mg/L)	130	170	170	140	140		130	170	150
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	94.00	96.36	102.00	97.32	96.32		94.00	102.00	97.20
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	94.00	96.36	102.00	97.32	96.32		94.00	102.00	97.20
TDS (mg/L)	3200	3350	3360	3320	3350		3200	3360	3316

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well SNL-17 is a 5 ½-inch FRP-cased well, constructed in 2006 and is located southwest of the WIPP site. There were no notable differences in analyte concentrations from 2006 to the average of 2017-2020 data in any of the analytes measured. In cases where the values exceeded 10% difference, the values were very low in concentration and may have higher percentage of error associated to them.

Information Only

Well: SNL-18

SNL-18	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	6/14/2016	7/12/2017	8/8/2018	7/11/2019	7/23/2020				
pH (pH units)	7.88	7.69	7.81	7.75	7.67		7.67	7.88	7.76
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	17000	34000	31000	31000	37000		17000	37000	30000
CHARGE BALANCE ERROR (%)	1	1	2	3	5		1	5	2
FLUORIDE (mg/L)	1.20	ND	ND	ND	ND		1.20	1.20	1.20
CHLORIDE (mg/L)	3800	9500	6700	8800	8100		3800	9500	7380
BROMIDE (mg/L)	2.70	7.70	6.50	3.80	4.30		2.70	7.70	5.00
NITRATE+ NITRITE (mg/L)	ND	ND	ND	1.30	ND		1.30	1.30	1.30
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	2500	3100	2700	3200	2700		2500	3200	2840
CALCIUM (mg/L)	870	1100	970	1100	1100		870	1100	1028
MAGNESIUM (mg/L)	240	380	300	370	370		240	380	332
POTASSIUM (mg/L)	44	120	82	110	110		44	120	93
SODIUM (mg/L)	2300	5500	3700	4800	5200		2300	5500	4300
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	46.76	60.92	64.88	69.52	69.96		46.76	69.96	62.41
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	46.76	60.92	64.88	69.52	69.96		46.76	69.96	62.41
TDS (mg/L)	10300	19500	14400	17700	19000		10300	19500	16180

ND=Not Detected at the Reporting Limit
NA=Not Applicable, No Available Data

Well SNL-18 is a 5 ½-inch Outer Diameter (OD) FRP-cased well with slotted Culebra screen interval constructed in 2006 located northwest of the WIPP site. There were no notable differences between 2016 historical values and the average for 2017-2020 for pH. Fluoride was detected in the 2016 sample at 1.2 mg/L but was not detected in any other sampling years. Chloride concentrations increased from the 2016 historical value to the average of the 2017-2020 value by 118%. Over-all bromide also increased by 106% from 2016 to the average of 2017-2020 nitrate + nitrite was detected in 2019, at a concentration of 1.3 mg/L but was not seen in any other sampling years. Sulfate concentrations did not fluctuate significantly, but over-all did increase in concentration from historical value of 2500 mg/L to an average for 2017-2020 to 2925 mg/L, which is a 17% increase. Calcium, magnesium, potassium and sodium also increased from 2016 to the average of 2017-2020 by 23, 48, 140 and 109% respectively. Total alkalinity increased every sample year with modern sample average compared to historical with an increase over-all of 42%. TDS concentration increased by 71% from 2016 to the average of 2017-2020.

It should be noted that well maintenance and development at well SNL-18 was performed in July of 2018 prior to the 2018 sampling. Anomalies in parameters for 2018 are most likely an effect of the recent pumping, during well maintenance and development.

Information Only

Well: SNL-19

SNL-19	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	6/14/2016	7/11/2017	7/24/2018	7/10/2019	7/22/2020				
pH (pH units)	7.62	7.48	7.52	7.46	6.53		6.53	7.62	7.32
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	12000	13000	13000	14000	14000		12000	14000	13200
CHARGE BALANCE ERROR (%)	3	ND	1	3	4		1	4	3
FLUORIDE (mg/L)	ND	ND	ND	1.30	0.86		0.86	1.30	1.08
CHLORIDE (mg/L)	2800	2800	2700	3000	2600		2600	3000	2780
BROMIDE (mg/L)	ND	ND	1.70	1.40	1.50		1.40	1.70	1.53
NITRATE+ NITRITE (mg/L)	3.00	2.90	3.50	8.20	0.00		0.00	8.20	3.52
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	2200	2200	2100	2400	2100		2100	2400	2200
CALCIUM (mg/L)	820	790	740	800	760		740	820	782
MAGNESIUM (mg/L)	220	210	200	220	220		200	220	214
POTASSIUM (mg/L)	43	40	37	41	34		34	43	39
SODIUM (mg/L)	1700	1600	1600	1600	1600		1600	1700	1620
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	98.88	98.08	93.84	93.28	20.48		20.48	98.88	80.91
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	98.88	98.08	93.84	93.28	20.48		20.48	98.88	80.91
TDS (mg/L)	8140	8180	8050	8230	7910		7910	8230	8102

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well SNL-19 is a 5 ½-inch FRP-cased well, constructed in 2006 and is located northwest of the WIPP site. There were no notable changes from 2016 historical data to the averages for 2017-2020 for chloride, sulfate, calcium, magnesium, sodium, or TDS. The 2020 sample showed a significant decrease in pH and alkalinity by 14% and 79% respectively. Fluoride was detected in sampling years 2019 and 2020, but no detectable levels were seen in prior sample years. Bromide was detected in 2018-2020 with an average of 1.5 mg/L. The highest recorded level of nitrate + nitrite was seen in the 2019 (8.2 mg/L) a 173% increase compared to historical, however 2020 did not have detectable concentrations of nitrate + nitrite. Potassium decreased by 12% from 2016 to the average of 2017-2020.

Information Only

Well: WIPP-11

WIPP-11	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	2/20/2005	4/12/2017	4/24/2018	4/24/2019	5/28/2020				
pH (pH units)	7.03	8.59	8.88	8.79	7.44		7.03	8.88	8.15
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	160000	100000	100000	77000	100000		77000	160000	107400
CHARGE BALANCE ERROR (%)	NA	3	3	2	1		1	3	2
FLUORIDE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
CHLORIDE (mg/L)	26000	27000	28000	28000	28000		26000	28000	27400
BROMIDE (mg/L)	37.00	22.00	17.00	18.00	25.00		17.00	37.00	23.80
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	6300	3300	3400	4200	4200		3300	6300	4280
CALCIUM (mg/L)	1600	1600	1700	1700	1700		1600	1700	1660
MAGNESIUM (mg/L)	810	660	700	720	790		660	810	736
POTASSIUM (mg/L)	360	380	360	360	350		350	380	362
SODIUM (mg/L)	15000	17000	15000	16000	16000		15000	17000	15800
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	78.00	ND	ND	ND	62.52		62.52	78.00	70.26
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	16.08	41.52	34.16	0.00		0.00	41.52	22.94
ALKALINITY as $CaCO_3$ Total (mg/L)	78.00	30.80	46.84	46.08	62.52		30.80	78.00	52.85
TDS (mg/L)	49000	54000	49400	46300	48500		46300	54000	49440

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well WIPP-11 was a relatively high-flow well with 9.625-inch steel casing. Originally constructed in 1978 but recompleted and perforated in the Culebra formation in 2004 and was located North of the WIPP site. There were no notable differences from 2005 historical analyses compared to the averages of 2017-2020 for calcium, potassium, sodium, and TDS. pH increased from 2005 to the average of 2017-2020 by 20%. Averages for 2017-2020 for bromide decreased by 45% when compared to 2005. Sulfate concentrations in WIPP-11 decreased from 2005 to the averages of 2017-2020 by 40%. Magnesium concentrations decreased over-all from historical 2005 sampling to the average of 2017-2020 by 11%, however the difference in 2020 data and 2005 is only 2%. Total alkalinity decreased from 2005 to the average of 2017-2020 by 40%. WIPP-11 was plugged in 2020 and will not be included in any subsequent sampling, however a replacement well (WIPP-11R) was drilled in close proximity as a replacement well for WIPP-11. Once WIPP-11R is fully developed a water quality sample will be obtained establishing a baseline for comparison. Subsequent snap-sampling of a recently completed well will also provide a good test case for proving or disproving the usefulness of this passive sampling system for accurate water quality sampling in a recently completed, high-flow well.

Information Only

Well: WIPP-13

WIPP-13	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	2/16/1987	5/10/2017	5/23/2018	5/8/2019	5/20/2020				
pH (pH units)	6.74	8.04	8.22	7.26	7.43		6.74	8.22	7.54
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	96700	130000	130000	130000	120000		96700	130000	121340
CHARGE BALANCE ERROR (%)	NA	12	12	3	0		0	12	7
FLUORIDE (mg/L)	1.40	ND	ND	ND	ND		1.40	1.40	1.40
CHLORIDE (mg/L)	36000	33000	33000	37000	37000		33000	37000	35200
BROMIDE (mg/L)	39.00	34.00	35.00	26.00	31.00		26.00	39.00	33.00
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
SULFATE (mg/L)	4500	4500	4400	4900	5000		4400	5000	4660
CALCIUM (mg/L)	1450	1300	1400	1400	1500		1300	1500	1410
MAGNESIUM (mg/L)	1010	930	990	1100	1100		930	1100	1026
POTASSIUM (mg/L)	340	590	690	640	710		340	710	594
SODIUM (mg/L)	19000	15000	18000	21000	22000		15000	22000	19000
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	120.00	32.40	32.76	39.44	30.04		30.04	120.00	50.93
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	ND	ND	ND	ND	ND		ND	ND	ND
ALKALINITY as $CaCO_3$ Total (mg/L)	120.00	32.40	32.76	39.44	30.04		30.04	120.00	50.93
TDS (mg/L)	NA	65400	68300	68800	102000		65400	102000	76125

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well WIPP-13 is a 9.625-inch steel-cased well, constructed in 1978, recompleted in the Culebra formation in 1985 and is located north of the WIPP site. There were no notable differences (<10%) between the historical 1987 values and the average of the 2017-2020 values for chloride, sulfate, calcium, and magnesium. Fluoride was detected in the 1987 sample but was not detected in subsequent samplings. Bromide decreased over-all in 2017-2020 average from 1987 by 19%. Potassium concentrations increased from 1987 to 2020 by 109%. Sodium concentrations also increased from 1987 to 2020 by 16%. Total alkalinity decreased from 1987 to the averages of 2017-2020 by 72%. TDS was not measured for the 1987 historical value, however TDS increased from 2017 to 2020 by 36%.

Information Only

Well: WIPP-19

WIPP-19	Historical	2017	2018	2019	2020	Trend	Min	Max	Mean
Sample Date	5/2/1995	6/7/2017	6/20/2018	6/12/2019	NA				
pH (pH units)	7.60	9.13	9.25	8.96	NA		7.60	9.25	8.74
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	89300	140000	160000	140000	NA		89300	160000	132325
CHARGE BALANCE ERROR (%)	NA	2	3	1	NA		1	3	2
FLUORIDE (mg/L)	ND	ND	ND	ND	NA		ND	ND	ND
CHLORIDE (mg/L)	34500	42000	36000	42000	NA		34500	42000	38625
BROMIDE (mg/L)	48.00	49.00	31.00	31.00	NA		31.00	49.00	39.75
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	NA		ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	NA		ND	ND	ND
SULFATE (mg/L)	6580	5900	5400	5800	NA		5400	6580	5920
CALCIUM (mg/L)	1440	1600	1600	1500	NA		1440	1600	1535
MAGNESIUM (mg/L)	899	1000	850	890	NA		850	1000	910
POTASSIUM (mg/L)	485	590	550	550	NA		485	590	544
SODIUM (mg/L)	23200	25000	24000	26000	NA		23200	26000	24550
ALKALINITY Bicarbonate as $CaCO_3$ (mg/L)	45.30	ND	ND	30.72	NA		30.72	45.30	38.01
ALKALINITY Carbonate as $CaCO_3$ (mg/L)	NA	118.50	106.30	103.40	NA		103.40	118.50	109.40
ALKALINITY as $CaCO_3$ Total (mg/L)	NA	125.50	124.60	134.10	NA		124.60	134.10	128.07
TDS (mg/L)	65600	75000	74700	76300	NA		65600	76300	72900

ND=Not Detected at the Reporting Limit

NA=Not Applicable, No Available Data

Well WIPP-19 was a 5 ½-inch steel-cased well, constructed in 1978, recompleted in the Culebra formation in 1985 and is located north of the WIPP site. There were no notable changes from 1995 historical samplings to the averages of 2017-2019 for calcium, magnesium, and sodium. pH increased from 1995 to the average of 2017-2019 by 20%. Chloride concentrations increased from 1995 to the average of 2017-2019 by 16%. Bromide and sulfate concentrations decreased from 1995 to the average of 2017-2019 by 23% and 13% respectively. Bromide also decreased by 37% 2017 to 2019. from Potassium and TDS increased from 1995 to the average of 2017-2019 by 16% and 15% respectively. Total alkalinity increased from 2017 to 2019 by 6%.

No water quality data was collected from well WIPP-19 in 2020 as it was plugged on June 2020, before the well was able to be sampled.

Information Only

Wells: IMC-461, SNL-6, SNL-15, WIPP-25, WIPP-30, C-2737, H-15R, H-10cR, USGS-4, USGS-8, WQSP-1, WQSP-2, WQSP-3, WQSP-4, WQSP-5, WQSP-6

Water quality data for the wells listed in APPENDIX A were unable to be collected using the Snap-Sampler® in 2017-2020 sampling years due to the well diameter being too small, the well no longer existing, or the well no longer being a part of the WIPP monitoring network. Nevertheless, historical values collected from these wells are presented in APPENDIX A.

Information Only

4. Contour Mapping

Contour maps (Figure 3 to Figure 24) of the 2019 and 2020 data were created for each of the water quality constituents using the HEAL water quality analytical data and ESRI ArcGIS Pro (Build 2.8.2; ESRI, 2021) These maps show patterns and evolution of the water quality parameters reported by HEAL analyses with respect to flow in the Culebra. Each of the points on the maps represent a well sampled in years 2019 and 2020. For each dataset, the points were plotted and labeled with the representative values in ArcGIS Pro. A blank polyline feature class was created representing 'rough' contours, which were drawn using ArcGIS Pro's editing tools to establish a baseline geometry which complies with the point data. These 'rough' contours were then input with the point data in ArcGIS Pro's 'Topo To Raster' tool. Surfaces were generated using this tool with minimum and maximum values corresponding with those of each respective dataset. All other parameters for the interpolator were left at the system's default values. These surfaces were then contoured in ArcGIS Pro using the 'Contour List' tool, which allows the user to specify an irregularly-distributed contour interval for a given dataset. Further analysis of these data will be completed in an Analysis Report.

Information Only

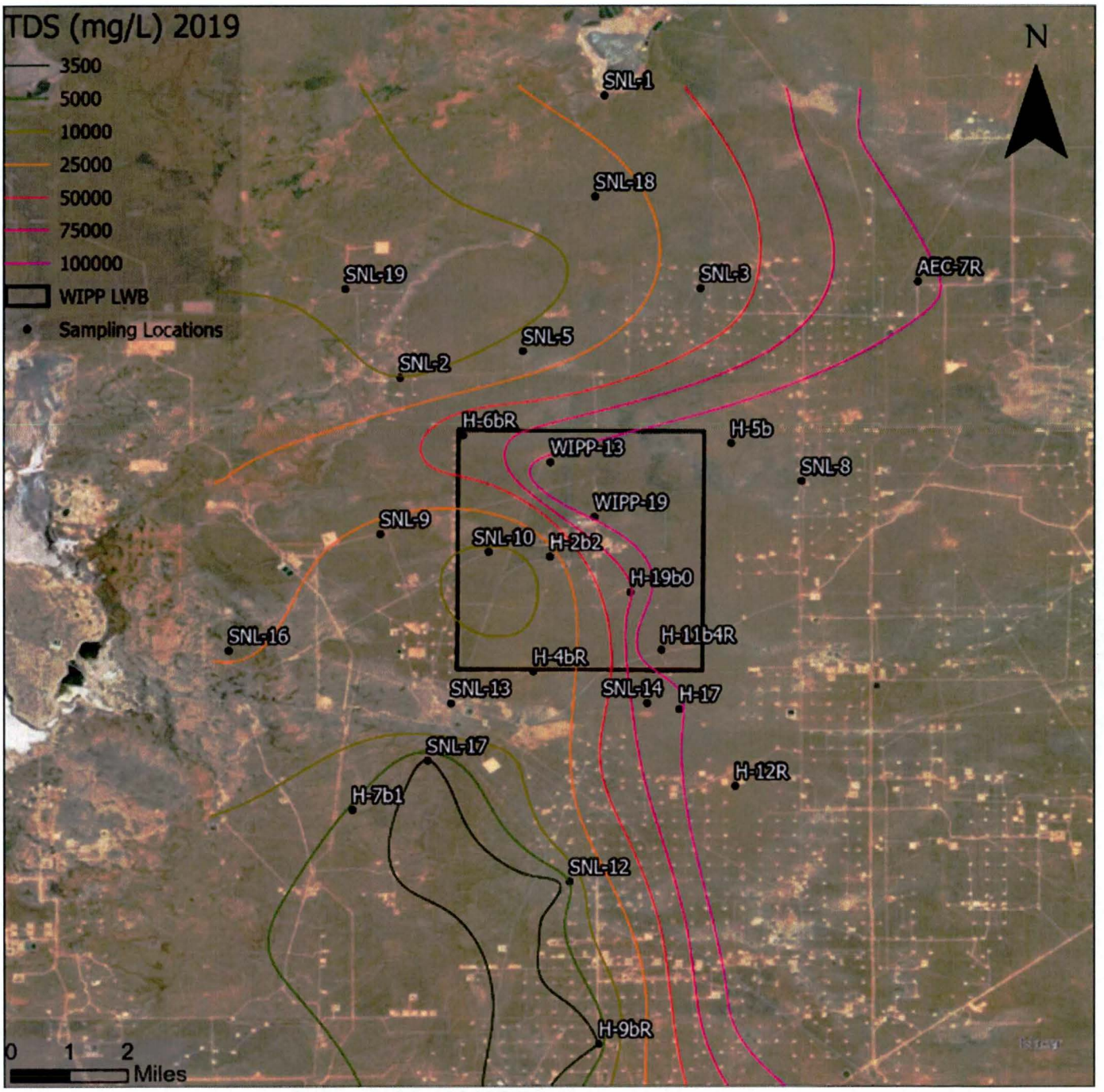

Figure 3. The 2019 TDS contour map.

Information Only

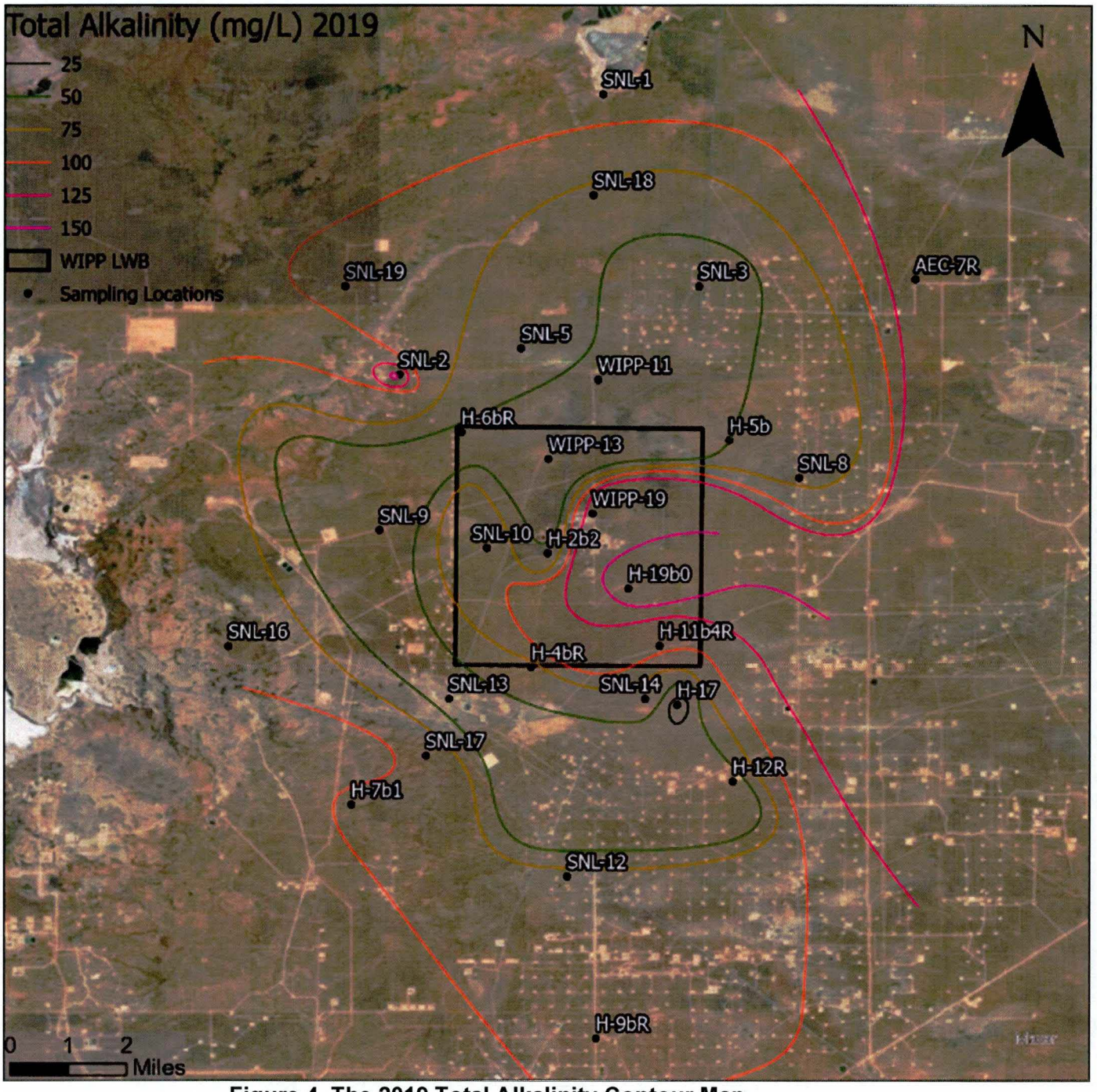

Figure 4. The 2019 Total Alkalinity Contour Map.

Information Only

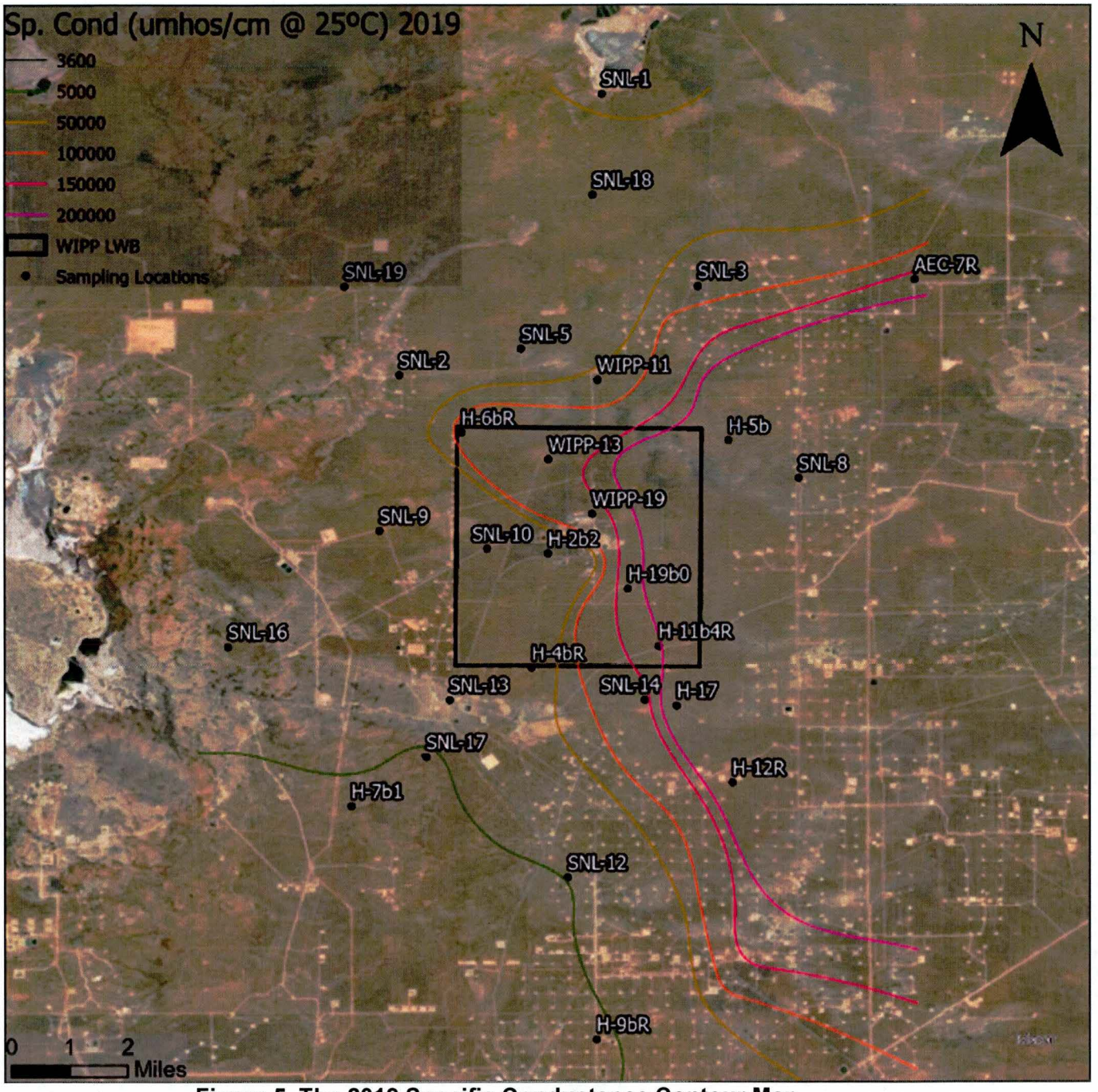

Figure 5. The 2019 Specific Conductance Contour Map.

Information Only

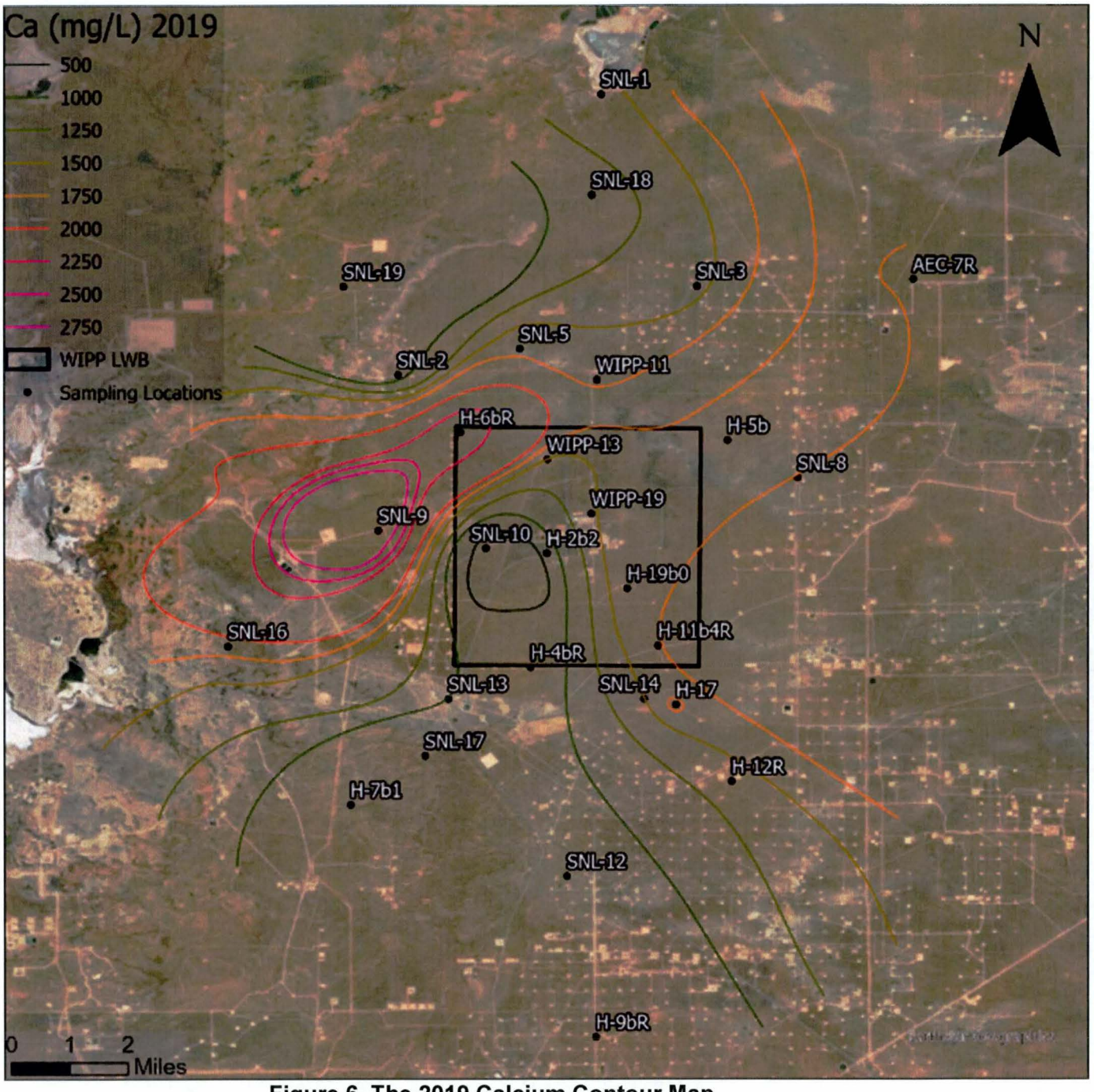

Figure 6. The 2019 Calcium Contour Map.

Information Only

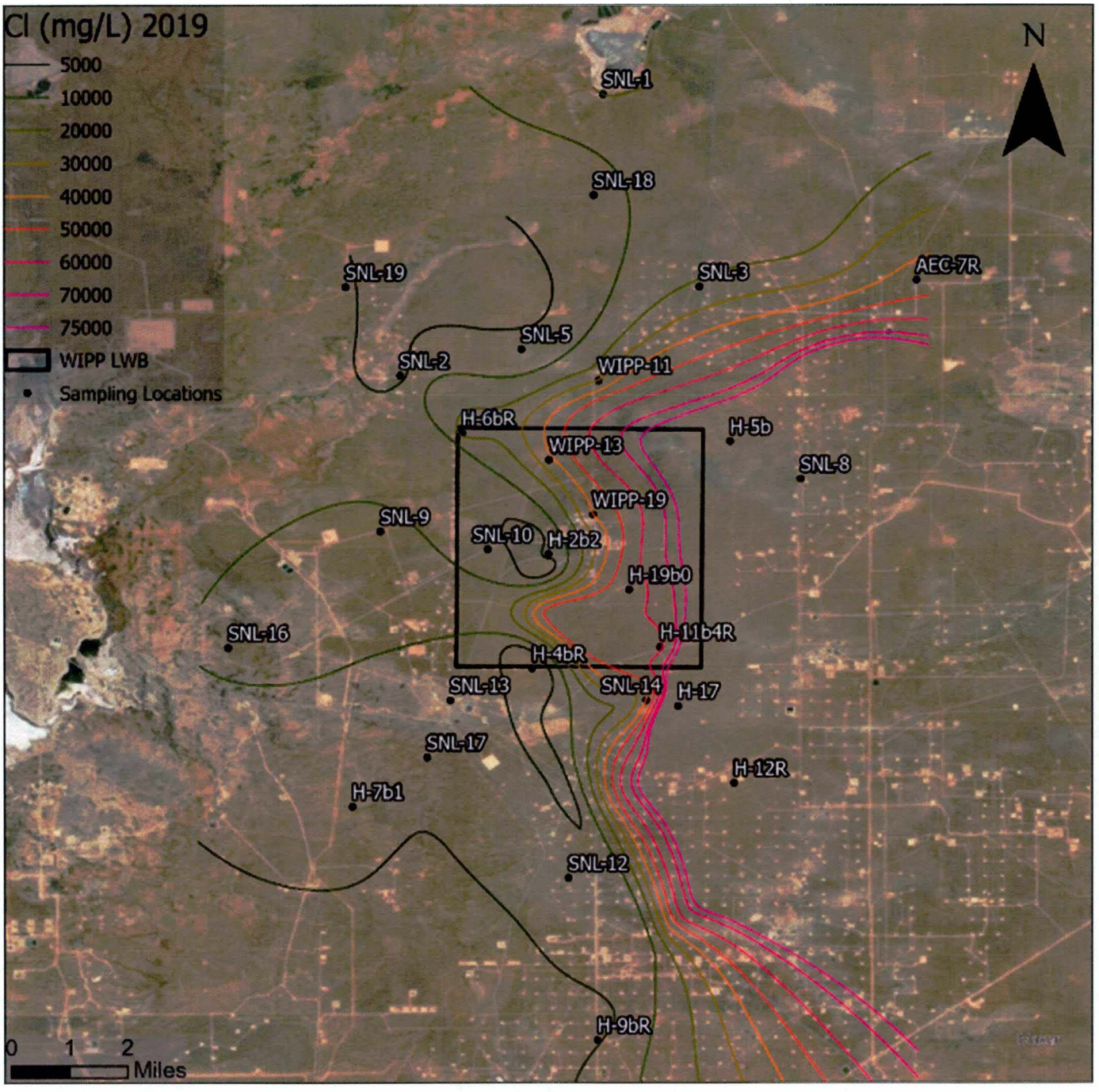

Figure 7. The 2019 Chloride Contour Map.

Information Only

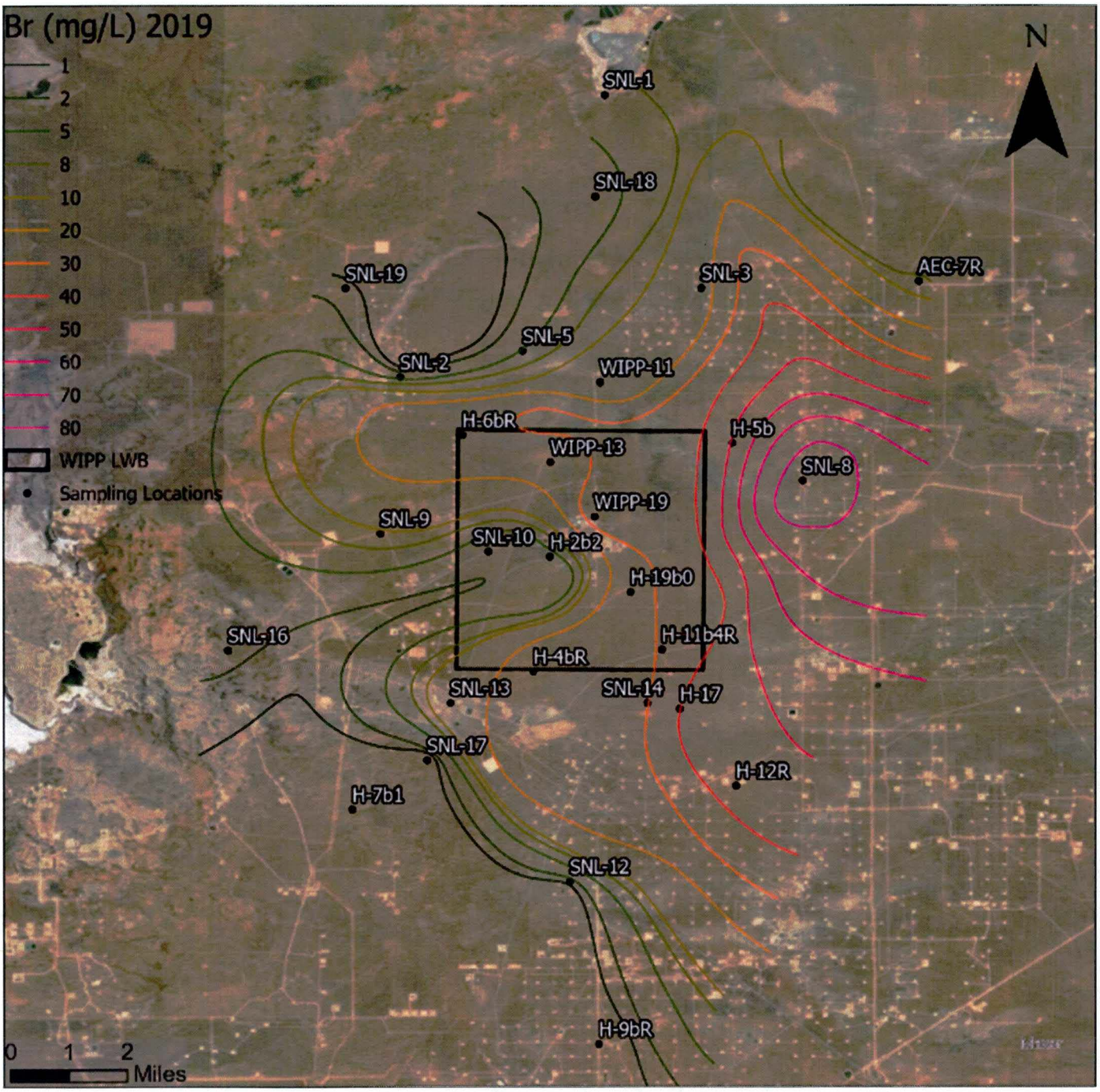

Figure 8. The 2019 Bromide Contour Map.

Information Only

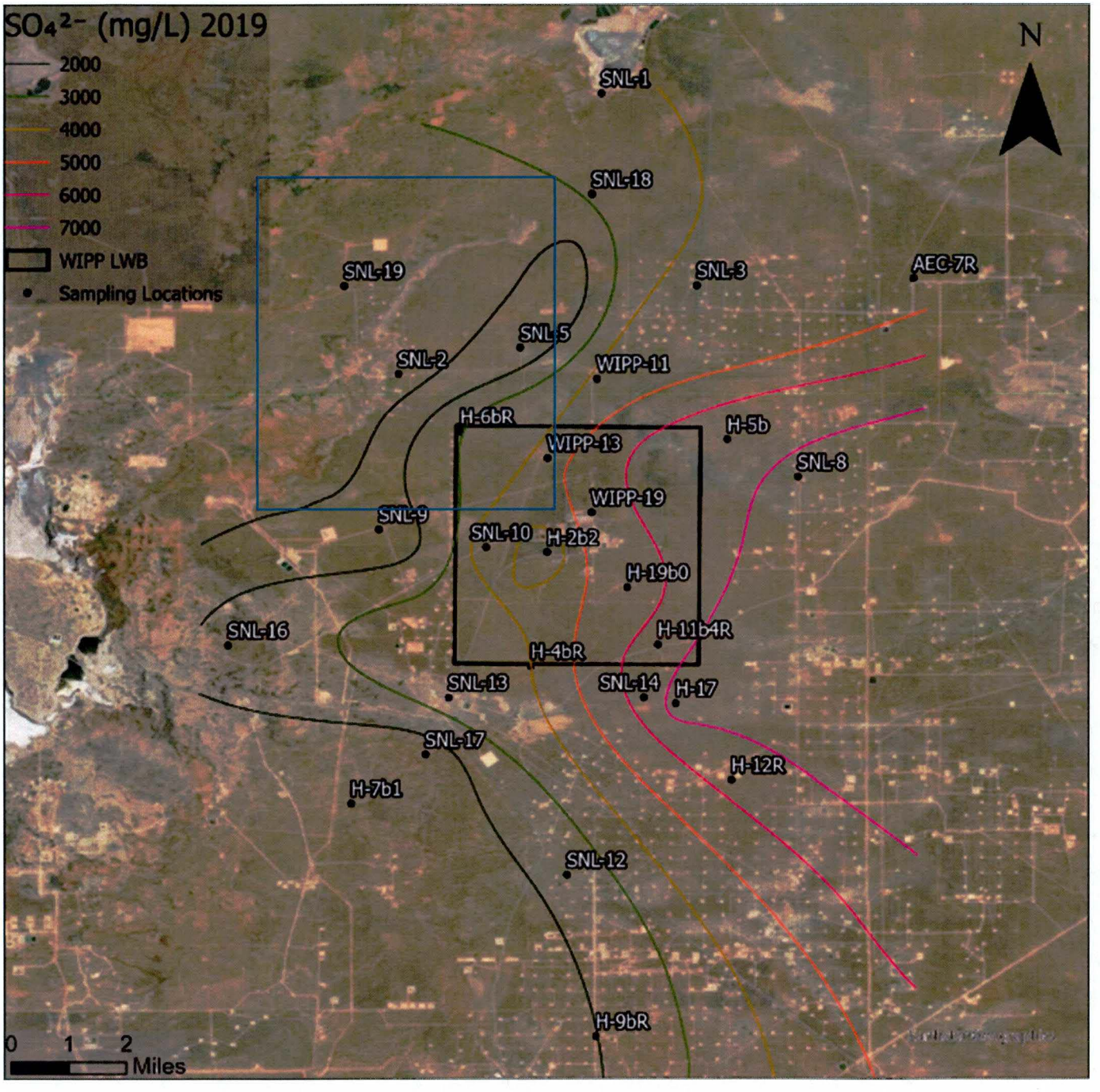

Figure 9. The 2019 Sulfates Contour Map

Information Only

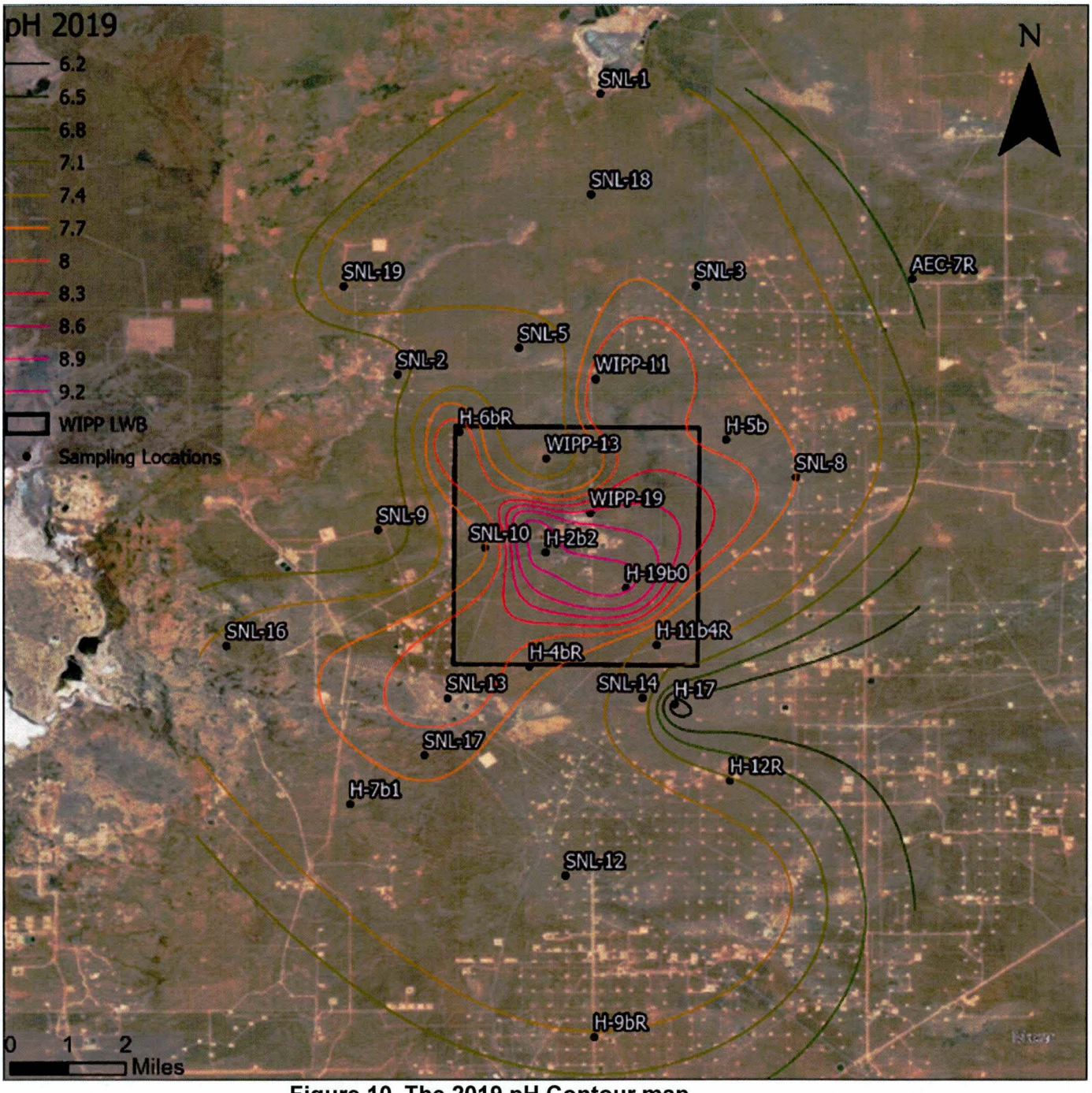

Figure 10. The 2019 pH Contour map.

Information Only

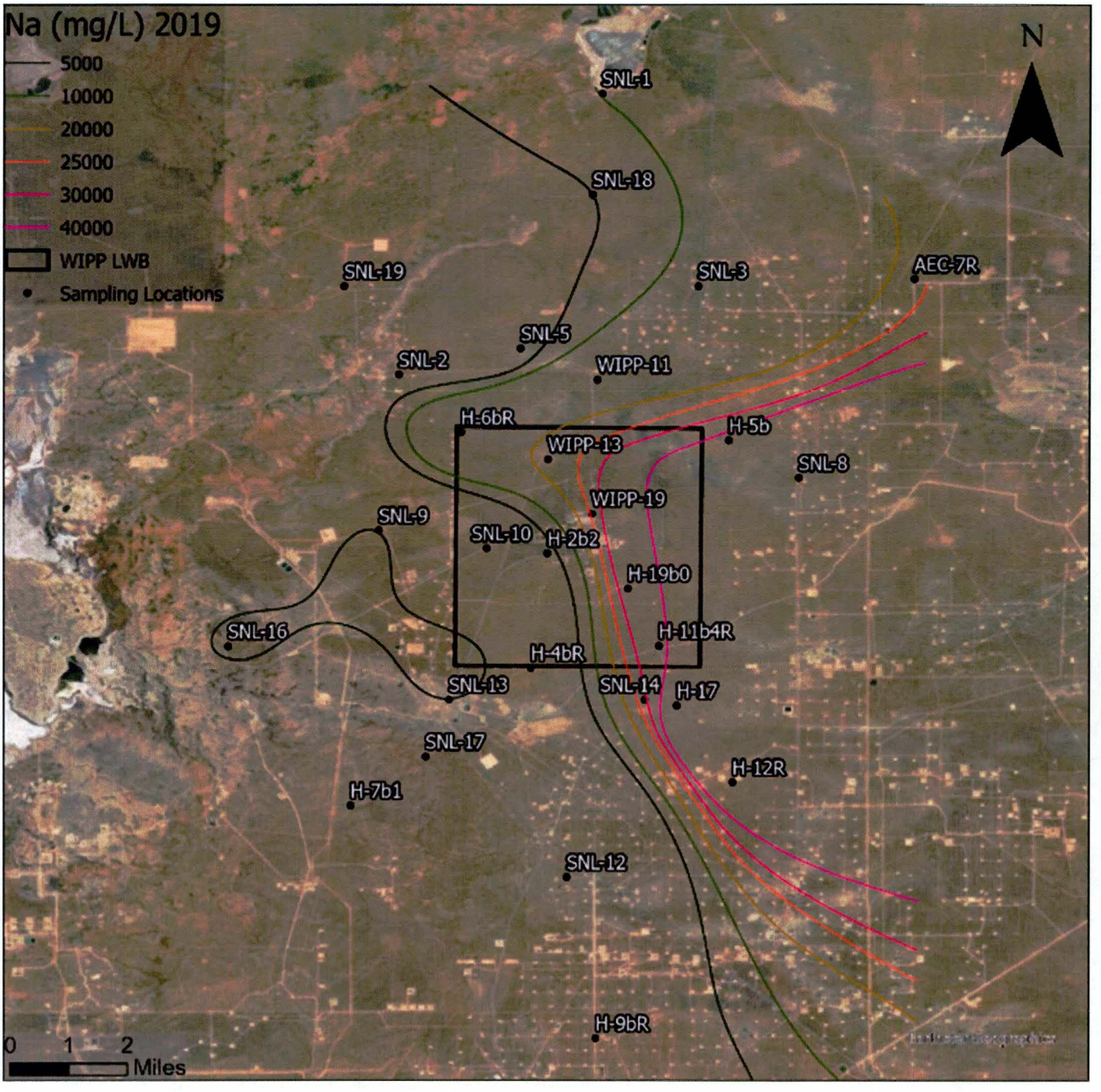

Figure 11. The 2019 Sodium Contour Map

Information Only

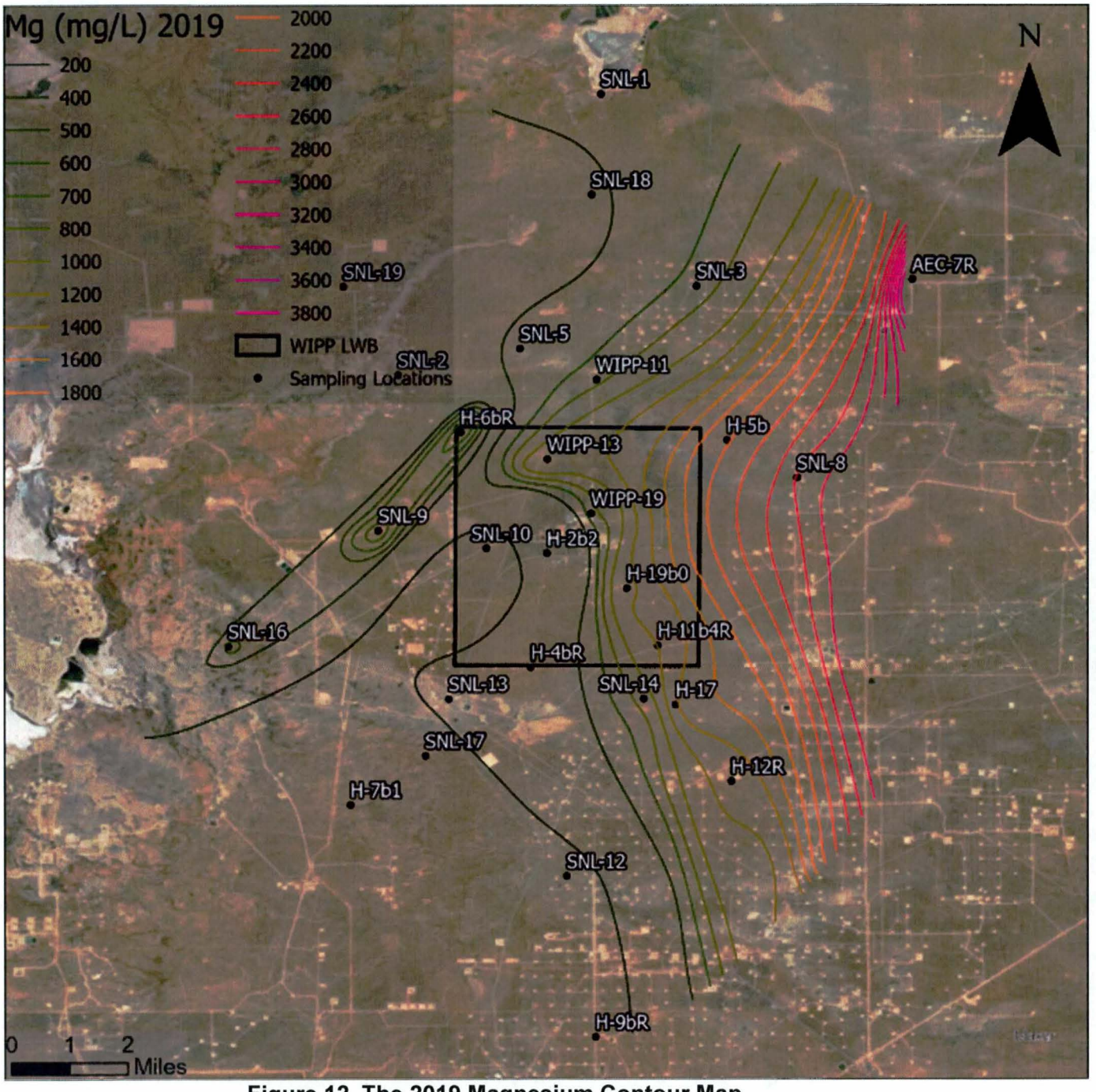

Figure 12. The 2019 Magnesium Contour Map

Information Only

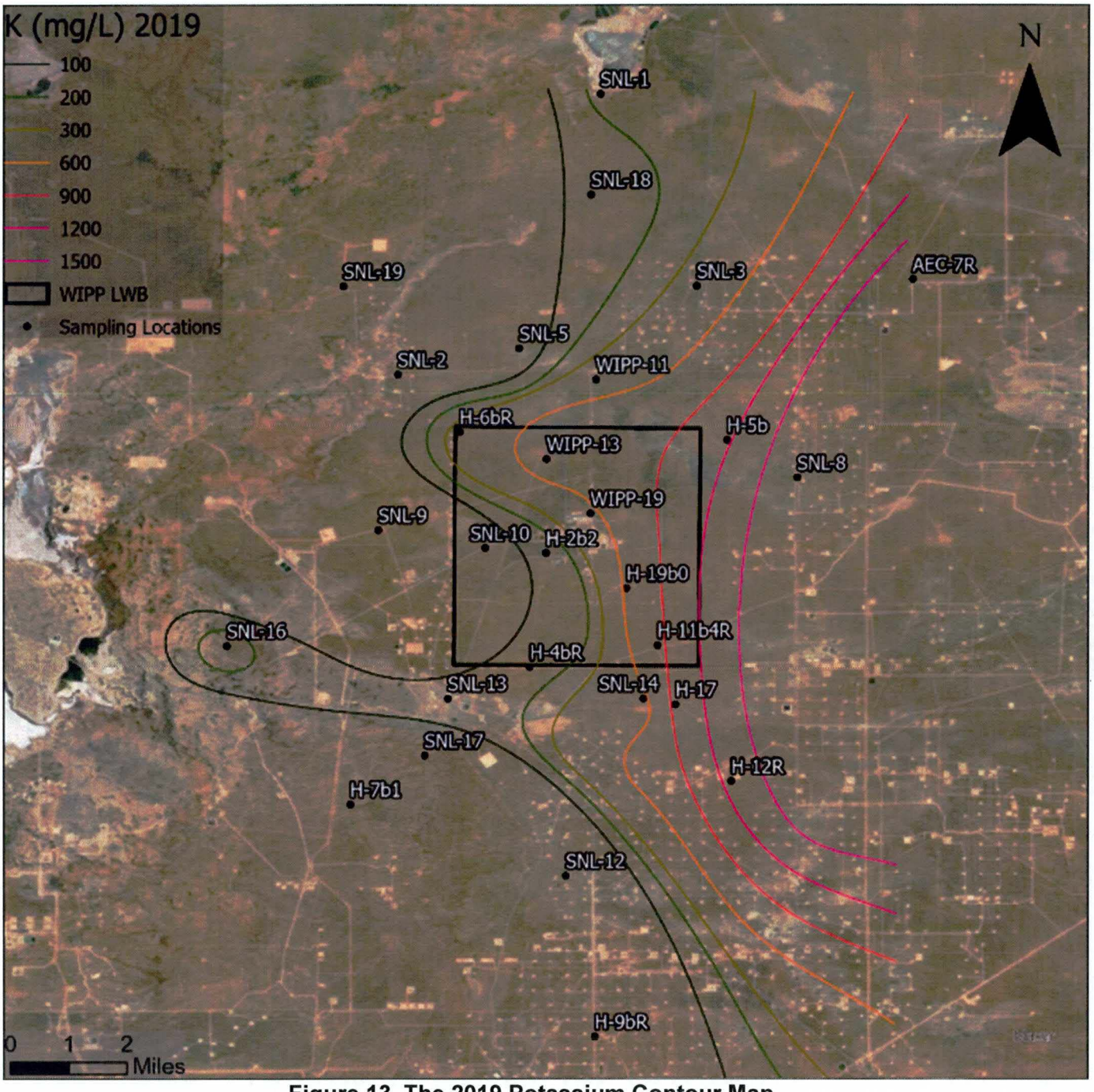

Figure 13. The 2019 Potassium Contour Map

Information Only

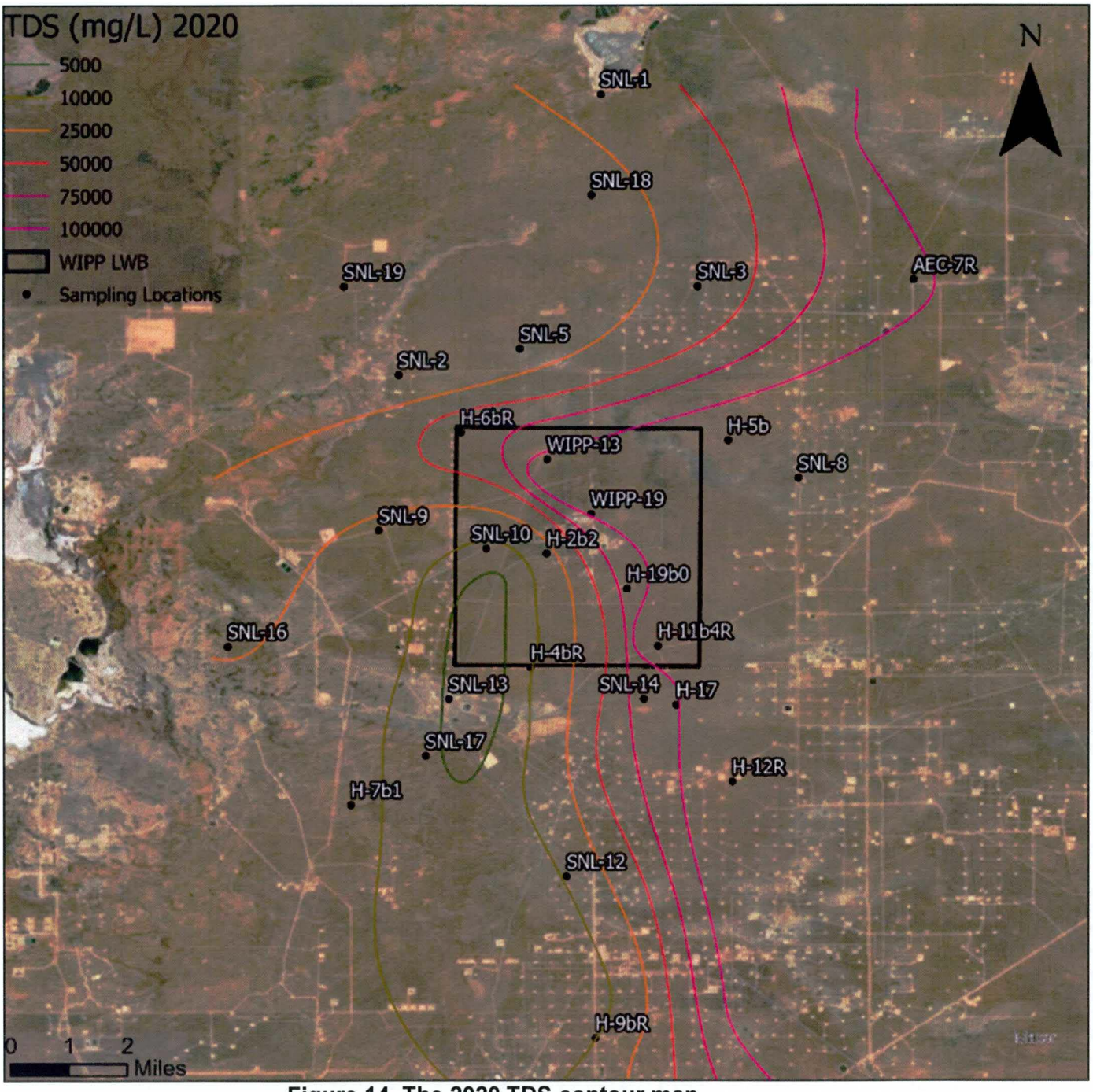

Figure 14. The 2020 TDS contour map

Information Only

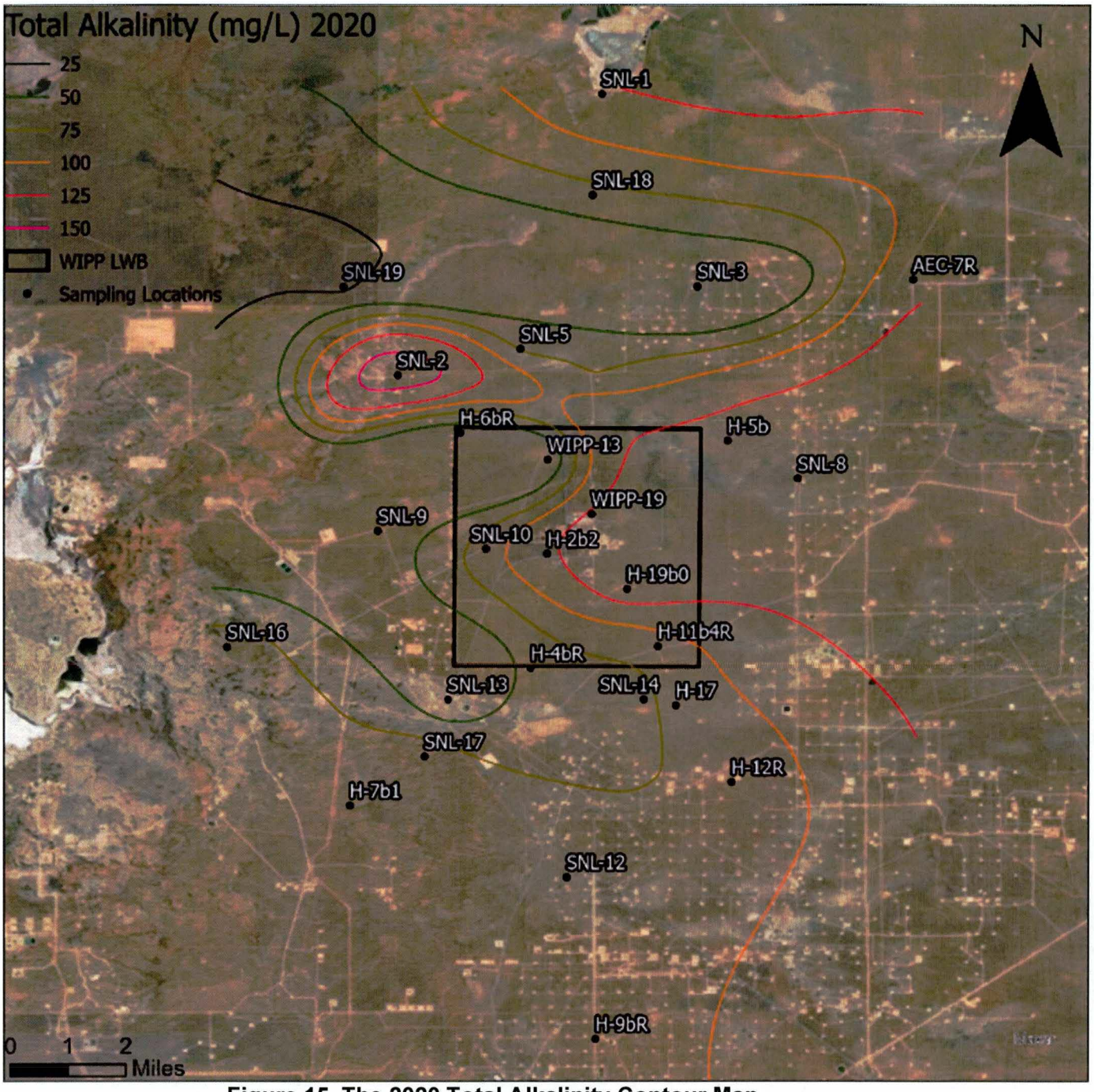

Figure 15. The 2020 Total Alkalinity Contour Map

Information Only

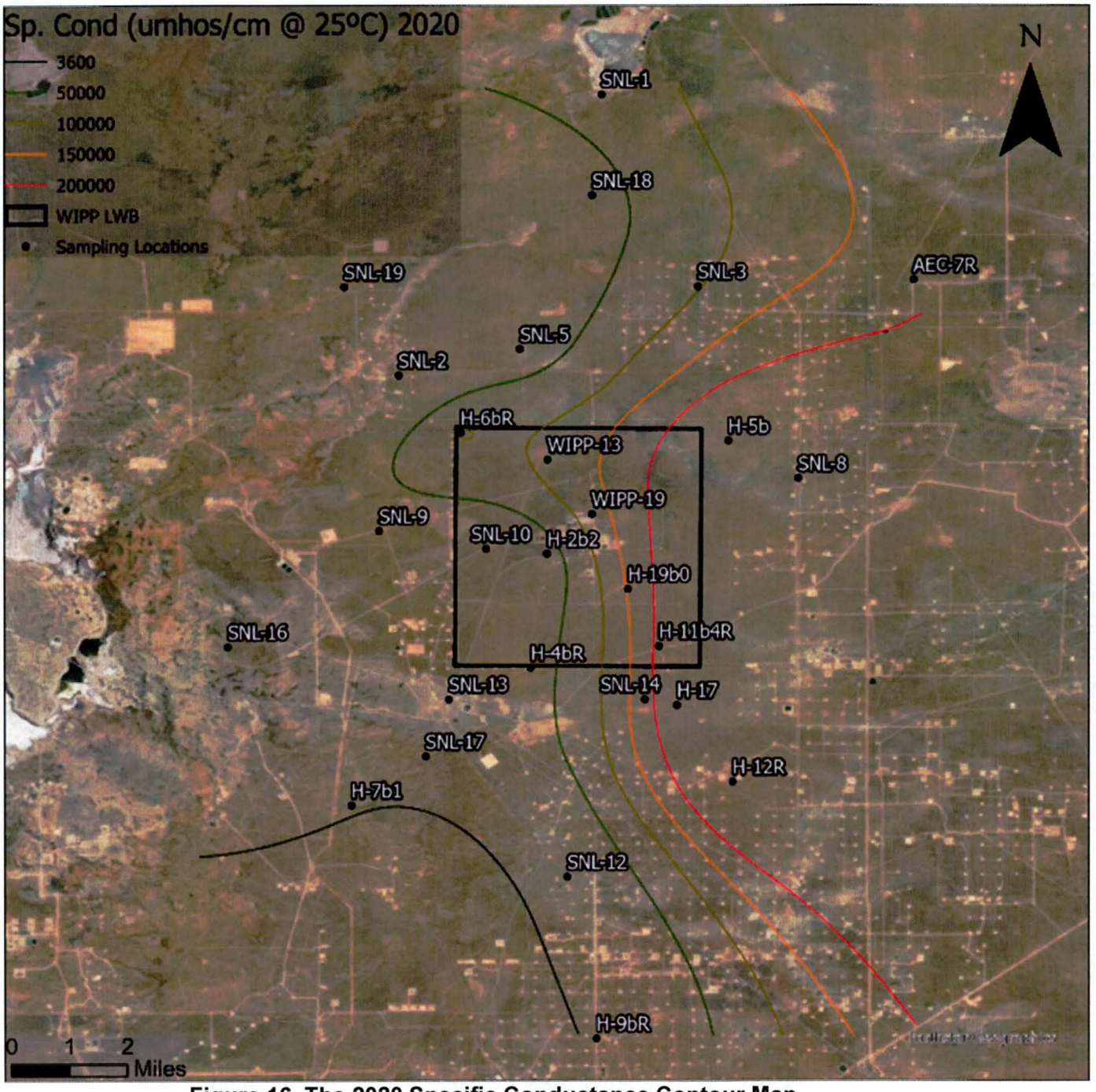

Figure 16. The 2020 Specific Conductance Contour Map

Information Only

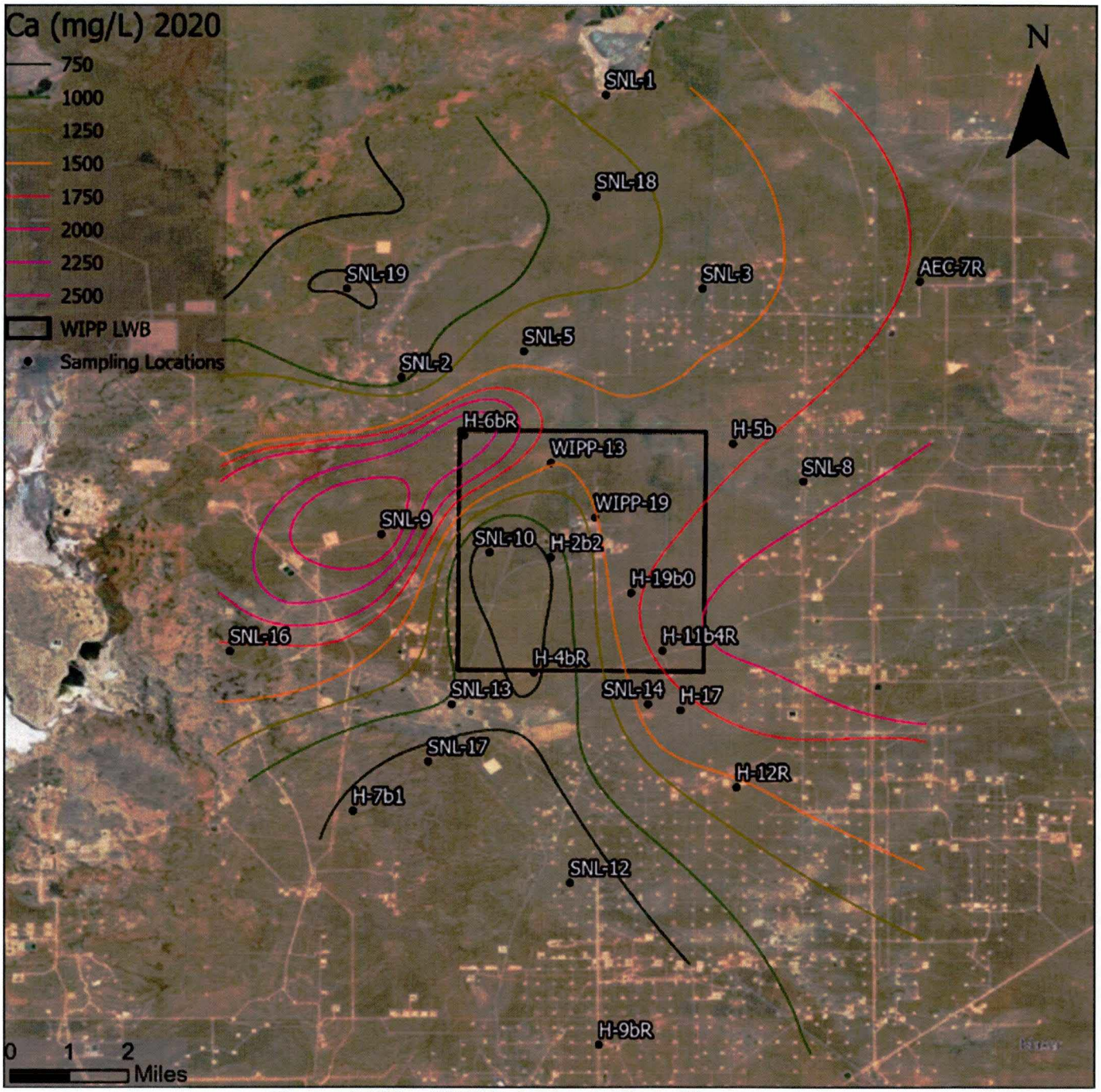

Figure 17. The 2020 Calcium Contour Map

Information Only

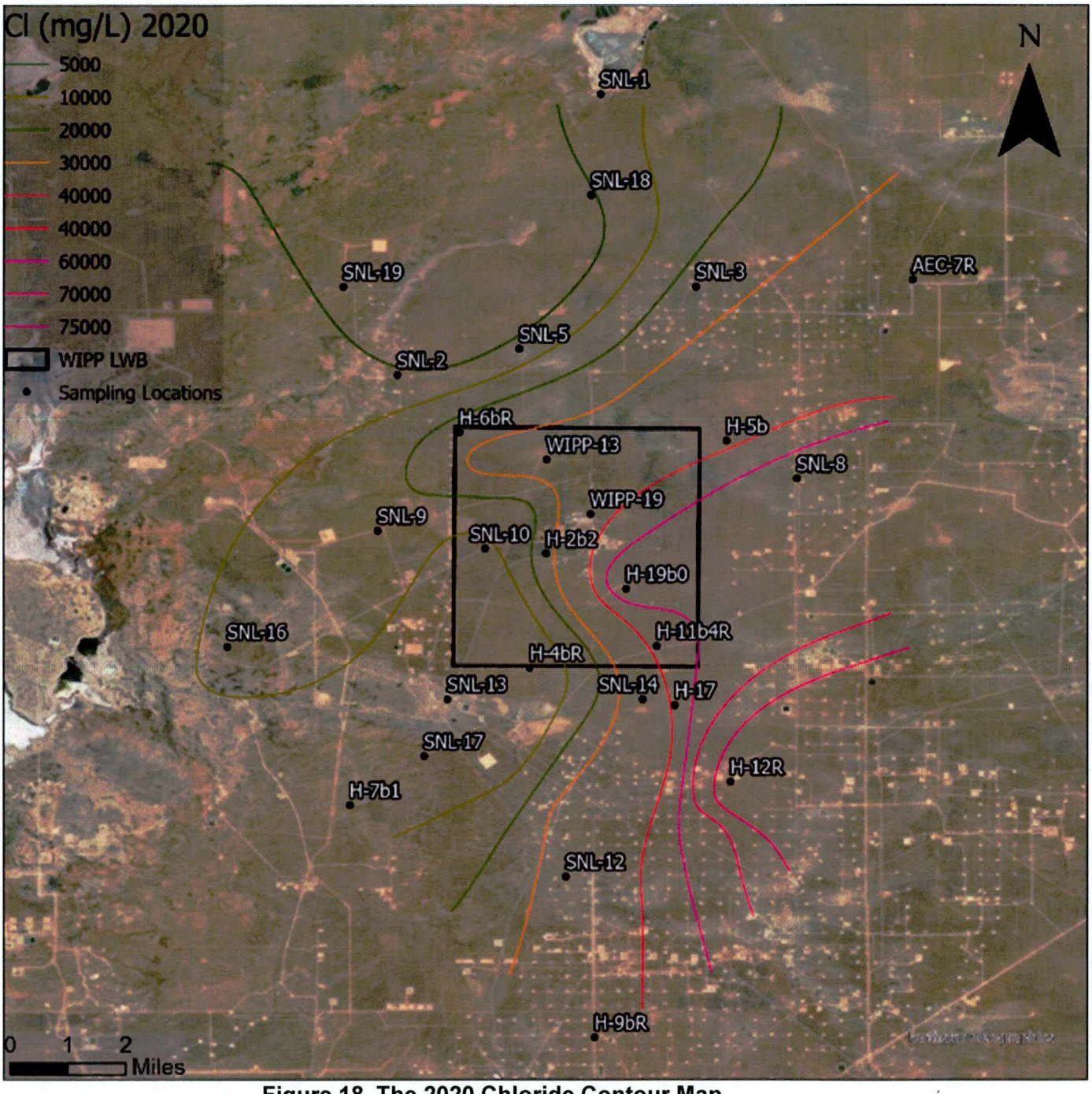

Figure 18. The 2020 Chloride Contour Map

Information Only

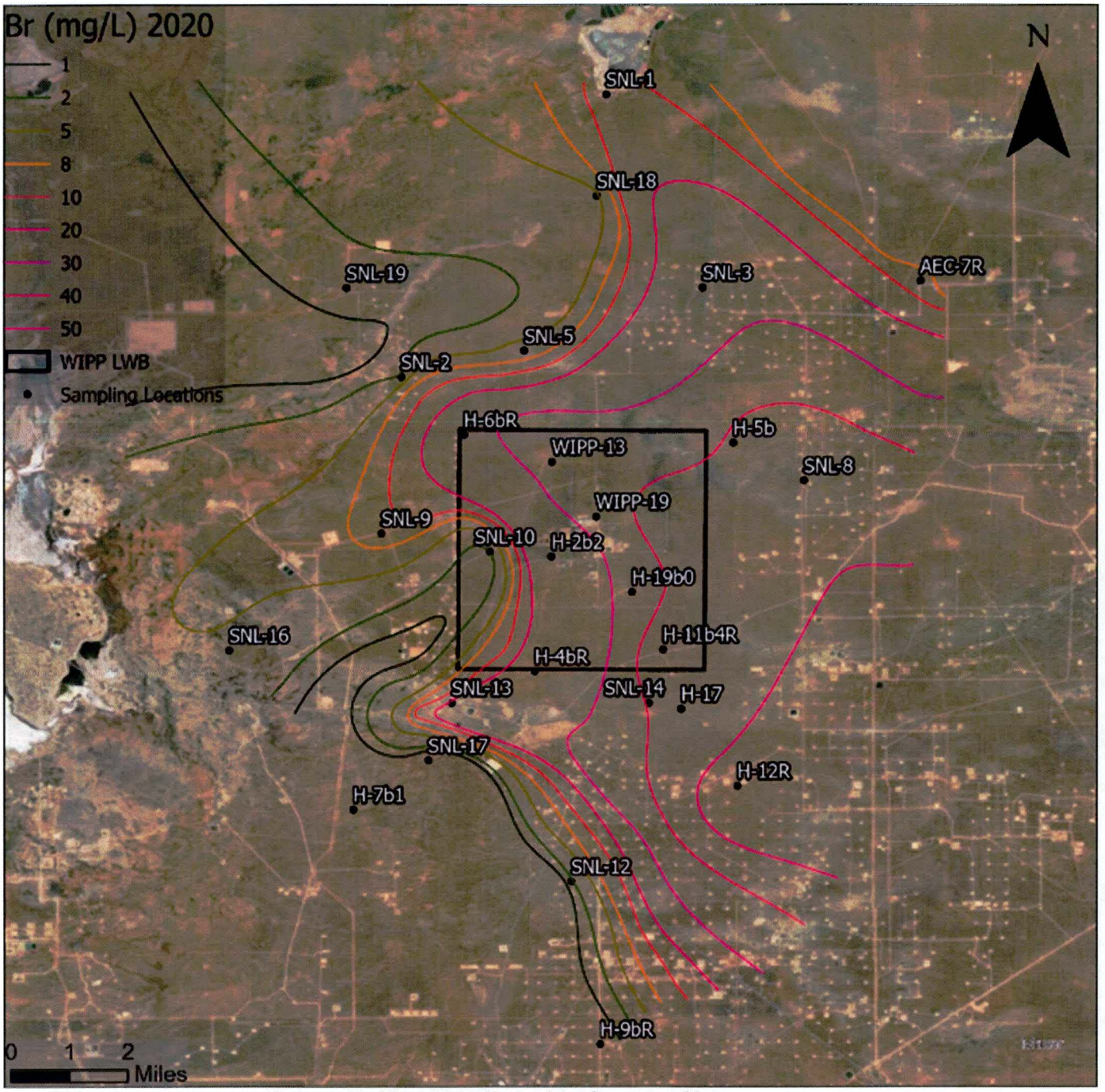

Figure 19. The 2020 Bromide Contour Map

Information Only

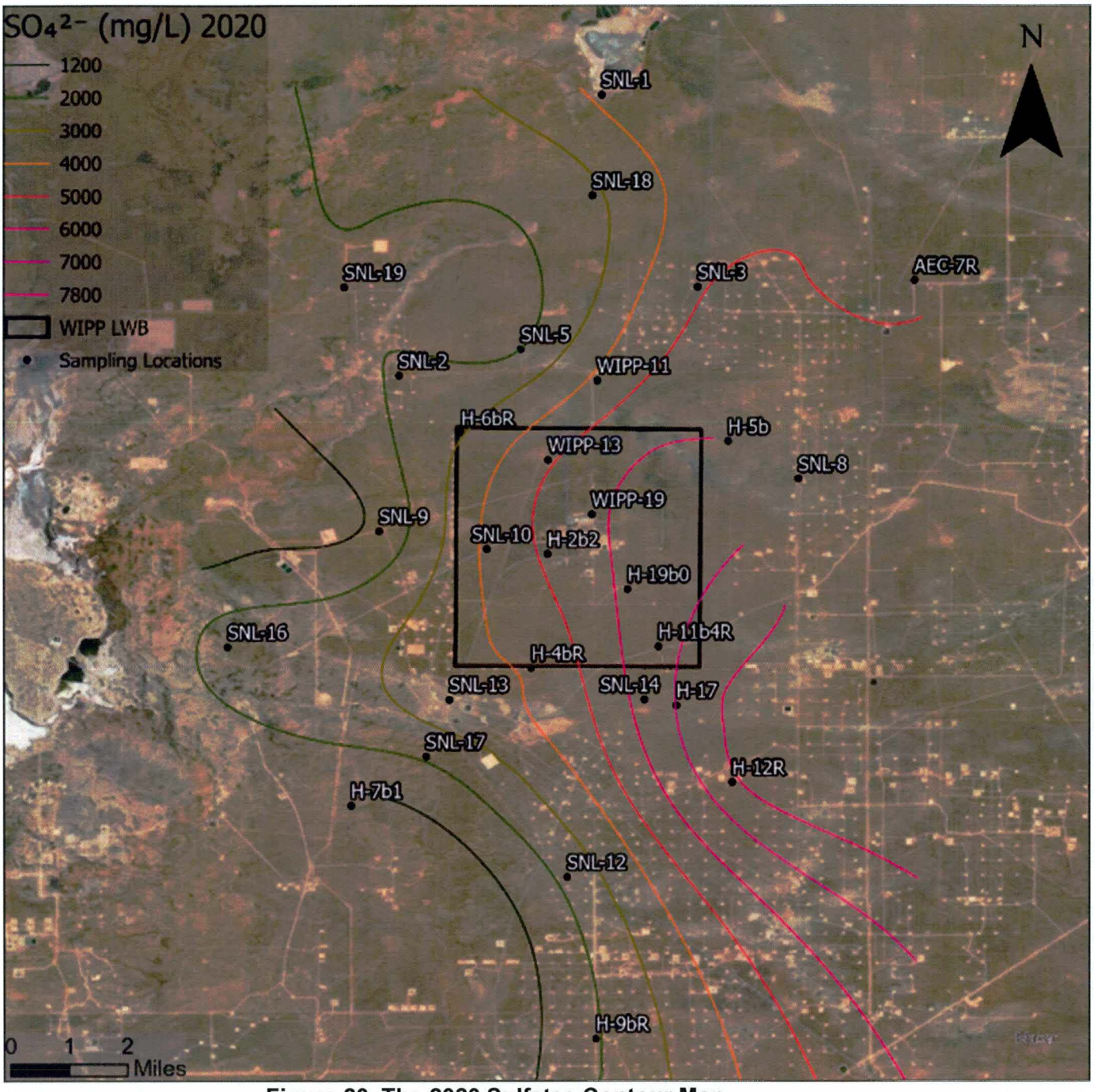

Figure 20. The 2020 Sulfates Contour Map

Information Only

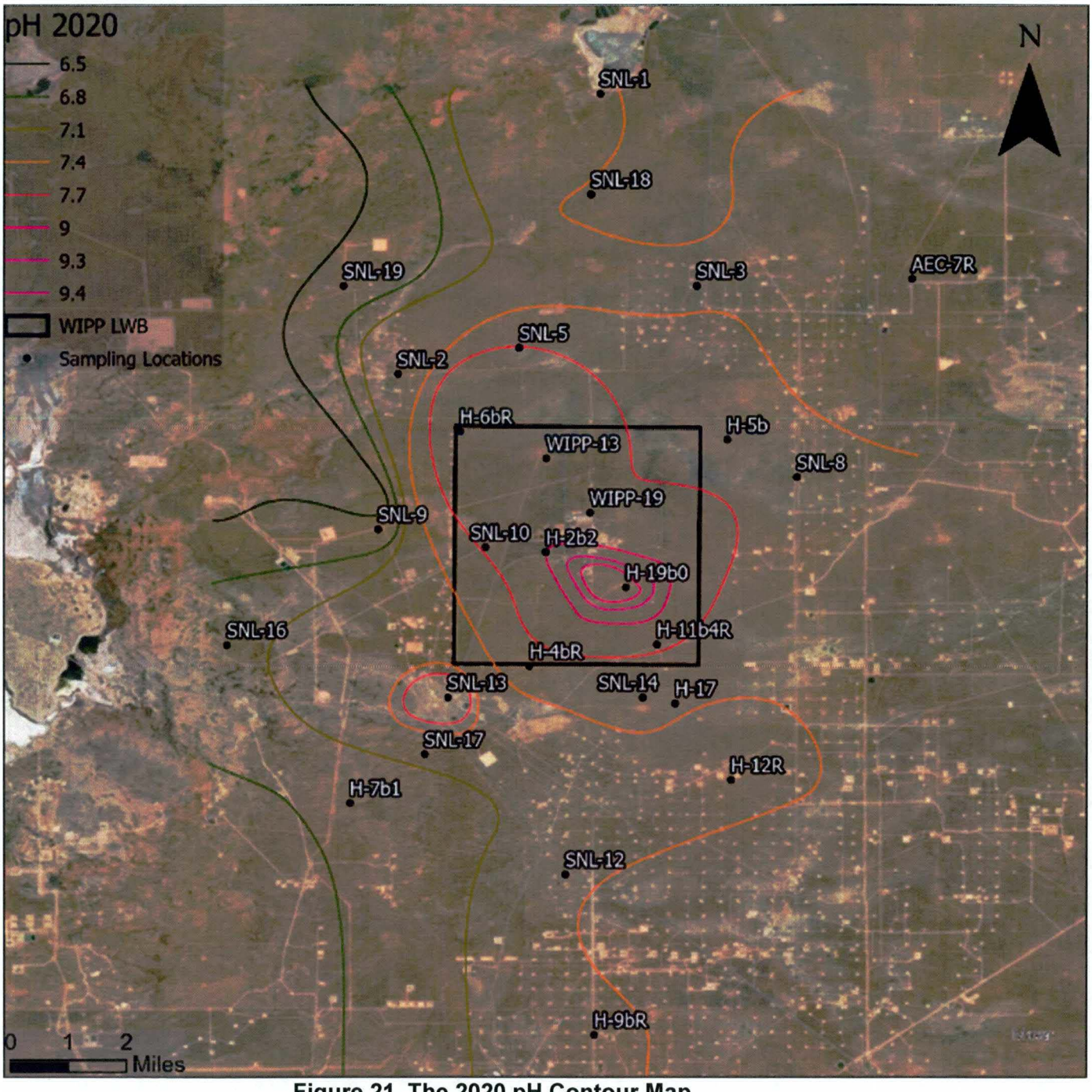

Figure 21. The 2020 pH Contour Map

Information Only

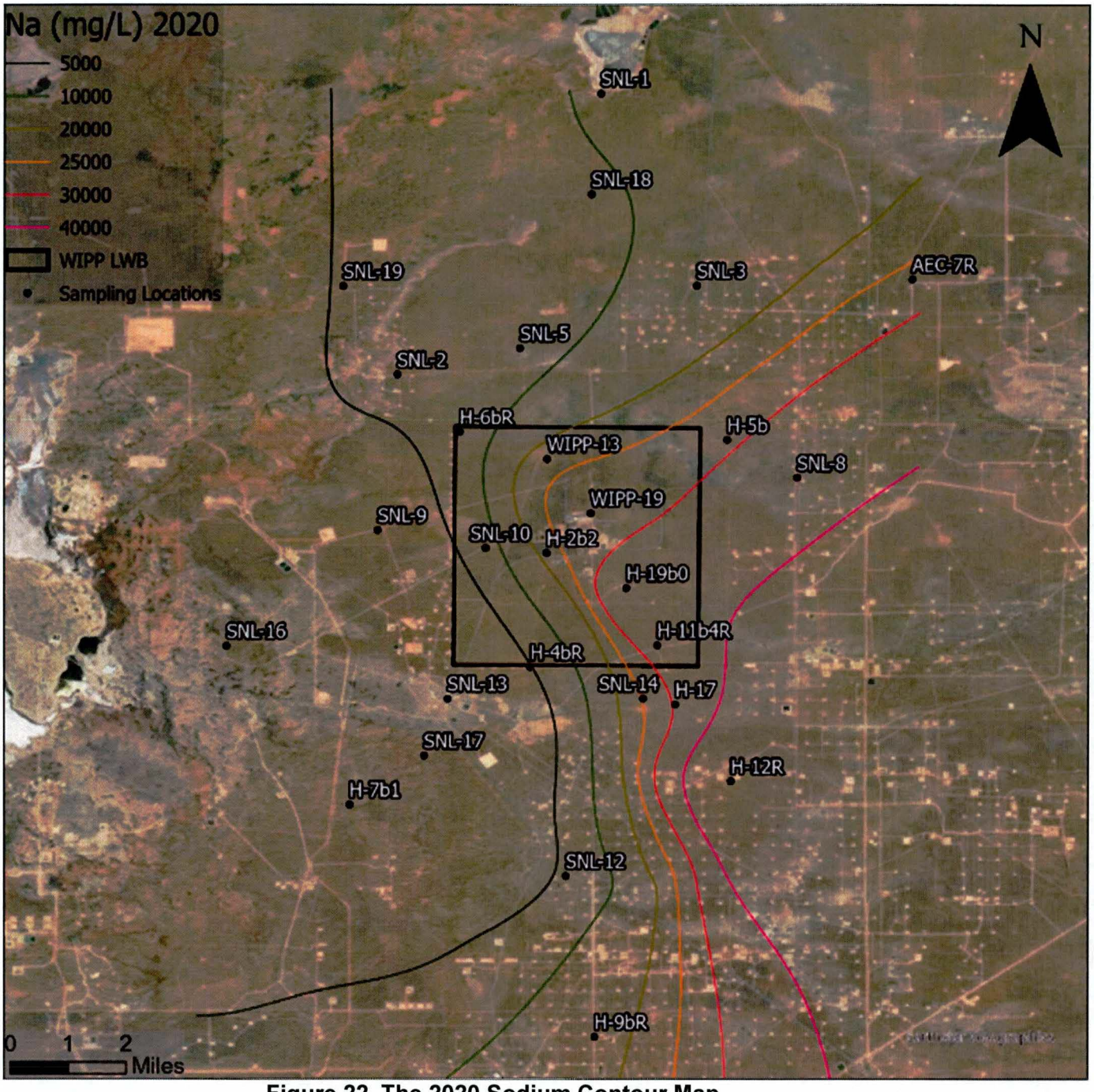

Figure 22. The 2020 Sodium Contour Map

Information Only

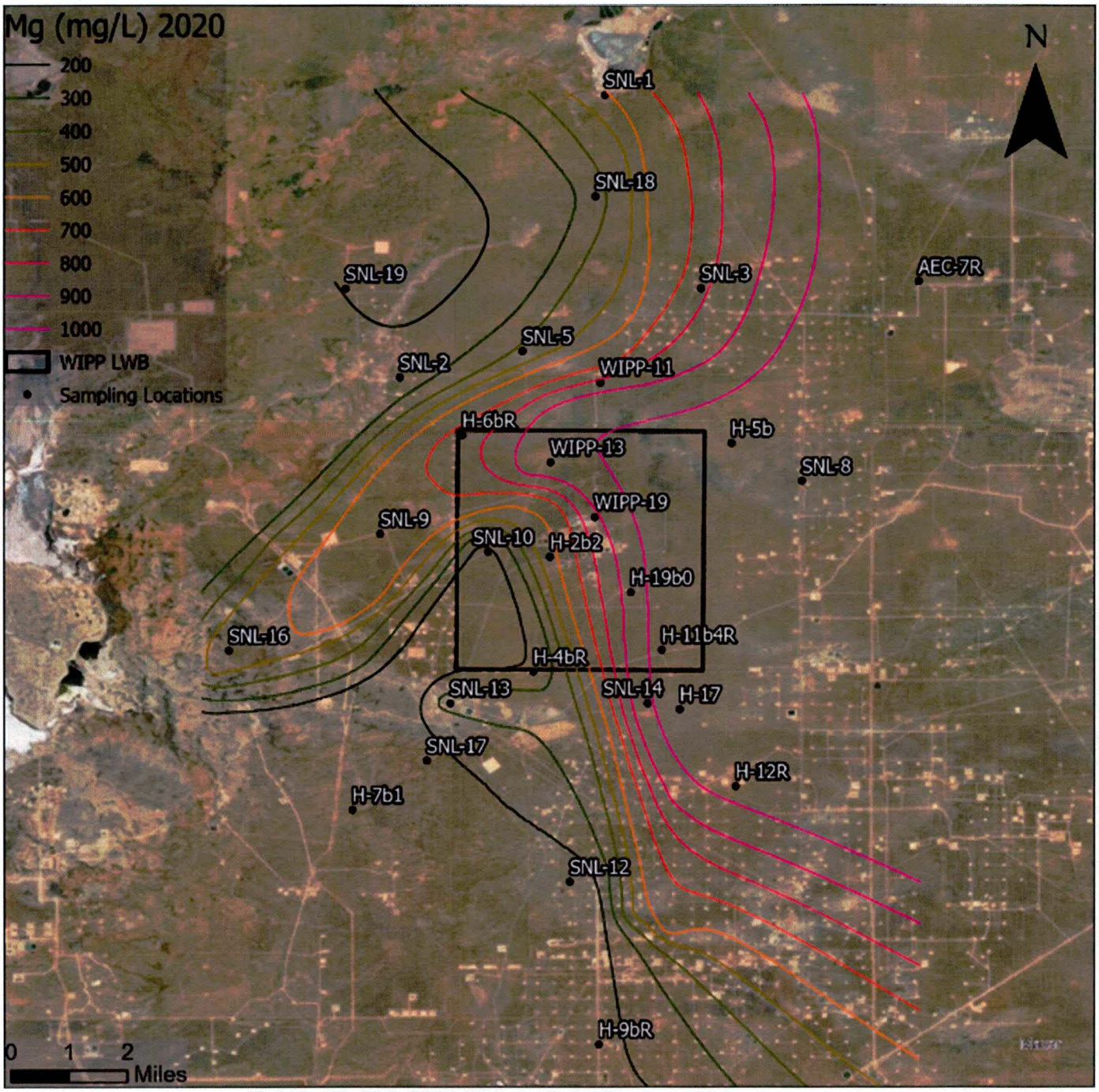

Figure 23. The 2020 Magnesium Contour Map

Information Only

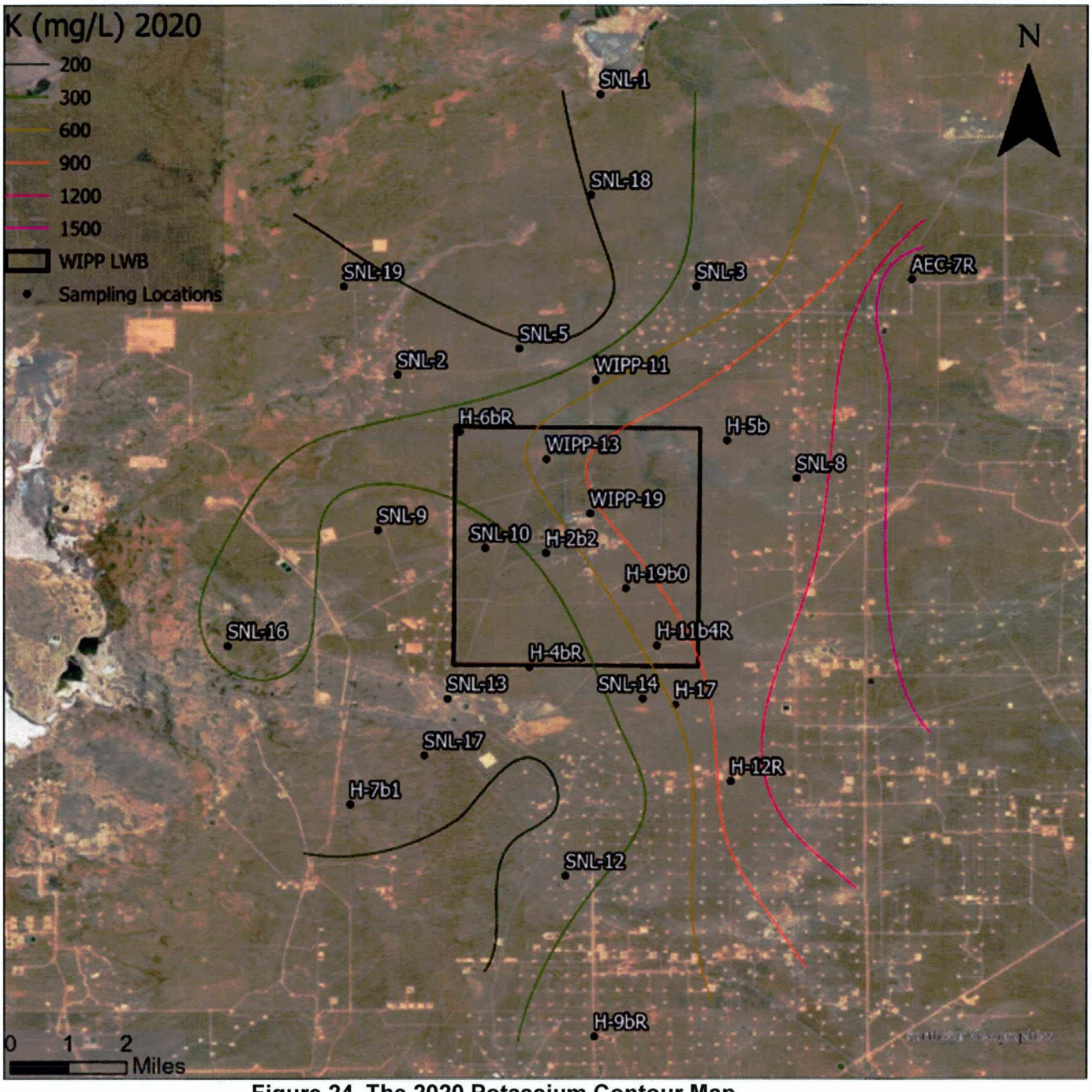

Figure 24. The 2020 Potassium Contour Map

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5. Piper Diagrams

A Piper diagram is a ternary plot used to present the predominant constituents of the water in a graph form. They are used in this report as a graphical representation of the chemistry of the WIPP water samples for each year of sampling for showing multiple samples and trends in major ions. Figures 25-28 display the "water type" for each well in a given year with a map (Figure 29) that spatially displays the location of the well matching the symbology of the Piper diagram.

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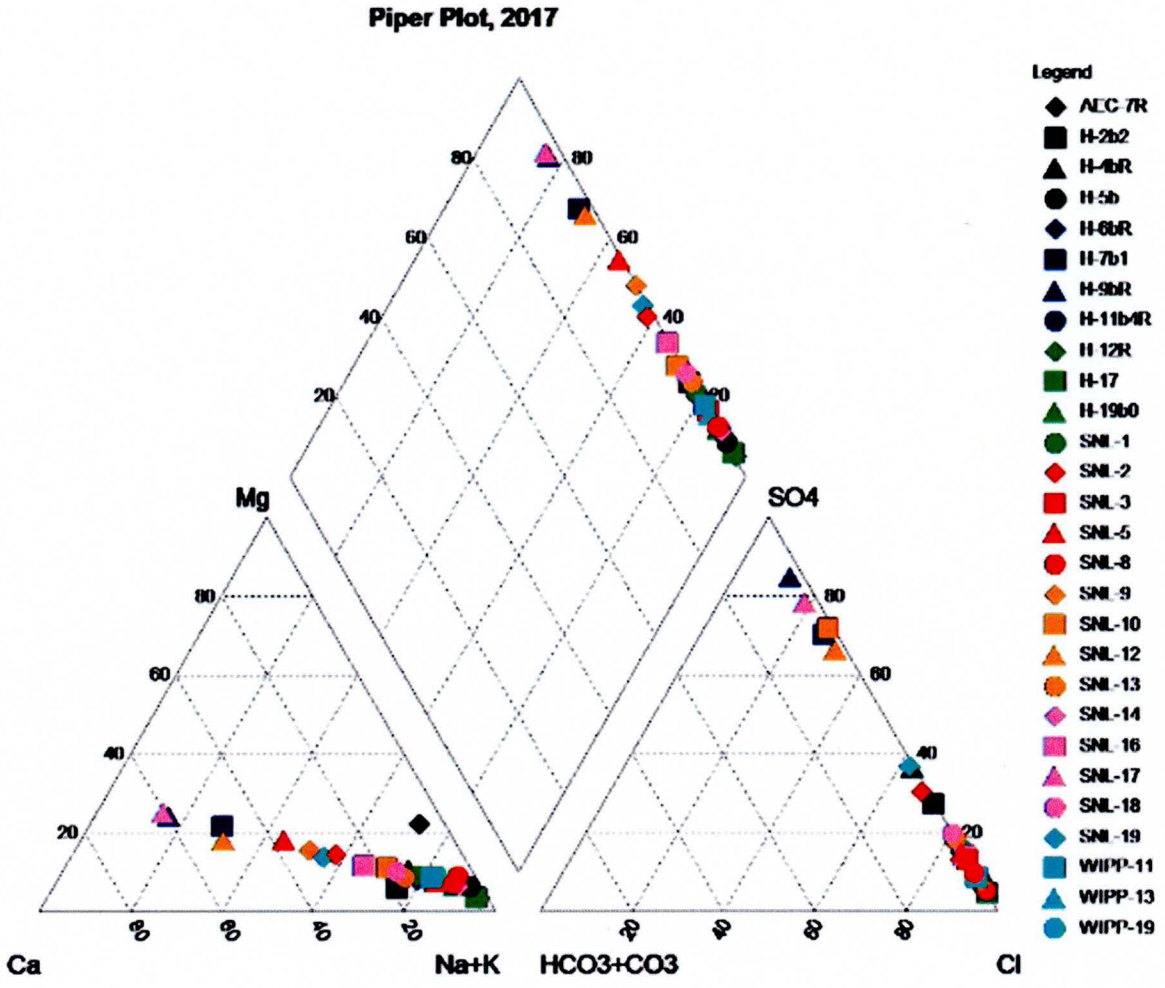

Figure 25. The Piper Plot for 2017 Water Quality Analysis

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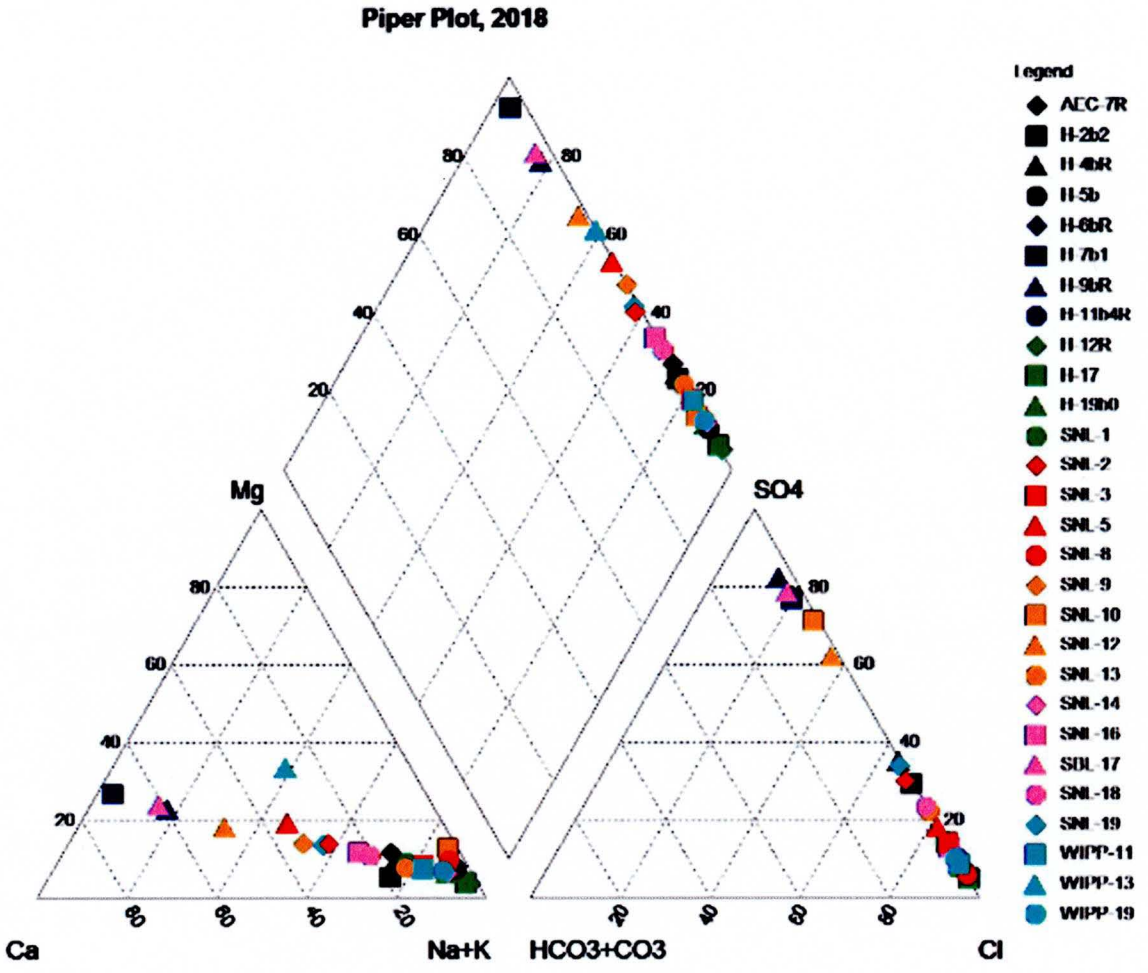

Figure 26. The Piper Plot for 2018 Water Quality Analysis

Information Only

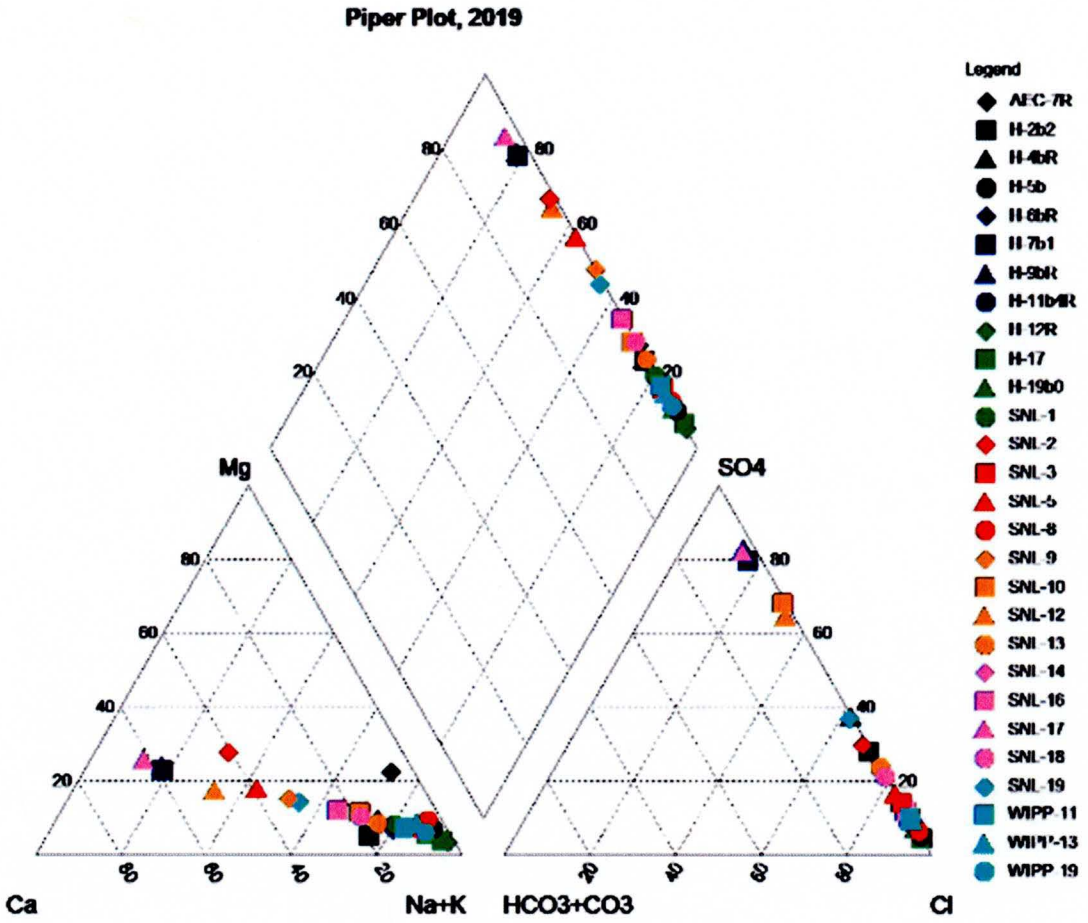

Figure 27. The Piper Plot for 2019 Water Quality Analysis

Information Only

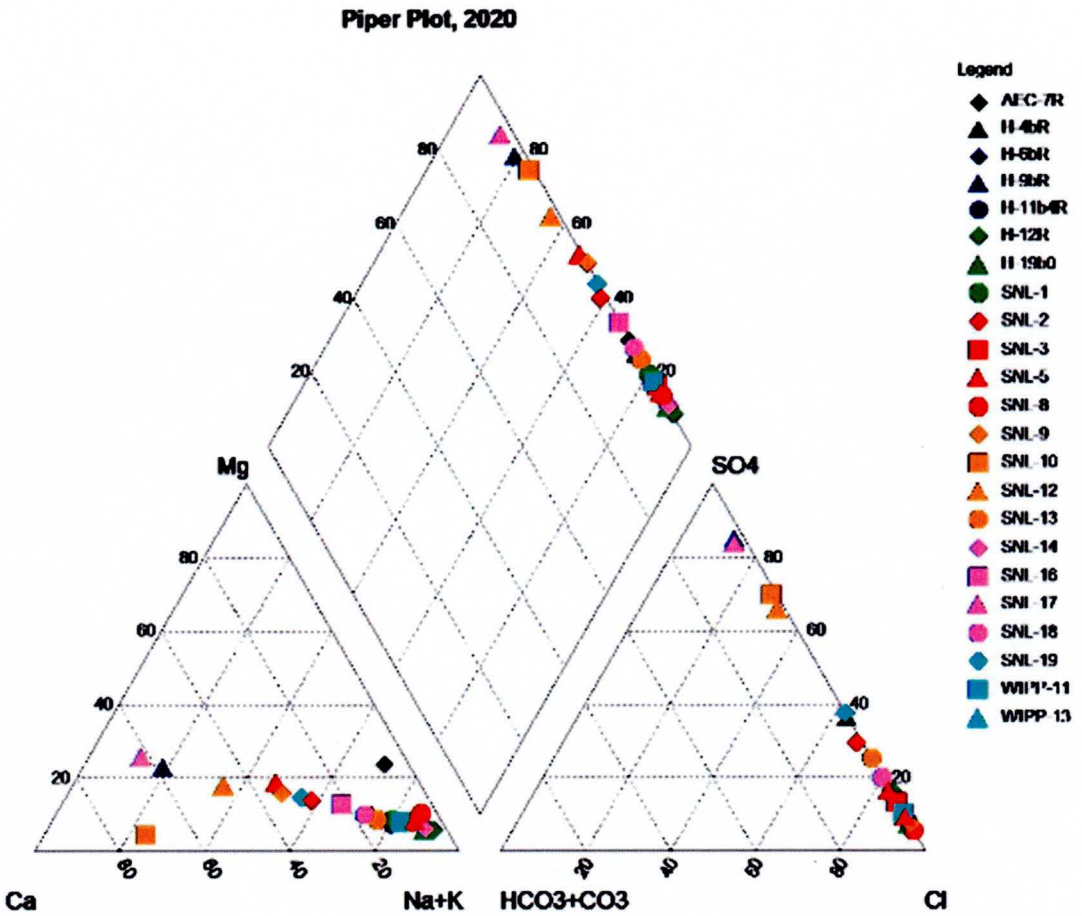

Figure 28. The Piper Plot for 2020 Water Quality Analysis

Information Only

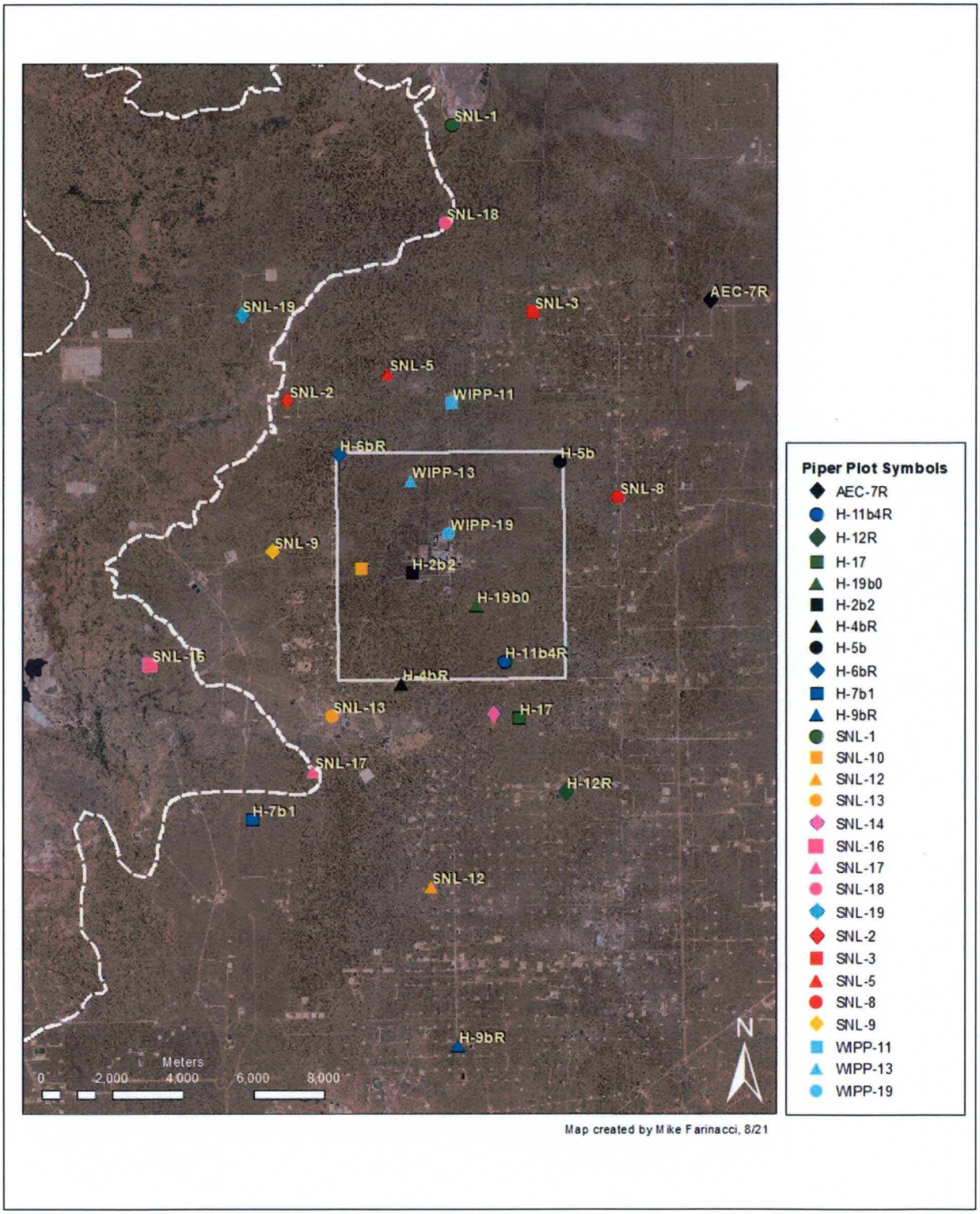

Figure 29. WIPP Well Location Map for Piper Plot Water Quality Analysis

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6. Future Work

In the Bowman 2019 Milestone Report several opportunities were presented in the future work section for continued research utilizing the snap-sampled water quality data from years 2017 – 2018 and combining it with the 2019 and 2020 data to inform future research opportunities. With the full four years of snap-sampling now completed and the data reviewed, many of the opportunities to expand our knowledge of the water chemistry still exist and should be examined further in subsequent reports (ARs).

Casing, gravel pack, drilling muds, etc. have the potential to disturb natural chemical composition and processes of aquifer (formation) waters. Even after a new well is purged, there is the potential that long-term stagnant water in the wells will become compositionally dissimilar to formation waters. It is also important to note that formation diffusivity may have an effect on the degree of water stagnation in each well as it varies by ten orders of magnitude over the study area (Powers et al., 2006). Subsequently, it is encouraged that more than one well be tested for Snap-Sampler® method verification. Using the Snap-Sampler® to verify water quality presents questions of how much the stagnant well water differs from the "true" water quality parameters of the formation water. The traditional water quality sampling method via well pumping, is designed to remedy the effects of construction and water stagnation by purging the well until stable water quality parameters are achieved. The Snap-Sampler® method considerably lessens the cost of water quality sampling (less time, no water disposal, less equipment/personnel) however, it also removes the ability to continuously monitor formation water parameters for stability.
Two new wells, H-5bR and WIPP-11R , will be added into the WIPP well monitoring network in 2021 and provide opportunity where recent baseline water quality analysis from water collected via traditional pumping (two or more wellbore volumes) can be compared to more recent snap-sampled water quality analysis. The narrower time window between the conventional sampling and snap-sampling should provide a more reliable comparison between the methods and can be combined with a more rigorous snap-sampling regimen of 1 per quarter over the period of a year to better monitor change in analytes over a shorter time. This can aid in determining how different or similar snap-sampling results are when compared to more recent conventional results and how different these results are when comparing a low transmissivity (rate at which water passes through an aquifer) well, H-5bR to a high transmissivity well, WIPP-11R.

Additionally, studies may need to be conducted on Snap-Sampler ® residence time and if it should be increased. Residence time of the sampler, so far, has been either 24 hours or 1 hour based upon well location and equipment safety. The changes to water quality parameters with respect to sampler residence time is presently unclear. A comparative study in a well may better characterize the best length of residence time. Increasing residence times in certain wells that have low transmissivity may yield better results with capturing native formation water. This can be researched by selecting several of the wells that had a 24-hour dwell time, where multiple years of modern sampling data exists, and increase the dwell time of the Snap-Sampler ® in the well to a week or more. Comparisons can be made with the averages of the 24-hour dwell time data to the newer extended dwell times for determining if more time allows for better equilibration, yielding comparable results to conventional water quality sampling. Analyses of

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these changes, and their patterns, may give more accurate insight to the chemical evolution of the Culebra, especially with the inclusion of new data with increased dwell times for sampling.

A biologic study based on geochemistry could provide foreknowledge of potential biologic growth in WIPP wells. Algae growth, as with any plant growth, is tied to preferred growth conditions. Characterizing wells in which such conditions exist would allow us to proactively maintain the well network and better understand certain chemistry changes or anomalies. A similar characterization of water quality with respect to their potential corrosion effects on well casing could be investigated to enhance maintenance activities for the well network. Steel-, fiberglass- or PVC-cased wells may also drive changes to the water chemistry based on the presence or absence of specific water constituents. Mineral growth may also be tied to both water flow and water quality constituents in each well and could be better understood with detailed chemistry analysis of each well. Prescription of potential mineralization in the wells can be just as important for well maintenance as understanding biologic growth. Biological Activity Reaction (BART) Test kits are available for Iron Bacteria, Sulfur Reducing Bacteria, and Slime Forming Bacteria and can help in establishing the bacterial type and predominance in the well. These tests may be beneficial and could be incorporated into the field water quality sampling if deemed necessary.

Another component of the monitoring program that is presently being researched is the vertical distribution of water constituents with respect to pressure density and over-all constituent water stratification. The relationships between water quality constituents, diffusivity, and vertical water density distribution could provide additional information to enhance water quality analysis, maintenance and over-all understanding of the Culebra well monitoring network.

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APPENDIX A

Historical WQ Values	IMC-461	SNL-6	SNL-15	WIPP-25	WIPP-30	C-2737	H-15R	H-10cR	USGS-4
Sample Date	8/4/2006	1/16/2008	3/30/2007	9/23/2004	5/5/2005	3/4/2004	1/22/2009	7/26/2017	7/19/2006
pH (pH units)	NA	6.17	6.64	7.55	8.01	6.92	7.53	7.5	6.8
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	14000	580000	610000	130000	130000	140000	300000	270000	5900
FLUORIDE (mg/L)	2.3	ND	6.2	ND	3.3	0.7	5.9	ND	2.3
CHLORIDE (mg/L)	3900	220000	180000	14000	18000	44000	110000	72000	1100
BROMIDE (mg/L)	ND	5100	1100	ND	12	65	61	58	ND
NITRATE+ NITRITE (mg/L)	3.1	ND	ND	7.7	ND	ND	ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND
SULFATE (mg/L)	2300	1800	1600	2600	3900	6000	6400	7100	1800
CALCIUM (mg/L)	1000	5500	4800	1800	1300	1600	1800	1600	530
MAGNESIUM (mg/L)	250	22000	12000	660	320	770	2100	2200	120
POTASSIUM (mg/L)	30	4800	6800	720	170	320	1200	960	15
SODIUM (mg/L)	1800	97000	90000	8000	13000	28000	66000	35000	540
ALKALINITY as CaCO3 Total (mg/L)	100	170	200	100	44	71	63	65.44	35
TDS (mg/L)	9900	320000	280000	28000	38000	89000	200000	146000	4300

Historical WQ Values	USGS-4	USGS-8	WQSP-1	WQSP-2	WQSP-3	WQSP-4	WQSP-5	WQSP-6
Sample Date	7/30/2008	7/30/2008	11/15/2006	11/1/2006	10/25/2006	10/18/2006	10/4/2006	9/13/2006
pH (pH units)	6.36	7.75	7.12	7.18	6.75	7.05	7.03	7.82
SPECIFIC CONDUCTANCE (umhos/cm@ 25 C)	5100	5500	120000	110000	420000	190000	58000	26000
FLUORIDE (mg/L)	2.3	ND	ND	2.9	ND	ND	ND	4
CHLORIDE (mg/L)	1100	1000	32000	30000	120000	55000	14000	5400
BROMIDE (mg/L)	ND	ND	35	49	88	69	58	9.4
NITRATE+ NITRITE (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND
PHOSPHORUS (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND
SULFATE (mg/L)	1400	1800	4500	5000	7100	6100	4900	4600
CALCIUM (mg/L)	600	570	1600	1600	1500	1600	990	710
MAGNESIUM (mg/L)	120	97	1100	1100	2400	1200	420	220
POTASSIUM (mg/L)	15	16	470	520	1600	730	280	160
SODIUM (mg/L)	650	810	19000	21000	78000	35000	8500	4300
ALKALINITY as CaCO3 Total (mg/L)	31	35	50	47	33	40	46	46
TDS (mg/L)	4100	4400	64000	62000	210000	100000	31000	15000

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Figure TFIELD 2-1. Title 40 CFR Part 191 Subparts B and C Compliance Recertification Application 2014 for the Waste Isolation Pilot Plant. Appendix TFIELD-2014 Transmissivity Fields.

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Standard Operating Procedure for the Standard/Well-Volume Method for Collecting a Ground-Water Sample From Monitoring Wells for Site Characterization. https://www.epa.gov/sites/production/files/2015-06/documents/finalgwsamp_sop.pdf

Thomas, M., M. Schuhen, and P. Johnson. 2016 "A Basis, Review, and Five-Year Projection for the Waste Isolation Pilot Plant Integrated Hydrology Program, Revision 0" ERMS # 565860. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

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WIPP Water Quality Scientific Notebook #1 (WWQM-1) 2017. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

WIPP Water Quality Supplemental Notebook #1 2017-2018. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

WIPP Water Quality Supplemental Notebook #2 2018. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

Software:

ESRI 2016. ArcGIS Desktop: Release 10.4.1. Redlands, CA: Environmental Systems Research Institute.

ESRI 2021 ArcGIS Pro: Build 2.8.2, Redlands, CA: Environmental Systems Research Institute.

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Water quality parameter reports and/or documents that contains the water quality data described in this report are referenced in the following table. This format was chosen as opposed to the traditional format above for the sake of clarity and ease-of-use. In the three cases where N/A is listed, we are using values provided by a spreadsheet tracking historic water quality values. We have not yet found the original sources of this data, but we also have no reason to believe the data to be false.

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Water Quality Report References

Well ID	Sample Date	Order #	ERMS
AEC-7R	3/11/2015	1503573	565245
AEC-7R	5/10/2017	1705619	569911
AEC-7R	6/20/2018	1806EE07	571129
AEC-7R	7/15/2014	1407862	565246
AEC-7R	6/12/2019	1906816	572338
AEC-7R	6/24/2020	2006C94	575782
C-2737	3/4/2004	403066	536430
H-11b4R	6/14/2012	1206666	557912
H-11b4R	3/9/2017	1703564	569904
H-11b4R	3/28/2018	1803G28	569942
H-11b4R	3/7/2019	1903408	572328
H-11b4R	3/5/2020	2003280	575773
H-12R	4/22/2015	1504A90	564052
H-12R	5/10/2017	1705621	569915
H-12R	5/23/2018	1805D41	571126
H-12R	5/8/2019	1905496	572334
H-12R	5/20/2020	2005918	575780
H-15R	1/22/2009	901317	550900
H-17	10/27/1987	538123	243850
H-17	9/7/2017	1709401	569932
H-17	9/19/2018	1809C21	571145
H-17	9/5/2019	1909278	572349
H-19b0	8/31/2006	609003	544602
H-19b0	5/10/2017	1705620	569912
H-19b0	5/23/2018	1805D39	571127
H-19b0	5/8/2019	1905490	572332
H-19b0	5/20/2020	2005914	575778
H-2b2	9/7/2017	1709402	569930
H-2b2	9/19/2018	1809C20	571144
H-2b2	9/5/2019	1909298	572350
H-4bR	8/13/2009	908237	552399
H-4bR	3/9/2017	1703565	569907
H-4bR	3/28/2018	1803G27	569940
H-4bR	3/7/2019	1903402	572327
H-4bR	3/5/2020	2003277	575771
H-5b	4/26/1994	N/A	N/A
H-5b	9/7/2017	1709400	569933
H-5b	9/19/2018	1809C22	571146
H-5b	8/16/2019	1908D58	572348
H-6bR	12/10/2008	812250	550752
H-6bR	8/9/2017	1708653	569928
H-6bR	8/8/2018	1808549	571137
H-6bR	8/7/2019	1908527	572347
H-6bR	9/23/2020	2009F71	572792
H-7b1	11/9/1990	N/A	N/A
H-7B1	7/12/2017	1707636	569919
H-7B1	7/25/2018	1807D96	571133
H-7b1	7/23/2019	1907C53	572344
H-9bR	8/20/2012	1208942	558247
H-9bR	6/7/2017	1706429	569914
H-9bR	5/23/2018	1805D37	571125
H-9bR	6/28/2011	1106C12	555875
H-9bR	5/8/2019	1905493	572333
H-9bR	5/28/2019	2005C59	575777
IMC-461	8/4/2006	608100	544263
SNL-1	6/15/2016	1606899	569903
SNL-1	8/8/2017	1708652	569925
SNL-1	8/7/2018	1808547	571138
SNL-1	5/29/2004	406004	536319
SNL-1	3/10/2005	503129	539157
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SNL-13	7/17/2006	607213	544169
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SNL-13	4/26/2005	504272	539860
SNL-13	3/6/2019	1903409	572325
SNL-13	3/5/2020	2003279	575772
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SNL-16	9/5/2018	1809389	571141
SNL-16	6/9/2006	606131	543869
SNL-16	11/9/2015	1511467	565247
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SNL-17	3/5/2020	2003278	575770
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SNL-18	7/12/2017	1707638	569921
SNL-18	8/8/2018	1808551	571136
SNL-18	8/18/2006	608258	544323
SNL-18	7/11/2019	1907625	572342
SNL-18	7/23/2020	2007C60	575784
SNL-19	6/14/2016	1606811	569901
SNL-19	7/11/2017	1707635	569922
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SNL-19	7/22/2020	2007C64	575786
SNL-2	1/24/2005	502030	538714
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SNL-2	1/17/2004	401111	536403
SNL-2	7/10/2019	1907623	572341
SNL-2	7/22/2020	2007C62	575785
SNL-3	4/16/2004	404155	536435
SNL-3	9/6/2017	1709399	569929
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SNL-3	11/6/2019	191375	572355
SNL-3	8/25/2020	2008F07	575789
SNL-5	7/24/2004	407301	537879
SNL-5	4/12/2017	1704563	569909
SNL-5	4/25/2018	1804D06	571122
SNL-5	4/24/2019	1904D34	572330
SNL-5	5/28/2020	2005C55	575775
SNL-6	1/16/2008	801223	548207
SNL-8	8/2/2007	708074	546868
SNL-8	9/6/2017	1709397	569931
SNL-8	9/5/2018	1809387	571143
SNL-8	9/4/2019	1909302	572351
SNL-8	9/23/2020	2009F74	575790
SNL-9	11/19/2004	411255	538237
SNL-9	6/7/2017	1706432	569916
SNL-9	6/20/2018	1806EE09	571130
SNL-9	6/12/2019	1906814	572337
SNL-9	6/24/2020	2006C90	575781
USGS-4	7/19/2006	607240	544304
USGS-4	7/30/2008	807446	549943
USGS-8	7/30/2008	807446	549945
WIPP-11	2/20/2005	502260	539066
WIPP-11	4/12/2017	1704564	569910
WIPP-11	4/24/2018	1804D07	571123
WIPP-11	4/24/2019	1904D36	572331
WIPP-11	5/28/2020	2005C54	575774
WIPP-13	2/16/1987	544896	243850
WIPP-13	5/10/2017	1705622	569913
WIPP-13	5/23/2018	1805D40	571128
WIPP-13	5/8/2019	1905498	572335
WIPP-13	5/20/2020	2005916	575779
WIPP-19	5/2/1995	N/A	N/A
WIPP-19	6/7/2017	1706428	569918
WIPP-19	6/20/2018	1806EE10	571132
WIPP-19	6/12/2019	1906811	572336
WIPP-25	9/23/2004	409263	537629
WIPP-30	5/5/2005	505083	540181
WQSP-1	11/15/2006	611201	545120
WQSP-2	11/1/2006	611023	544898
WQSP-3	10/25/2006	610313	544820
WQSP-4	10/18/2006	610203	544818
WQSP-5	10/4/2006	610047	544816
WQSP-6	9/13/2006	609147	544598

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The email correspondence acknowleging the lab error in the TDS analysis for well H-19b0 is referenced below.

Lofton, Owen W

From: Andy Freeman <andy@hallenvironmental.com>
Sent: Monday, October 11, 2021 10:20 AM
To: Lofton, Owen W
Subject: [EXTERNAL] RE: Report 2005914

Hi Owen,

Thanks for the email.

We have researched this discrepancy and all of our raw data supports the reported result. It my opinion that that the most likely cause for the TDS measured discrepancy is lab error. I think that the TDS measured result should be x2 higher than what is reported. Perhaps the analyst marked a x100 dilution on the prep sheet when it should have been a x200 dilution.

I am sorry for this likely lab error. I would use the calculated TDS value for the TDS result for this sample.

Please let me know if you have any questions.

Thank you,

Andy Freeman - Hall Environmental, 4901 Hawkins NE, Albuquerque, NM 87109, 505-345-3975, 505-345-4107 fax
www.hallenvironmental.com - andy@hallenvironmental.com - https://www.surveymonkey.com/r/NGVXRBV
For easy access to all of your past reports, setup an account on the Hall Environmental Web Portal. Just visit our website and follow the instructions for setting up an account.
We welcome your feedback. Please visit the survey monkey link to complete a brief survey on your experience with Hall Environmental.

From: Lofton, Owen W <owlofto@sandia.gov>
Sent: Thursday, October 7, 2021 8:55 AM
To: Andy Freeman <andy@hallenvironmental.com>; Jackie Bolte <jnb@hallenvironmental.com>
Cc: Nielsen, Shelly R <srjohn@sandia.gov>; Kirkes, Leslie <lkirkes@sandia.gov>
Subject: Report 2005914

Good morning Jackie and Andy,

Would you mind checking the results page of the subject report for our WIPP H-19b0 sample? We have fairly consistent TDS values in all sampling years for this well except for 2020 where we see a TDS value of 64300 mg/L, however 2017-2019 results are: 97700, 93200 and 93500 mg/L respectively. The measured vs. the calculated values on the Cation/Anion balance sheet for TDS further call this into question.

Can you confirm the 2020 analysis results for TDS are accurate, and if it changes, can you provide us with a corrected report?

Thank you,
Owen

Owen W. Lofton
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Contractor Associate for Sandia National Laboratories
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