Florida Department of Health
Onsite Nitrogen Reduction Strategies Study

Contract CORCL

TASK C.15
GCREC MOUND MONITORING
TRACER TEST NO. 2 MEMO

May 2012

1.0 Background

Task C of the Florida Onsite Sewage Nitrogen Reduction Strategies Study includes monitoring at field sites in Florida to evaluate nitrogen reduction in soil and groundwater, to assess groundwater impacts from various onsite wastewater systems, and to provide data for parameter estimation, verification, and validation of models developed in Task D. Controlled pilot-scale testing will be conducted at the GCREC soil and groundwater (S&GW) test facility to characterize nitrogen fate and transport under a variety of typical operating conditions. The Task C objectives, monitoring framework, sample frequency and duration, and analytical methods to be used at the GCREC S&GW test facility site have been documented in previous reports.

2.0 Purpose

This memo documents the tracer test that was conducted adjacent to the GCREC S&GW test facility from November 9, 2011 to January 16, 2012. The most direct method for groundwater velocity determination was used which consisted of introducing a tracer at one point in the flow field and observing its arrival at other points. The test was conducted to assess expected travel direction, times and uniformity of flow.

3.0 Materials and Methods

3.1 Experimental Location and Design

The tracer test was conducted at the GCREC S&GW test facility located at the University of Florida, Gulf Coast Research and Education Center (GCREC) in southeast Hillsborough County, Florida. The test was conducted northeast of the facility's onsite sewage treatment and disposal system (OSTDS) in soils representative of the S&GW test facility research area, but in an area that would not interfere with monitoring of the S&GW test area plumes (Figure 1).

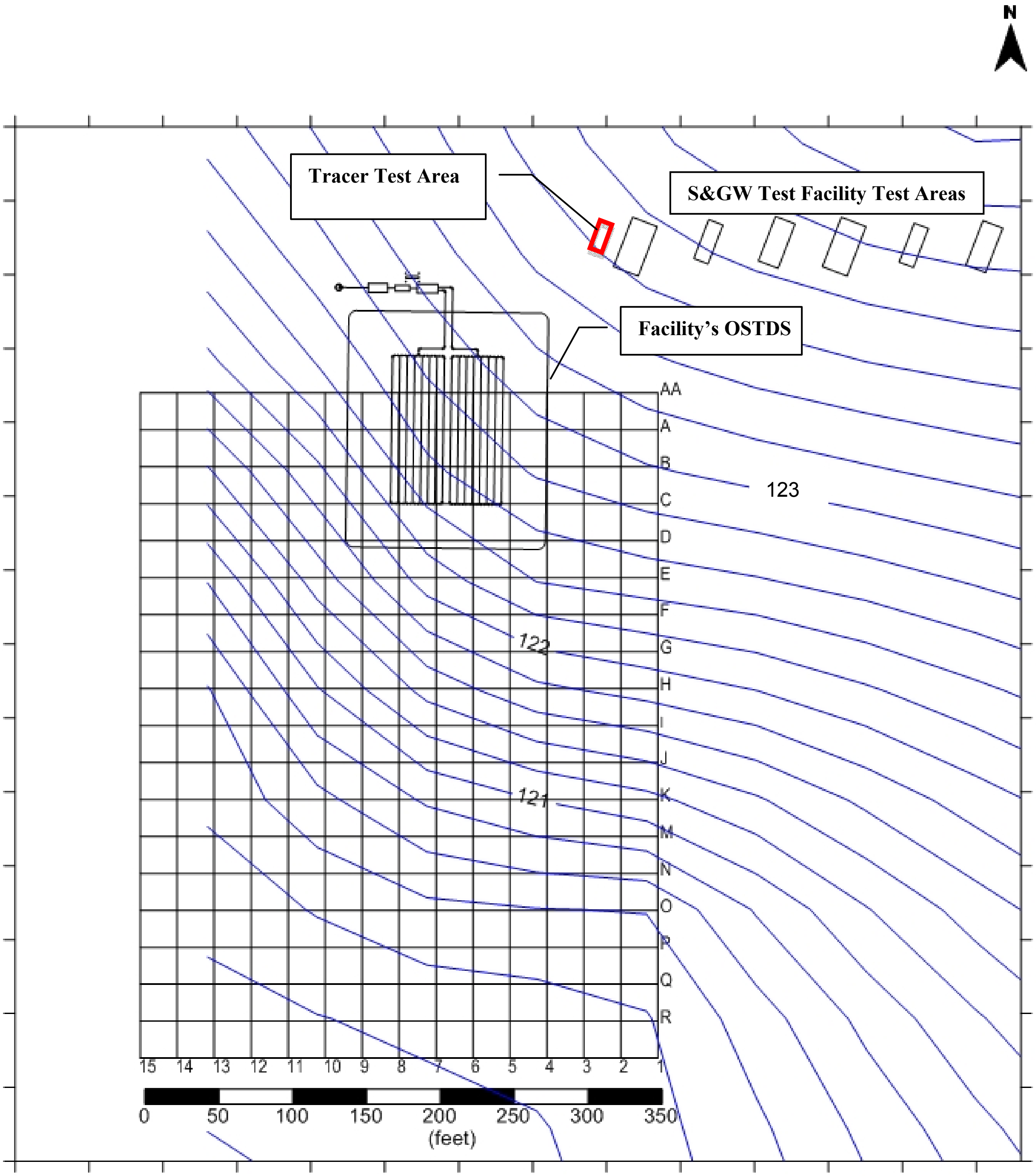

Figure 1
Schematic of S&GW test facility. The red box illustrates the location of the tracer test (Figure 2 illustrates a bigger picture of the same area). Groundwater contours were created from readings taken October 10, 2011.

Prior to designing the test, the approximate direction of the groundwater flow was determined for the S&GW test facility area (Figure 1) based on groundwater elevations in piezometers surrounding the site. The groundwater elevations have been monitored over several months, and although the groundwater elevations have been found to fluctuate due to periods of dry weather and/or heavy precipitation, routine monitoring of the groundwater elevations indicates that the general flow-path does not change significantly. Consequently, it was decided to deliver the tracer solution to a drip irrigation bed (tracer dose area) oriented roughly parallel to the groundwater flow (Figure 1). The tracer dose area was equivalent in size to one-third of the 20 ft by 2 ft S&GW pilot-scale test areas. The dose area was therefore approximately 6.67 ft long (parallel to flow) and 2 ft wide (perpendicular to flow). Four pressure compensating drip tubing lines were placed directly on the natural ground surface. The drip lines were covered with approximately a 4 in layer of sand. The drip lines were arranged with 8 in spacing between the lines and the drip emitters located at 2 ft intervals (Figure 2) for tracer dosing.

A 1 ft by 1 ft sampling grid for groundwater screening was developed downgradient of the tracer dose area. Transect lines Row 0 through Row 12 are parallel to the southern edge of the area and increase (higher number identification) moving southward from the dose area. Transect lines A through P (from east to west) are perpendicular to the southern edge of the dose area. The standpipe piezometers (monitoring wells) were installed using hand methods. Monitoring wells were constructed of 1-in diameter PVC and consisted of a 5 ft, 0.010 in well screen connected to a 5 ft section of PVC riser to bring the wells above ground surface (Figure 3). The monitoring wells were installed approximately 7.25 ft below the natural ground surface into the spodic horizon approximately 6 inches.

The tracer loading rate was designed to be the same loading as the pilot-scale test areas which used the maximum allowable loading rate for sandy soils of 0.8 gal per day per sqft., resulting in a daily flow of 32 gal per day over the 2 ft by 20 ft infiltrative area. Therefore, the loading rate to the 1/3 scale tracer test area was 10.7 gal per day. The drip emitters discharge tracer solution at a rate of 0.6 gal per hour. A 15 minute dose, 6 times a day was therefore planned to deliver the design loading rate at the same frequency as the S&GW test areas. Two-hundred gallons of tracer solution was prepared in a 250-gallon tank positioned adjacent to the trench (Figure 4) and was enough volume to dose tracer solution for approximately 18 days at the design loading rate.

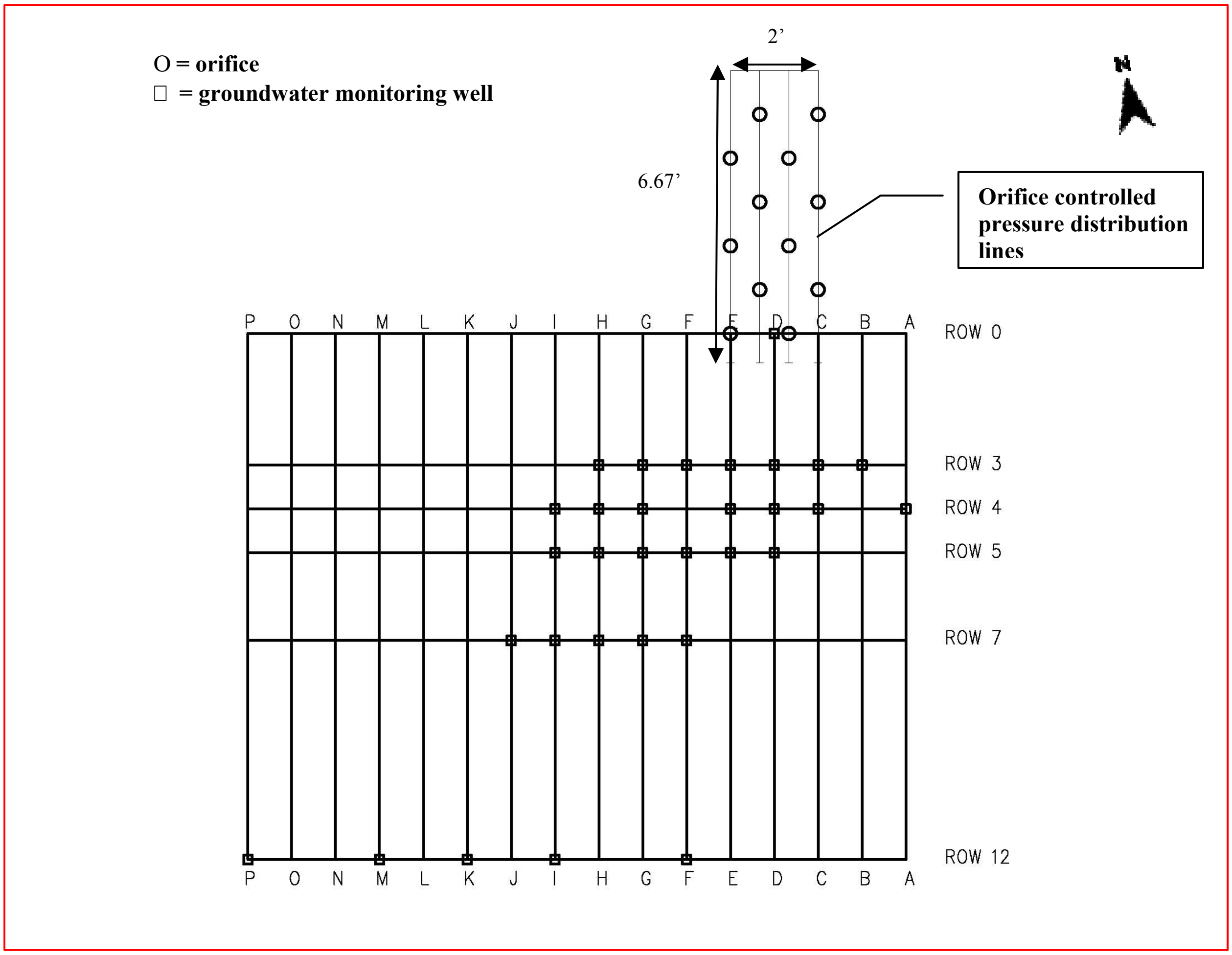

Figure 2

Enlarged schematic illustrating the area of the tracer test

Figure 3
Tracer test area with initial wells installed downgradient

Figure 4
The 250-gallon tank containing the tracer solution, dosing pump on top of tank

3.2 Tracer Solution and Standards

Tracers are usually chemical or radioactive compounds that flow in a fluid phase without altering the transport properties of the phase. Bromide (Br^-) was chosen as the most appropriate tracer as it is conservative, and thus representative of the water movement through soil (although some diffusion from mobile to immobile water may occur). A target bromide concentration of 1,500 ppm was selected to ensure detection of the tracer in downgradient locations. To prevent density profiles the solution was mixed onsite. A submersible pump to which a PVC stirring tree was attached was placed inside the 250-gallon tank to ensure that the solution was mixed during the experiment.

Four bromide detection probes were used during the test. Three submersible water quality sensor dataloggers (AquiStar TempHion smart sensors) were installed within various wells to continuously record the bromide concentration. In addition, a bromide ion selective electrode (ISE) connected to a pH/mV meter was used to analyze pumped samples. Seven bromide standards (ranging from 10 ppm to 10,000 ppm) were prepared prior to the start of the tracer test. The standards were used to create a calibration curve to which the ISE probe and datalogging sensors could be calibrated. The bromide standards were prepared using standard dilution as shown in Table 1. After the standards were prepared, each was measured with the ISE probe. The resulting readings (in mV) for the standards are shown in Table 2, and the calibration curve associated with the standards is illustrated in Figure 5.

Table 1. Stock preparation method

CONCENTRATION	DILUTION	PREPARATION
10,000 ppm = A	1:1	14.8 g of KBr in 1,000 mL
5,000 ppm	1:2	250 mL of A plus 250 mL DI in 500 mL flask
1,000 ppm	1:10	50 mL of A plus 450 mL DI in 500 mL flask
500 ppm	1:20	25 mL of A plus 475 mL DI in 500 mL flask
100 ppm	1:100	5 mL of A plus 495 mL DI in 500 mL flask
50 ppm	1:200	2.5 mL of A plus 497.5 mL DI in 500 mL flask
10 ppm	1:1000	0.5 mL of A plus 499.5 mL DI in 500 mL flask

DI = deionized water

Dilution factor expressed as: volume of analyte: total volume

Table 2. The mV equivalent for the six standards.

Bromide Stock	Br Concentration
(mV)	(ppm)
108.4	10
74.8	50
63.5	100
23.9	500
4.2	1,000
-35.7	5,000

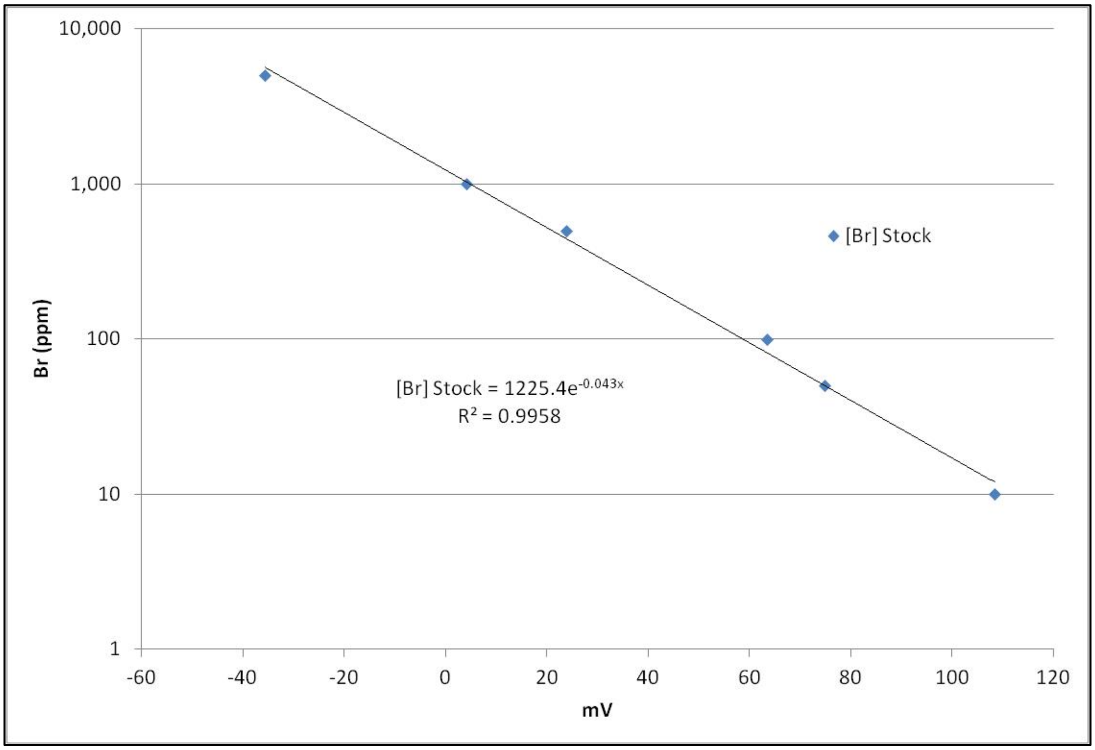

Figure 5
Bromide calibration curve – ISE probe

3.3 Pumped Sample Analysis

Groundwater samples were collected using ¼ in diameter dedicated linear low density polyethylene tubing in each monitoring well and a peristaltic pump. A very low flow rate was used to minimize flow into the well during sampling. The tubing was first purged (approximately 200 mL), and then groundwater was collected in a 100 mL beaker. A 10 mL sample was taken from the beaker using a pipette and placed in a 50 mL beaker, and 2 mL of 5M $NaNO_3$ ion strength adjustment solution (ISA) was added to each sample. A bromide ISE probe connected to a pH/mV meter or ion meter was used to measure the mV of the tracer solution. In addition, the concentration of the bromide solution in the 250-gallon tank was measured prior to and during the tracer test to ensure proper mixing of the solution.

3.4 Submersible Sensors

The three AquiStar^{TM} submersible water quality sensor dataloggers were initially calibrated and installed within the wells at grid locations 0D, 3D and 4D. The sensors were set to record the bromide concentration every 15 minutes. Following detection in the pumped samples, the sensors were moved to the well grid locations within the anticipated peak concentration flow path.

4.0 Results

4.1 Bromide Breakthrough Curves

The tracer test was started at the GCREC S&GW field site on November 9, 2011. Bromide tracer solution samples collected from the 250 gallon storage tank were sent for analyses in a NELAC certified laboratory (Appendix A) to confirm the bromide concentration as summarized in Table 3. The average bromide concentration of the tracer dose solution was 1,260 ppm. Tank samples analyzed in the field using the bromide ISE sometimes differed considerably from the laboratory results. Although the ISE probe was calibrated daily, it was not temperature compensating, and it is believed that changes in temperature were the cause of the differences. The laboratory results are therefore the most accurate.

Table 3. Bromide solution within dose tank laboratory results

Date	Time Sample Collected	Laboratory Result Bromide Concentration (ppm)
11/9/2011	7:59	1,200
11/9/2011	13:35	1,300
11/9/2011	16:10	1,300
11/10/2011	16:15	1,300
11/11/2011	9:45	1,200
Average		1,260

Following five days of tracer dosing, the bromide solution within the tank was nearly empty. It appeared that the tank solution was siphoning through the pump and the drip emitters; therefore, the test area had been dosed continuously since start-up. On November 14th, the tracer solution tank was completely empty (after 120 hours of dosing), and the actual tracer test loading was calculated to be approximately 36.1 gal per day instead of the 10.7 gal per day intended. Following the tracer dosing, the tank was cleaned and filled with clean water, and clean water was then dosed continuously to the test area through December 17, 2011 (for 784 hours) at the same loading rate as the tracer solution.

4.2 Unsaturated Zone Transport

An analysis of the initial bromide datalogger data at location 0D provides an opportunity to evaluate the unsaturated zone travel time since this monitoring point was directly below an emitter as depicted in Figure 6. Figure 7 is the breakthrough curve generated for this location. The bromide tracer breakthrough (103 ppm Br) started approximately 180 hours after the initial tracer dose. The peak bromide concentration (1,192 ppm Br) occurred 308 hours after the tracer dosing. At the start of the test, the groundwater elevation was approximately five feet below the natural grade. Therefore, the unsaturated zone travel time was approximately 0.4 to 0.7 ft per day under the hydraulic loading conditions studied.

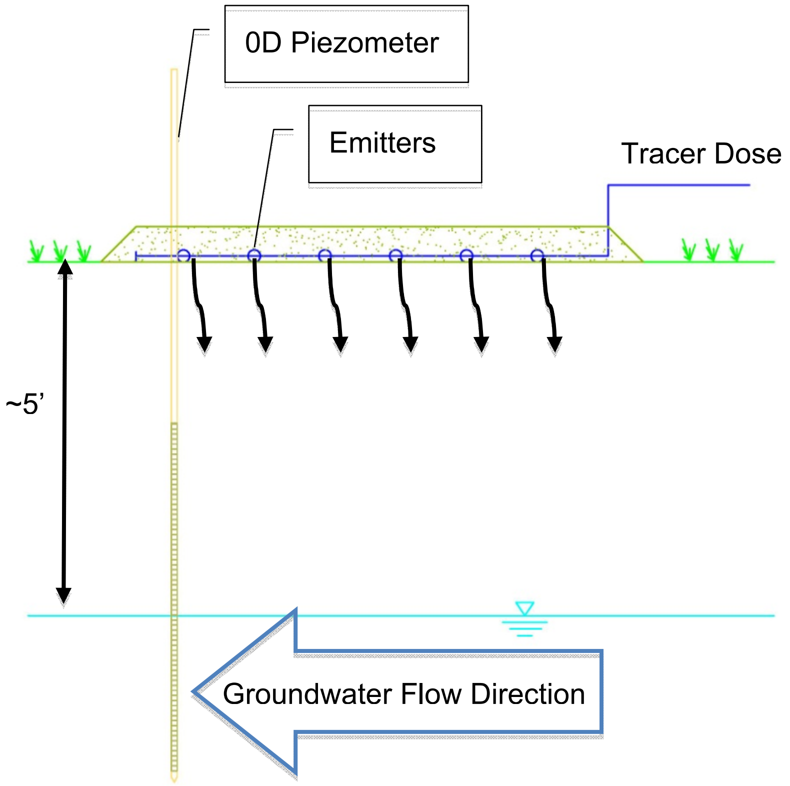

Figure 6
Cross Section of Tracer Test Area

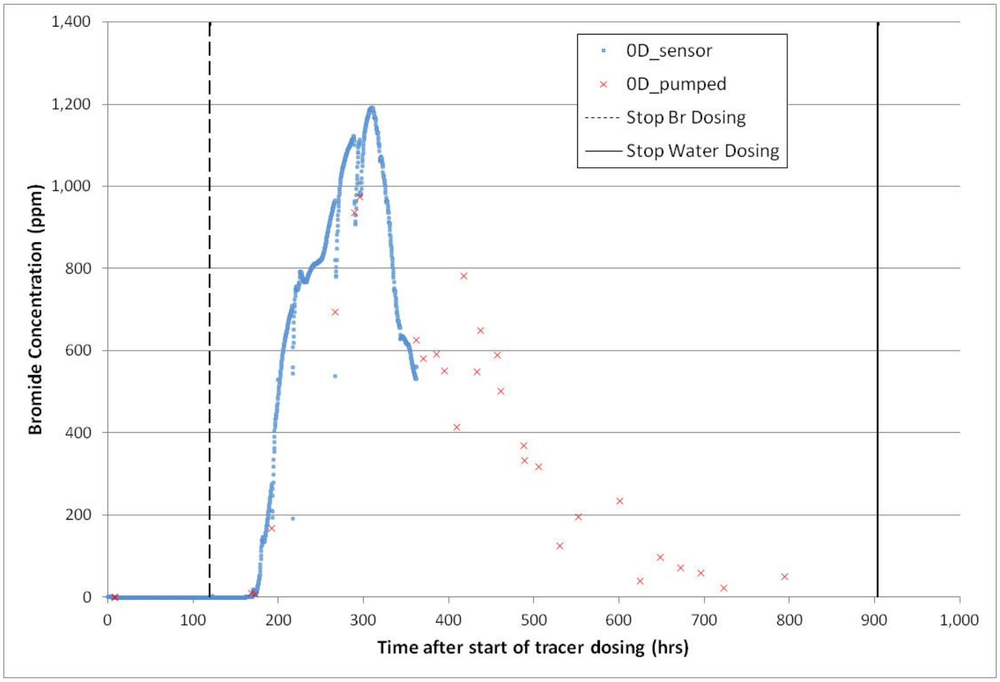

Figure 7
Piezometer 0D Breakthrough Curve

4.3 Groundwater Transport

Pumped samples were collected starting with the closest well to the test area and continuing with those placed further away. The sampling interval was initially three times per day (morning, noon and evening). To allow for a better visualization of the pumped data collected at the site, the mapping program **Surfer** was utilized for each sample event. **Surfer** is a grid-based mapping program that interpolates irregularly spaced XYZ data into a regularly spaced grid. Although there are several methods used in Surfer to fill in areas where data is missing, the Kriging method output gave the most informative graphs for determining the general peak bromide concentration flow direction (Appendix B, Figures B-1 through B-30). Although these graphs illustrate bromide movement as one might expect, the area without monitoring wells on the left side of the graphs represent Kriging results from Surfer that are not well supported by field data. Nonetheless, the Surfer graphs in Appendix B depict the general flow path and time of peak bromide concentrations.

The graphs for time 312 hours (Figure 8) and time 552 hours (Figure 9) are presented here to illustrate this general flow path for the peak bromide concentration (Figure 10) which follows approximately grid locations 3G → 5H → 7I.

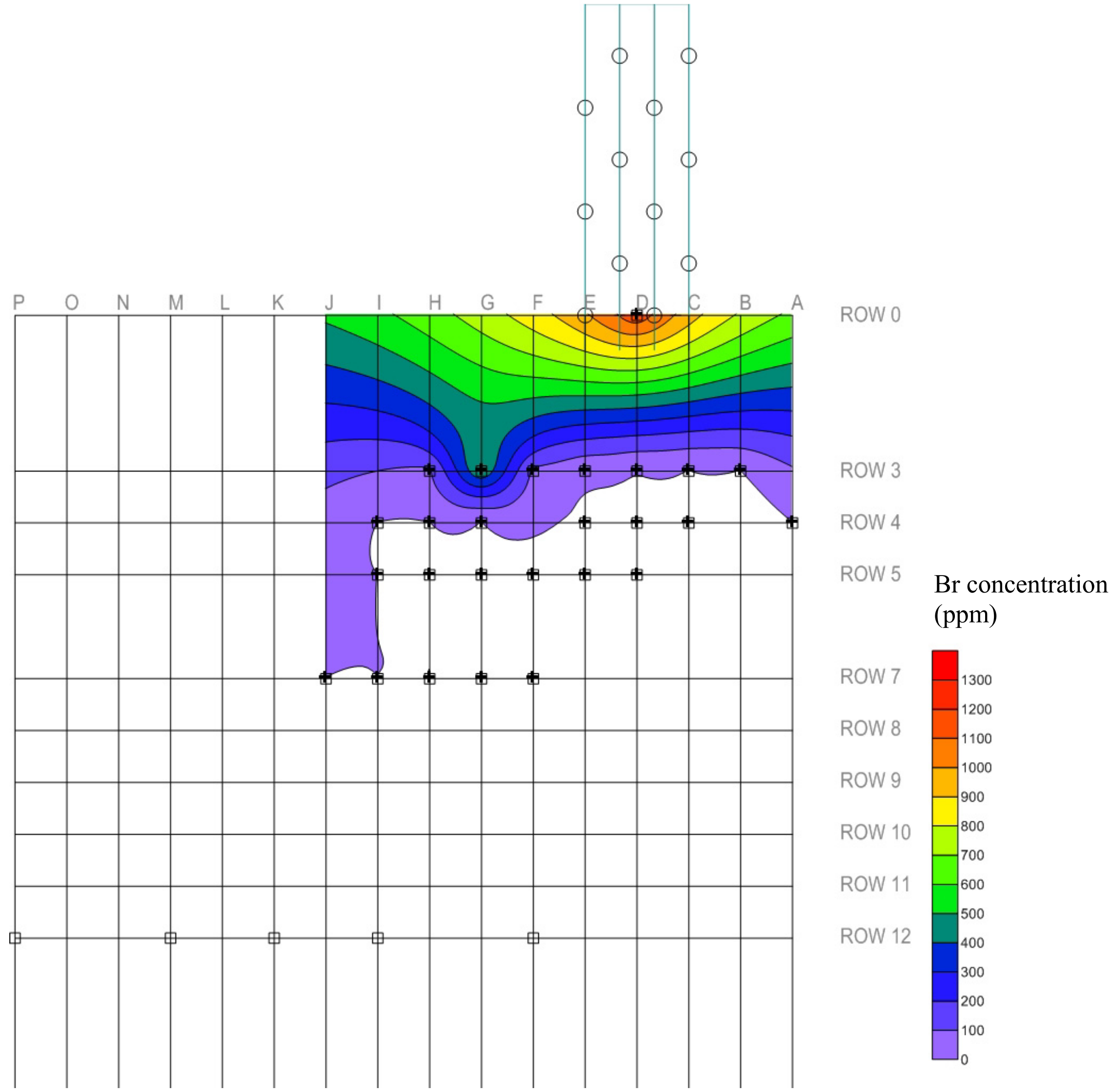

Figure 8
Time 312 hours, pumped samples
November 22nd 8am

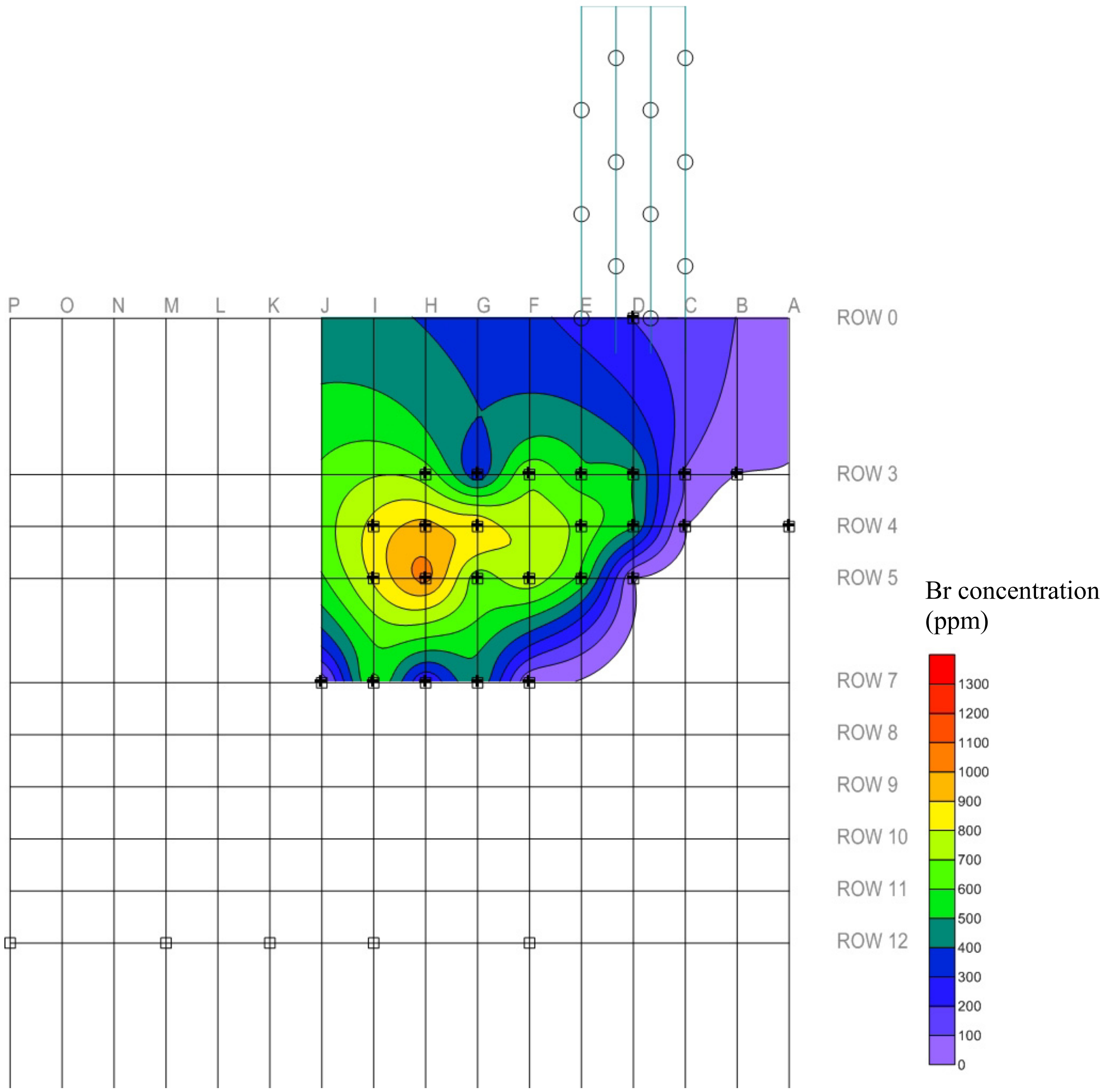

Figure 9
Time 552 hours, pumped samples
December 2nd 8am

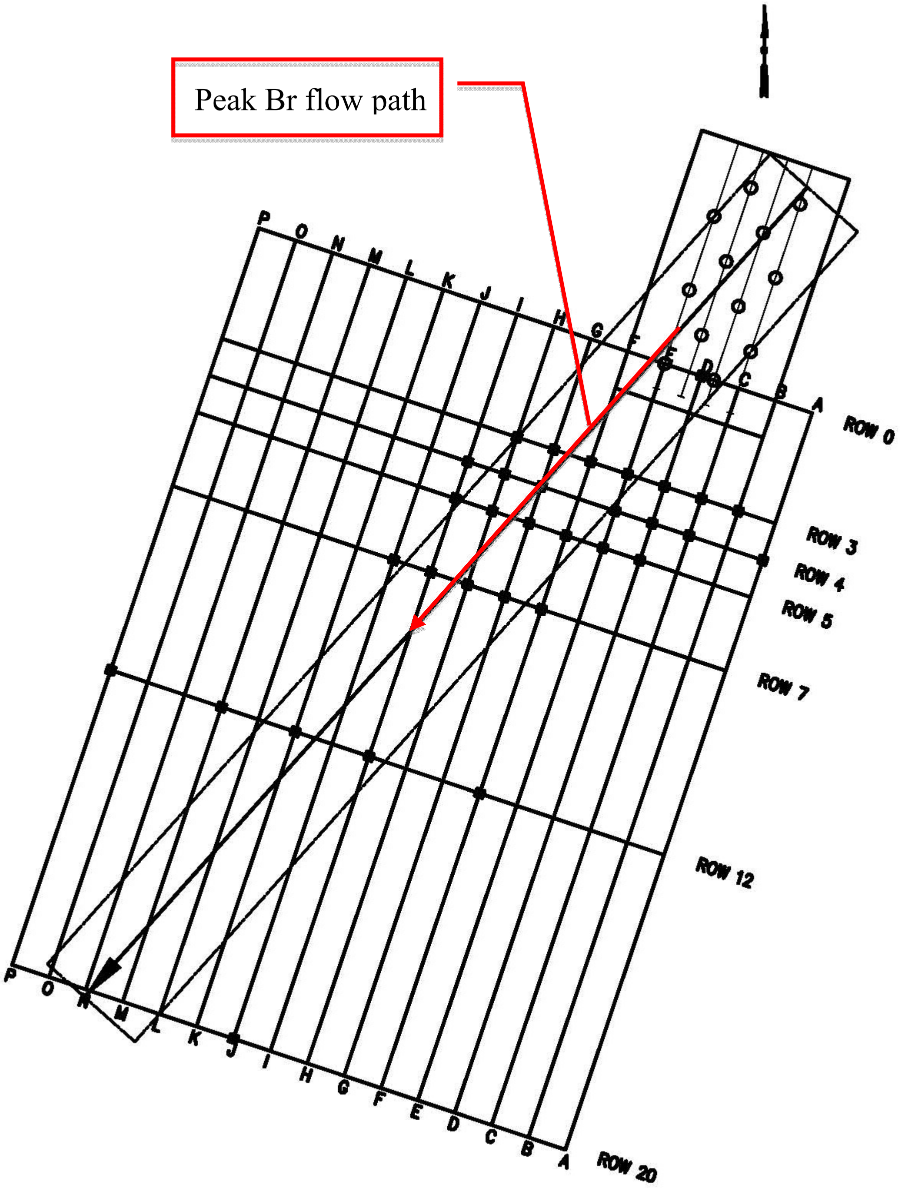

Figure 10
Approximate peak bromide concentration flow direction

Breakthrough curves were generated for each of the wells where a datalogging sensor was installed. Figure 11 illustrates several of these curves at key locations downgradient of the bromide dosing area.

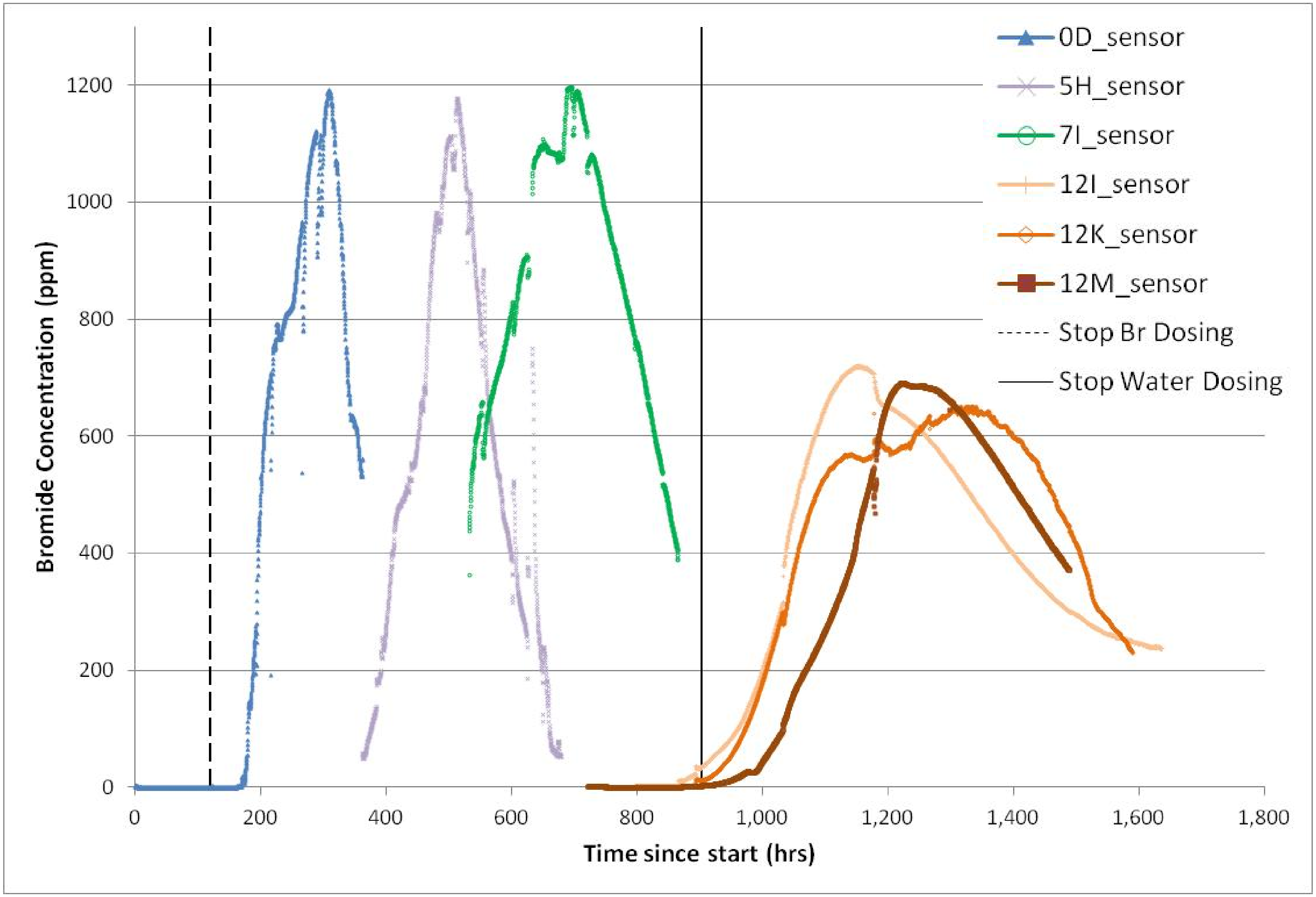

Figure 11
Breakthrough curves for wells, bromide sensor data

4.4 Groundwater Velocity and Hydraulic Conductivity Estimations

Various analytical methods are available for calculating the average interstitial velocity of groundwater flow. One approach in calculating the horizontal velocity is the empirical method where the distance is divided by the time of peak concentration occurrence (Table 4). During the 62-day period of bromide monitoring, the bromide plume moved horizontally away from the dosing area a distance of over 15 ft. Table 4 shows the calculated linear velocity in the area immediately downgradient of the dosing area. This velocity ranged from 0.21 to 0.64 ft per day with a median value of 0.30 ft per day. The velocity data show that the groundwater flow was faster near the source during dosing of tracer solution and water which is most likely attributed to a slightly increased gradient during dosing. Therefore, the further downgradient values in Table 4 are likely most representative of natural groundwater flow conditions at the time, and these values ranged from approximately 0.2 to 0.3 ft per day.

Table 4. Groundwater Velocity using Empirical Method

Peak to Peak Well Ids	X, distance (ft)	Peak concentration occurred (days between peaks)	Velocity (ft/day)
0D→5H	5.44	8.52	0.64
0D→7I	7.62	16.03	0.48
0D→12K	13.06	42.00	0.31
5H→7I	2.17	7.52	0.29
5H→12K	7.61	33.48	0.23
7I→12K	5.44	25.97	0.21
Median			0.30
Range			0.21 – 0.64

[1] Peak flow path generally follows 5H → 7I→ 12K

Huang (1991) presented an approach for one-dimensional tracer models using analytical solutions and the tracer breakthrough curve to calculate the average velocity. The following equations, developed by Huang (1991), were used to compare the peak 0D and 12M concentrations and travel time.

$$U_{max} = \frac{t_1 t_{max}}{t_{1-t_{max}}} ln \frac{C_1\sqrt{t_1}}{C_{max}\sqrt{t_{max}}}$$

$$V = \sqrt{\frac{2U_{max} - t_{max}}{2U_{max} - t_1} \frac{x}{t_{max}}}$$

$$D = \frac{x^2 - \mathrm{V}^2 t_{max}^2}{2t_{max}}$$

Where C_{max} is the max concentration and t_{max} is the time associated with C_{max}, C_1 is the concentration at time t_1, x is the distance to the tracer dose point, and V is the estimated average linear velocity. U_{max} is a calculated function relating tracer concentrations and travel times.

The tracer breakthrough and peak data for the 12M curve is summarized in Table 5. The estimated average horizontal groundwater linear velocity is 0.39 ft per day, which agrees well with the data in Table 4. The associated dispersion coefficient of the tracer is approximately 0.04 ft^2 per day.

Table 5. Breakthrough Curve Data

Well ID	t_1 Tracer breakthrough started (days after 0D peak)	C_1 Tracer breakthrough bromide concentration (ppm)	t_{max} Peak concentration occurred (days after 0D peak)	C_{max} Peak bromide concentration (ppm)	U_{max}	X distance from 0D (ft)	V Velocity (ft/day)	D Dispersion coefficient (ft^2/day)
12M	30.17	104.60	38.13	691.20	289.8	15.00	0.39	0.04

The saturated hydraulic conductivity, K_{sat}, can also be estimated from the tracer results using Darcy's law as follows:

$v = \frac{K_{sat} * gradient}{n_e}$, solving for K_{sat}

$$K_{sat} = \frac{v * n_e}{gradient}$$

where K_{sat} is the saturated hydraulic conductivity, and n_e is the effective porosity. Using the groundwater velocity determined from the breakthrough curve data (0.39 ft/day), the average hydraulic gradient across the tracer test area (0.0075), and an estimated effective porosity of 33%; the estimated saturated hydraulic conductivity is 17 ft per day. This agrees with slug testing conducted elsewhere at the GCREC mound site.

5.0 Summary

The results of the tracer testing will be used in evaluating the fate and transport of nitrogen at the soil and groundwater test facility. In addition, the data will be used in the development of the Task D models.

References

Huang, H., 1991. On a One-Dimensional Tracer Model. Ground Water 29 (1):18-20.

Toride, N., F.J. Leij, and M.T. Van Genuchten. (1995). *The CXTFIT code for estimating transport parameters from laboratory or field tracer experiments, Version 2.1.* Research Report No. 137. Prepared for US Salinity Laboratory, USDA, ARS, Riverside CA

Appendix A: Laboratory Results

SOUTHERN ANALYTICAL LABORATORIES, INC.
110 BAYVIEW BOULEVARD, OLDSMAR, FL 34677 813-855-1844 FAX 813-855-2218

Hazen and Sawyer
10002 Princess Palm Ave, Suite 200
Tampa, FL 33619

November 25, 2011
Work Order: 1110862

Laboratory Report

Project Name **GCREC Mound Groundwater Analyses**

Parameters	Units	Results *	Method	PQL	MDL	Prepared	Analyzed	By
Sample Description		**Tank Conc 1500ppm**						
Matrix		**Groundwater**						
SAL Sample Number		**1110862-01**						
Date/Time Collected		**11/09/11 07:59**						
Collected by		**Josephine Edeback-Hirst**						
Date/Time Received		**11/21/11 11:05**						
Inorganics								
Bromide	mg/L	1,200	EPA 300.0	0.20	0.040		11/23/11 17:07	MEJ
Sample Description		**Tank Conc 1500ppm**						
Matrix		**Groundwater**						
SAL Sample Number		**1110862-02**						
Date/Time Collected		**11/10/11 16:15**						
Collected by		**Josephine Edeback-Hirst**						
Date/Time Received		**11/21/11 11:05**						
Inorganics								
Bromide	mg/L	1,300	EPA 300.0	0.20	0.040		11/23/11 17:07	MEJ
Sample Description		**Tank Conc 1500ppm**						
Matrix		**Groundwater**						
SAL Sample Number		**1110862-03**						
Date/Time Collected		**11/09/11 16:10**						
Collected by		**Josephine Edeback-Hirst**						
Date/Time Received		**11/21/11 11:05**						
Inorganics								
Bromide	mg/L	1,300	EPA 300.0	0.20	0.040		11/24/11 01:20	MEJ
Sample Description		**3D Conc 0ppm**						
Matrix		**Groundwater**						
SAL Sample Number		**1110862-04**						
Date/Time Collected		**11/20/11 11:04**						
Collected by		**Josephine Edeback-Hirst**						
Date/Time Received		**11/21/11 11:05**						
Inorganics								
Bromide	mg/L	0.22	EPA 300.0	0.20	0.040		11/24/11 01:20	MEJ

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Laboratory Report

Project Name		**GCREC Mound Groundwater Analyses**						
Parameters	**Units**	**Results ***	**Method**	**PQL**	**MDL**	**Prepared**	**Analyzed**	**By**
Sample Description		**Tank Conc 1500ppm**						
Matrix		**Groundwater**						
SAL Sample Number		**1110862-05**						
Date/Time Collected		**11/09/11 13:35**						
Collected by		**Josephine Edeback-Hirst**						
Date/Time Received		**11/21/11 11:05**						
Inorganics								
Bromide	mg/L	1,300	EPA 300.0	0.20	0.040		11/24/11 01:20	MEJ
Sample Description		**OD Conc 10ppm**						
Matrix		**Groundwater**						
SAL Sample Number		**1110862-06**						
Date/Time Collected		**11/16/11 12:29**						
Collected by		**Josephine Edeback-Hirst**						
Date/Time Received		**11/21/11 11:05**						
Inorganics								
Bromide	mg/L	9.6	EPA 300.0	0.20	0.040		11/24/11 01:20	MEJ
Sample Description		**OD Conc 1000ppm**						
Matrix		**Groundwater**						
SAL Sample Number		**1110862-07**						
Date/Time Collected		**11/20/11 10:31**						
Collected by		**Josephine Edeback-Hirst**						
Date/Time Received		**11/21/11 11:05**						
Inorganics								
Bromide	mg/L	570	EPA 300.0	0.20	0.040		11/24/11 01:20	MEJ
Sample Description		**Tank Conc 1500ppm**						
Matrix		**Groundwater**						
SAL Sample Number		**1110862-08**						
Date/Time Collected		**11/11/11 09:45**						
Collected by		**Josephine Edeback-Hirst**						
Date/Time Received		**11/21/11 11:05**						
Inorganics								
Bromide	mg/L	1,200	EPA 300.0	0.20	0.040		11/24/11 01:20	MEJ

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Laboratory Report

Project Name		**GCREC Mound Groundwater Analyses**						
Parameters	**Units**	**Results ***	**Method**	**PQL**	**MDL**	**Prepared**	**Analyzed**	**By**
Sample Description		**OD Conc 250ppm**						
Matrix		**Groundwater**						
SAL Sample Number		**1110862-09**						
Date/Time Collected		**11/17/11 08:15**						
Collected by		**Josephine Edeback-Hirst**						
Date/Time Received		**11/21/11 11:05**						
Inorganics								
Bromide	mg/L	150	EPA 300.0	0.20	0.040		11/24/11 01:20	MEJ
Sample Description		**OD Conc 1000ppm**						
Matrix		**Groundwater**						
SAL Sample Number		**1110862-10**						
Date/Time Collected		**11/18/11 08:17**						
Collected by		**Josephine Edeback-Hirst**						
Date/Time Received		**11/21/11 11:05**						
Inorganics								
Bromide	mg/L	340	EPA 300.0	0.20	0.040		11/24/11 01:20	MEJ

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Inorganics - Quality Control

Analyte	Result	PQL	MDL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit
Batch BK12302 - Ion Chromatography 300.0 Prep										
Blank (BK12302-BLK1)					Prepared & Analyzed: 11/23/11					
Bromide	0.040 U	0.20	0.040	mg/L						
LCS (BK12302-BS1)					Prepared & Analyzed: 11/23/11					
Bromide	7.24	0.20	0.040	mg/L	7.5		97	85-115		
LCS Dup (BK12302-BSD1)					Prepared & Analyzed: 11/23/11					
Bromide	7.22	0.20	0.040	mg/L	7.5		96	85-115	0.3	200
Matrix Spike (BK12302-MS1)		**Source: 1110504-02**			Prepared & Analyzed: 11/23/11					
Bromide	7.03	0.20	0.040	mg/L	7.5		94	85-115		
Matrix Spike (BK12302-MS2)		**Source: 1110862-02**			Prepared & Analyzed: 11/23/11					
Bromide	2,050	0.20	0.040	mg/L	750	1330	96	85-115		
Batch BK12303 - Ion Chromatography 300.0 Prep										
Blank (BK12303-BLK1)					Prepared & Analyzed: 11/24/11					
Bromide	0.040 U	0.20	0.040	mg/L						
LCS (BK12303-BS1)					Prepared & Analyzed: 11/24/11					
Bromide	7.27	0.20	0.040	mg/L	7.5		97	85-115		
LCS Dup (BK12303-BSD1)					Prepared & Analyzed: 11/24/11					
Bromide	7.36	0.20	0.040	mg/L	7.5		98	85-115	1	200
Matrix Spike (BK12303-MS1)		**Source: 1110341-01**			Prepared & Analyzed: 11/24/11					
Bromide	73.9	0.20	0.040	mg/L	75	1.55	96	85-115		

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Inorganics - Quality Control

Analyte	Result	PQL	MDL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit
Batch BK12303 - Ion Chromatography 300.0 Prep										
Matrix Spike (BK12303-MS2)		**Source: 1110562-01**			Prepared & Analyzed: 11/24/11					
Bromide	73.6	0.20	0.040	mg/L	75	1.65	96	85-115		

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* Qualifiers, Notes and Definitions

Results followed by a "U" indicate that the sample was analyzed but the compound was not detected. Results followed by "I" indicate that the reported value is between the laboratory method detection limts and the laboratory practical quantitation limit.

A statement of estimated uncertainty of test results is available upon request.

For methods marked with **, all QC criteria have been met for this method which is equivalent to a SAL certified method.

Test results in this report meet all the requirements of the NELAC standards. Any applicable qualifiers are shown below.
Questions regarding this report should be directed to Client Services at 813-855-1844.

SOUTHERN ANALYTICAL LABORATORIES, INC.
110 BAYVIEW BOULEVARD, OLDSMAR, FL 34677 813-855-1844 fax 813-855-2218

SAL Project No. 1110862

Project 44237-001 Task 300

Client Name: Hazen and Sawyer

Contact / Phone: 813-630-449P

Project Name / Location: GCREC - Bromide Tracer Wimauma, FL

Turn Around Time Requested (*Surcharges may apply) 24 Hour* ☐ 48 Hour* ☐ 5 Bus. Days* ☐ 10 Bus. Days ☐
↳ ASAP

Samplers: (Signature)

Matrix Codes:
DW-Drinking Water WW-Wastewater
SW-SurfaceWater SL-Sludge SO-Soil
GW-Groundwater SA-Saline Water O-Other
R-Reagent Water

PARAMETER / CONTAINER DESCRIPTION

SAL Use Only Sample No.	Sample Description	Date	Time	Matrix	Composite	Grab	Bromide Conc ~1500ppm	Bromide Conc ~0ppm	Bromide 10 Conc ~[illegible]ppm	Bromide Conc ~1000ppm	Bromide Conc ~250ppm					No. of Containers (Total per each location)
01	Tank	11/9/11	7:59	GW		✓	✓									
02	Tank	11/10/11	16:15	GW		✓	✓									
03	Tank	11/9/11	16:10	GW		✓	✓									
04	3D	11/20/11	11:04	GW		✓		✓								
05	Tank	11/9/11	13:35	GW		✓	✓									
06	OD	11/16/11	12:29	GW		✓			✓							
07	OD	11/20/11	10:31	GW		✓				✓						
08	Tank	11/11/11	9:45	GW		✓	✓									
09	OD	11/17/11	8:15	GW		✓					✓					
10	OD	11/18/11	8:17	GW		✓				✓						

Containers Prepared/ Relinquished:	Date/Time:	Received:	Date/Time:
Relinquished:	Date/Time: 11/21/11	Received:	Date/Time: 11-21-11
Relinquished:	Date/Time: 11-21-11	Received:	Date/Time:
Relinquished:	Date/Time:	Received:	Date/Time:
Relinquished:	Date/Time:	Received:	Date/Time:

Seal intact? Y N [✓ N/A]
Samples intact upon arrival? [✓ Y] N N/A
Received on ice? Temp______ [✓ Y] N N/A
Proper preservatives indicated? [✓ Y] N N/A
Rec'd within holding time? [✓ Y] N N/A
Volatiles rec'd w/out headspace Y N [✓ N/A]
Proper containers used? [✓ Y] N N/A

Instructions / Remarks

Chain of Custody.xls
Rev.Date 11/19/01

Chain of Custody

Appendix B: Pumped Sample Graphs

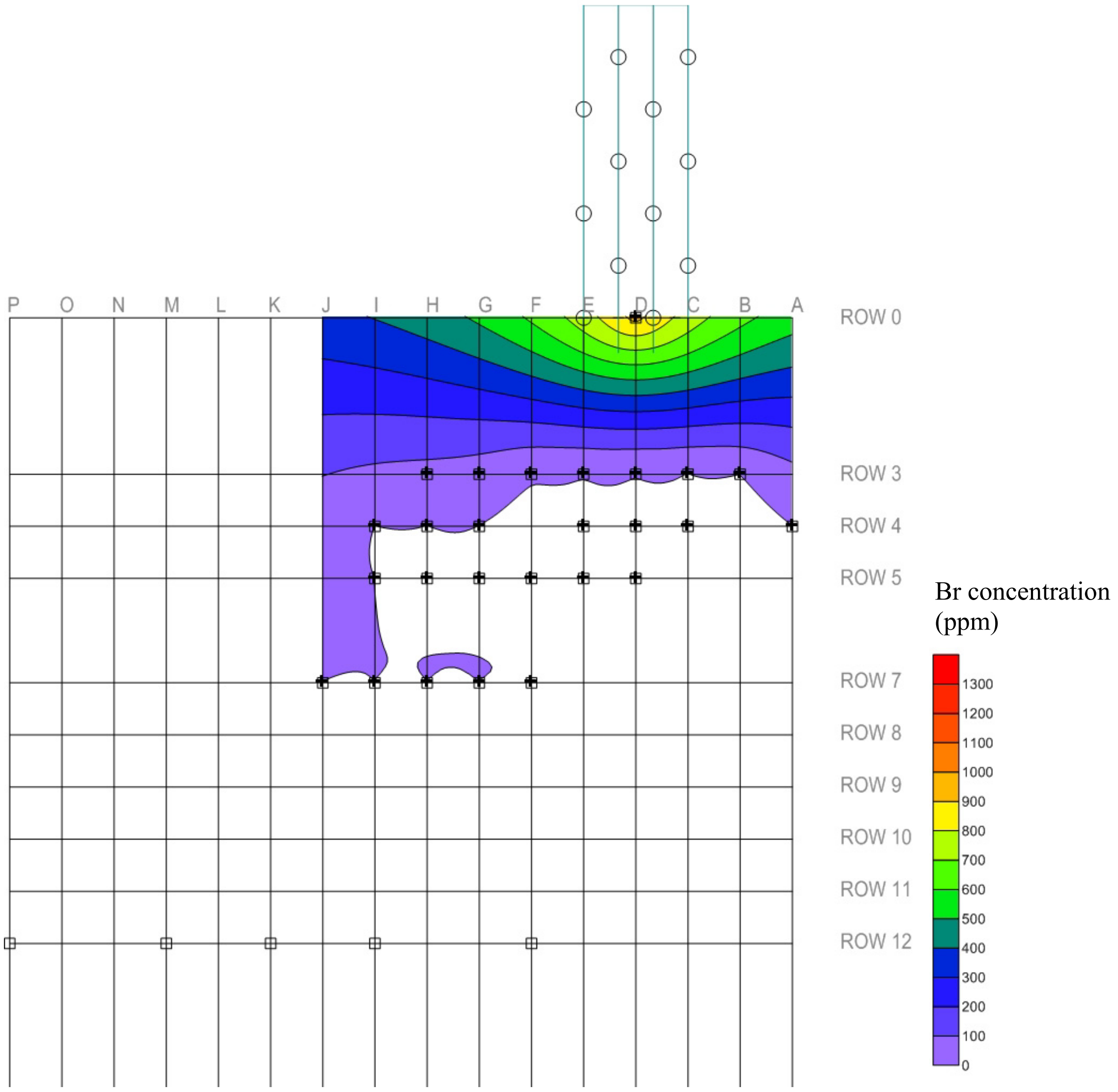

Figure A-1
November 21st 8am
288 hours, pumped samples

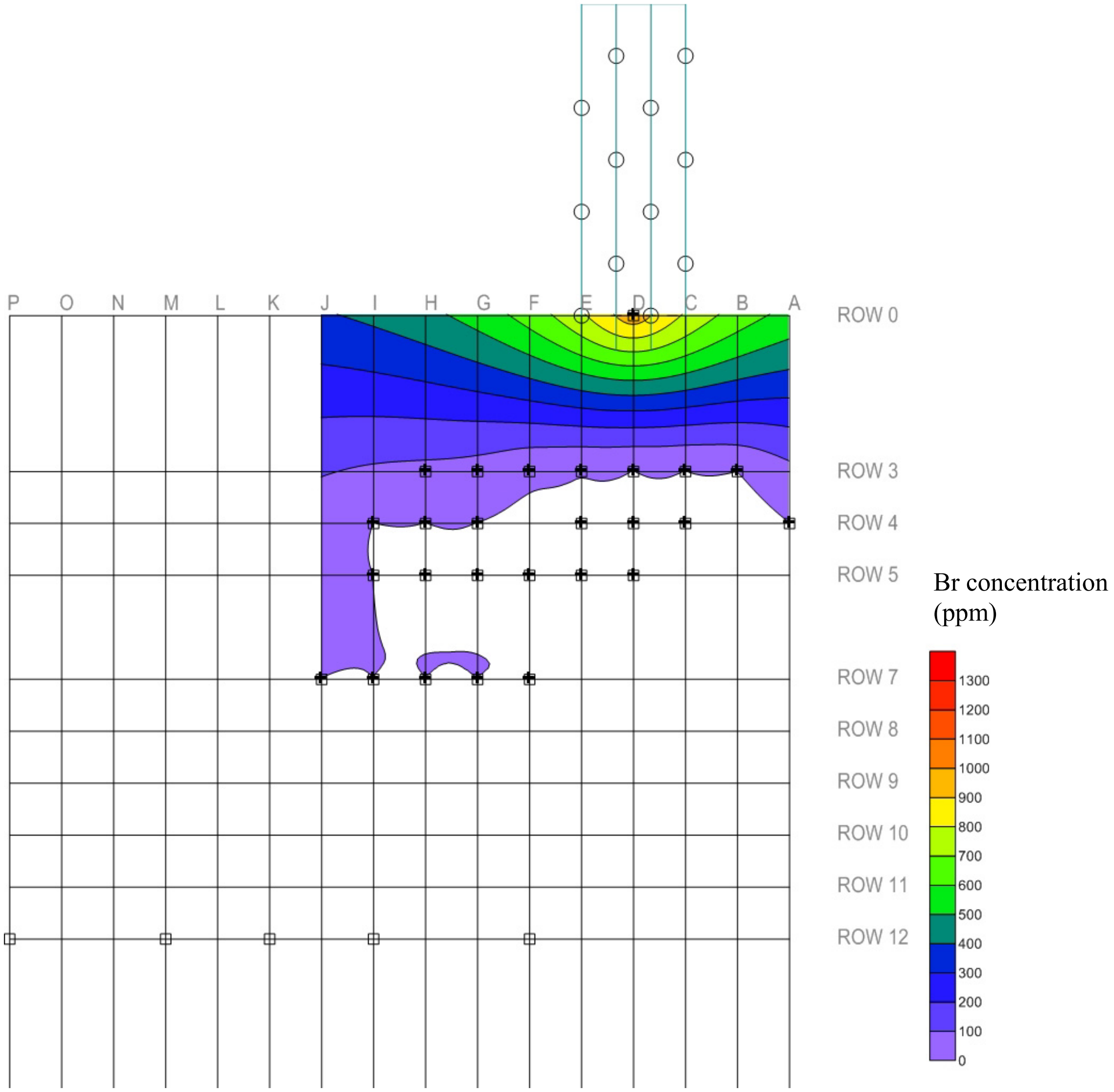

Figure A-2
November 21st 3pm
295 hours, pumped samples

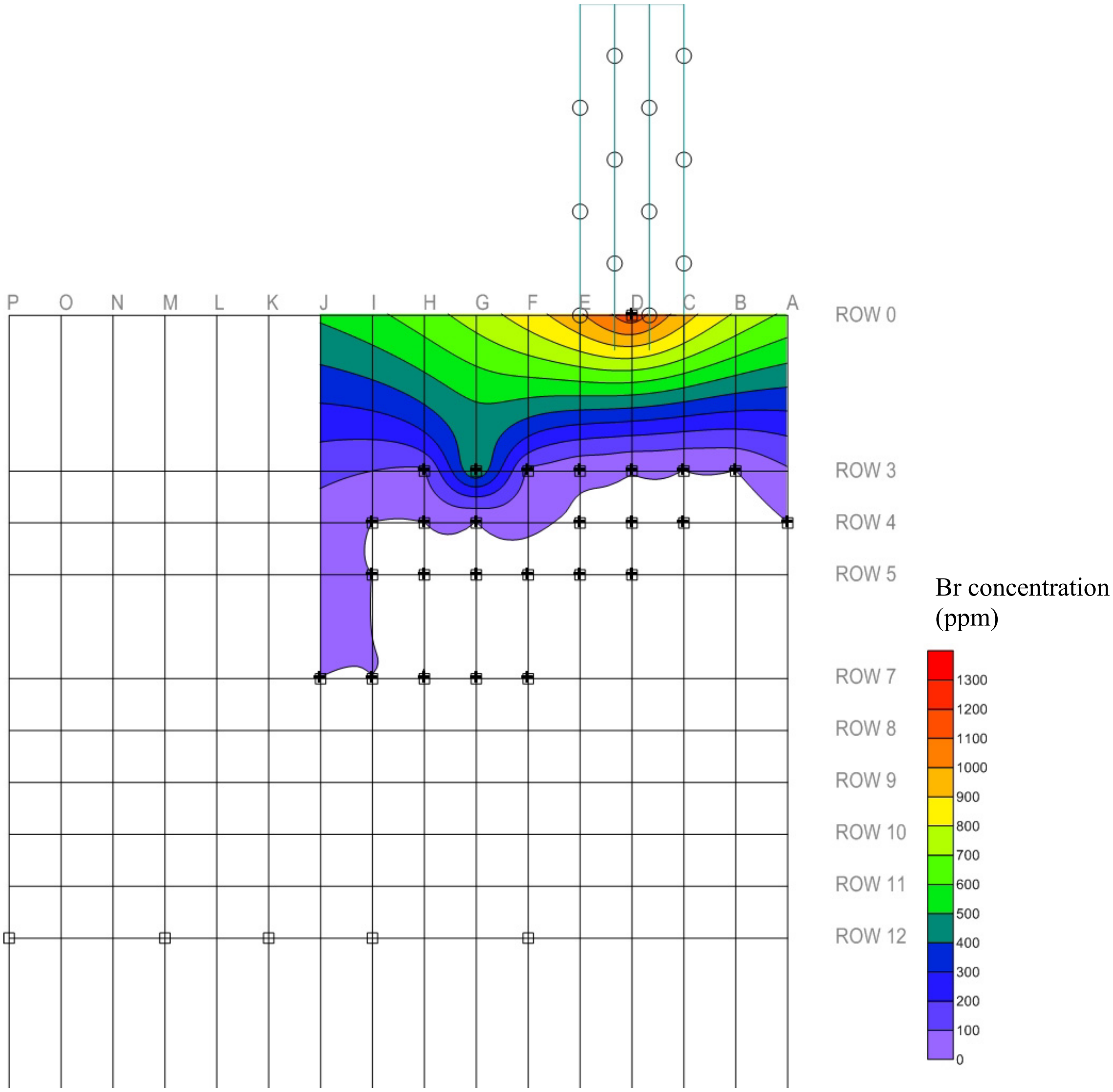

Figure A-3
November 22nd 8am
312 hours, pumped samples

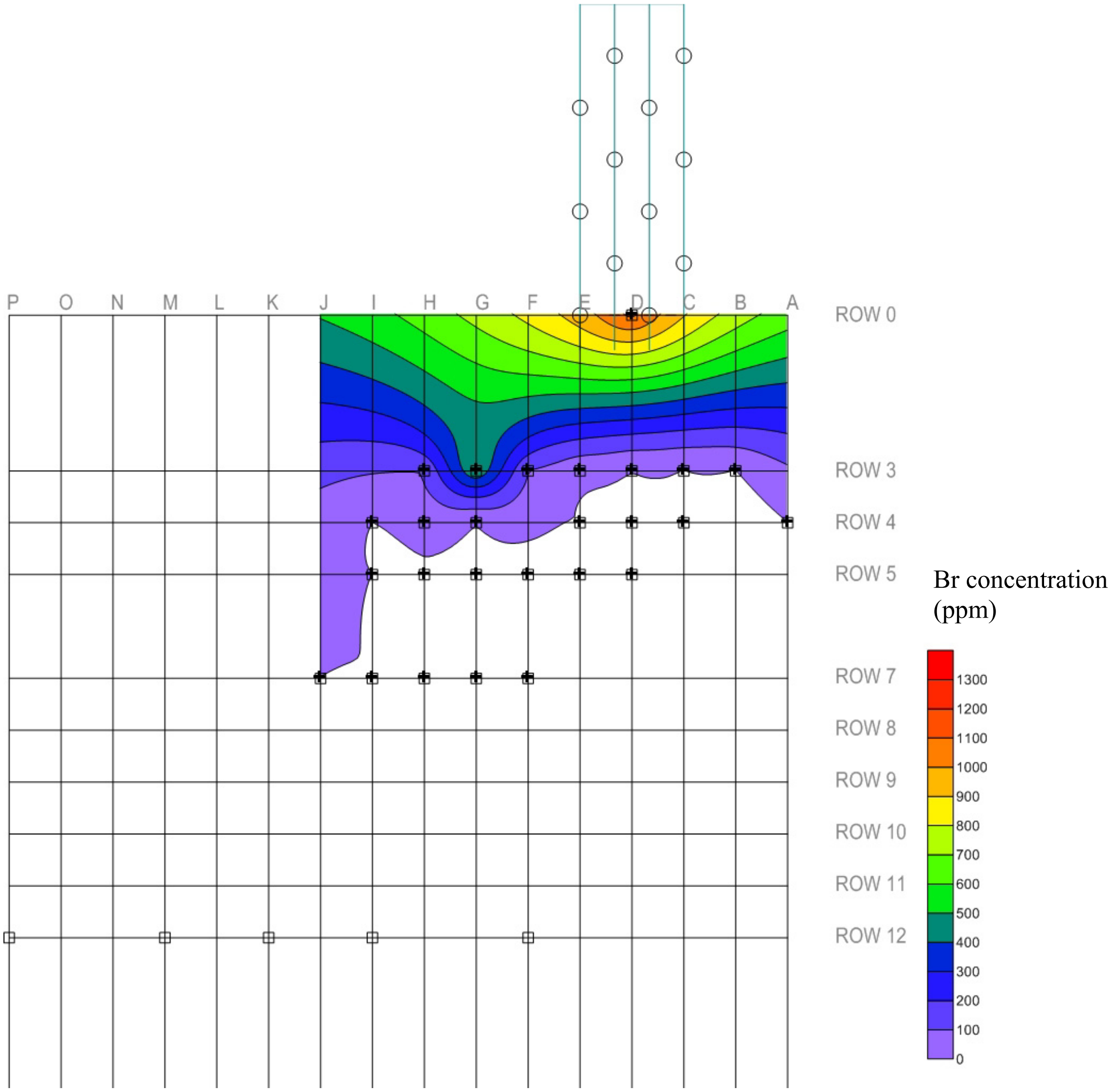

Figure A-4
November 22nd 12pm
316 hours, pumped samples

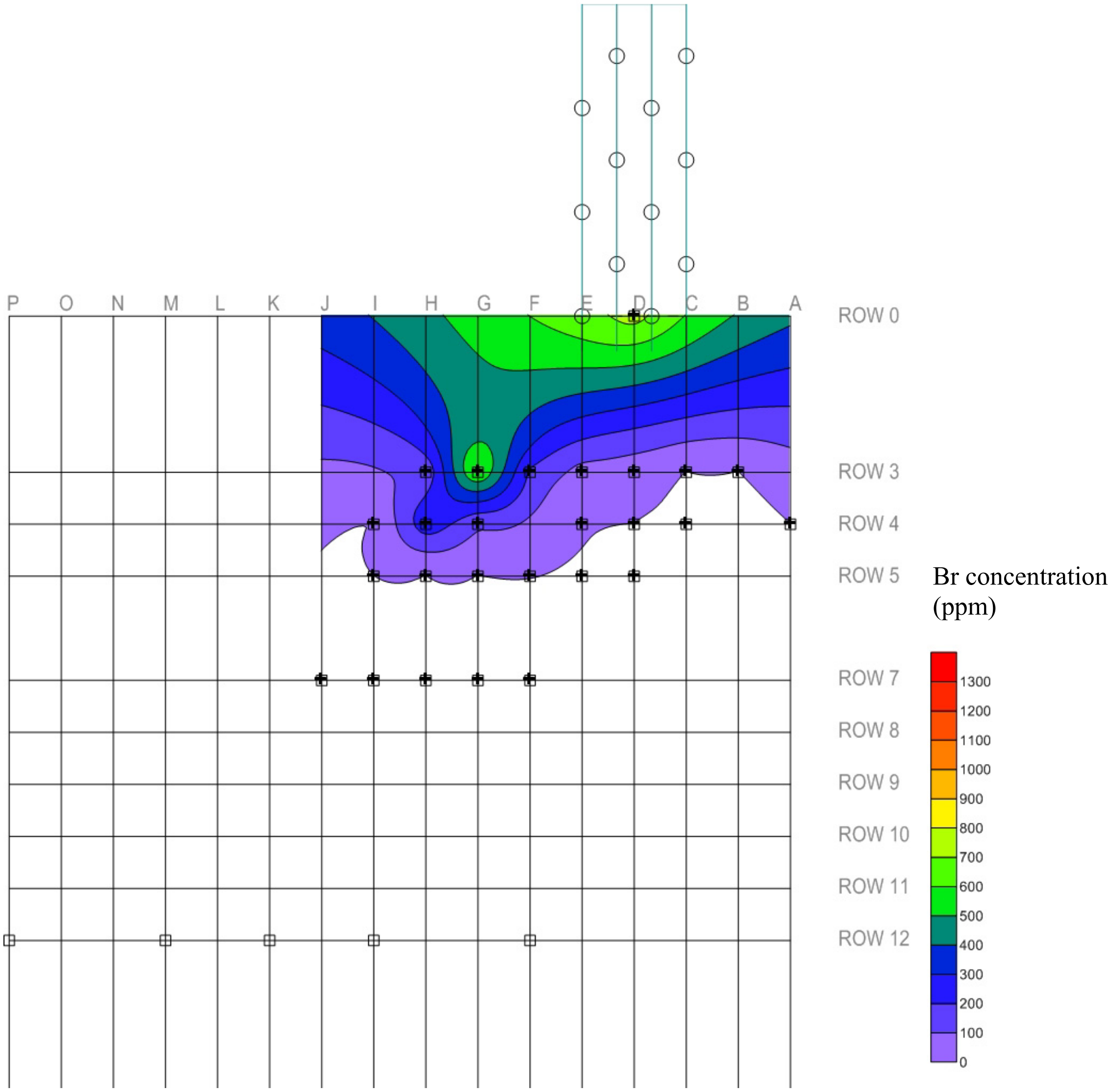

Figure A-5
November 23rd 8am
336 hours, pumped samples

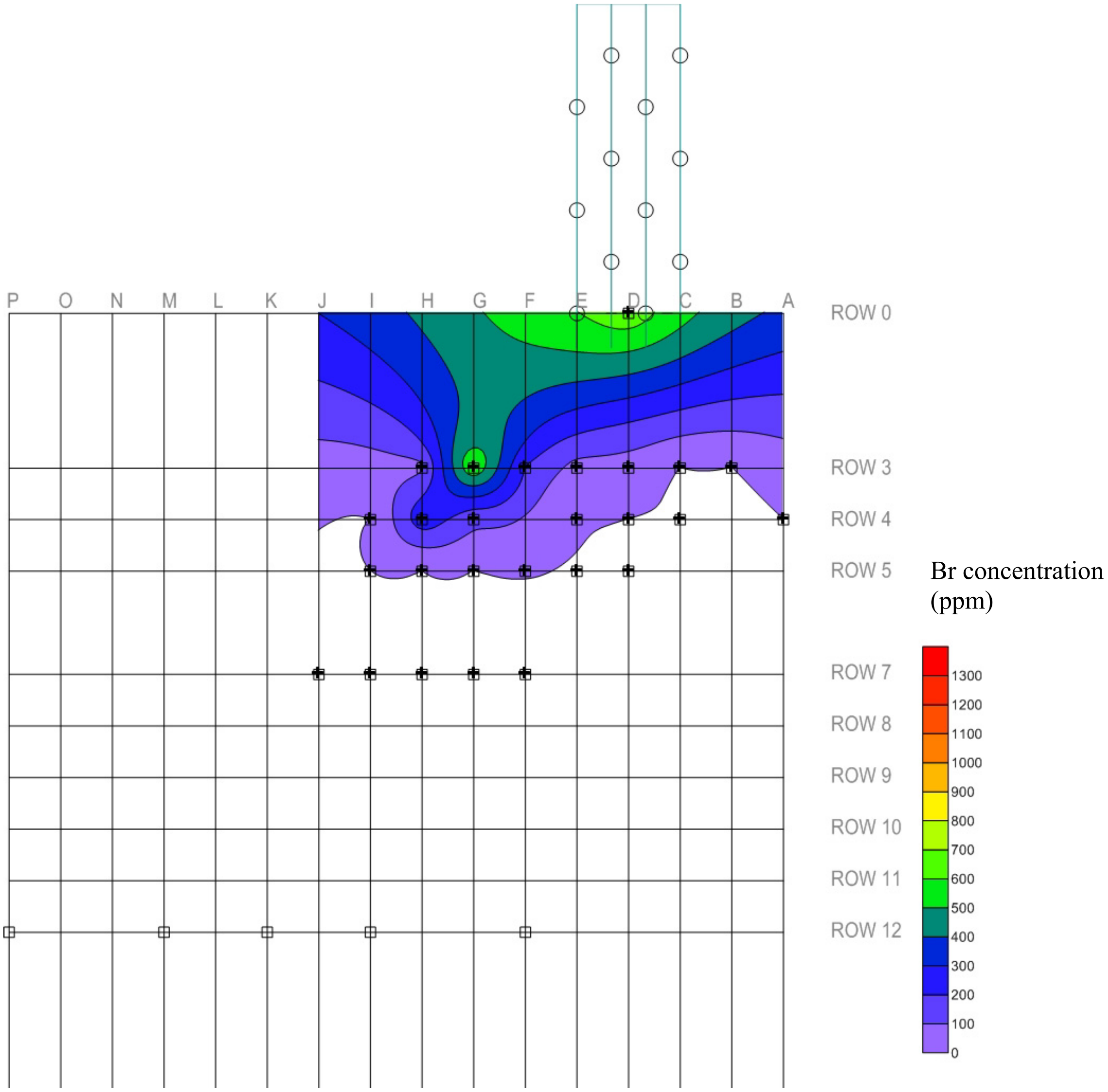

Figure A-6
November 23rd 12pm
340 hours, pumped samples

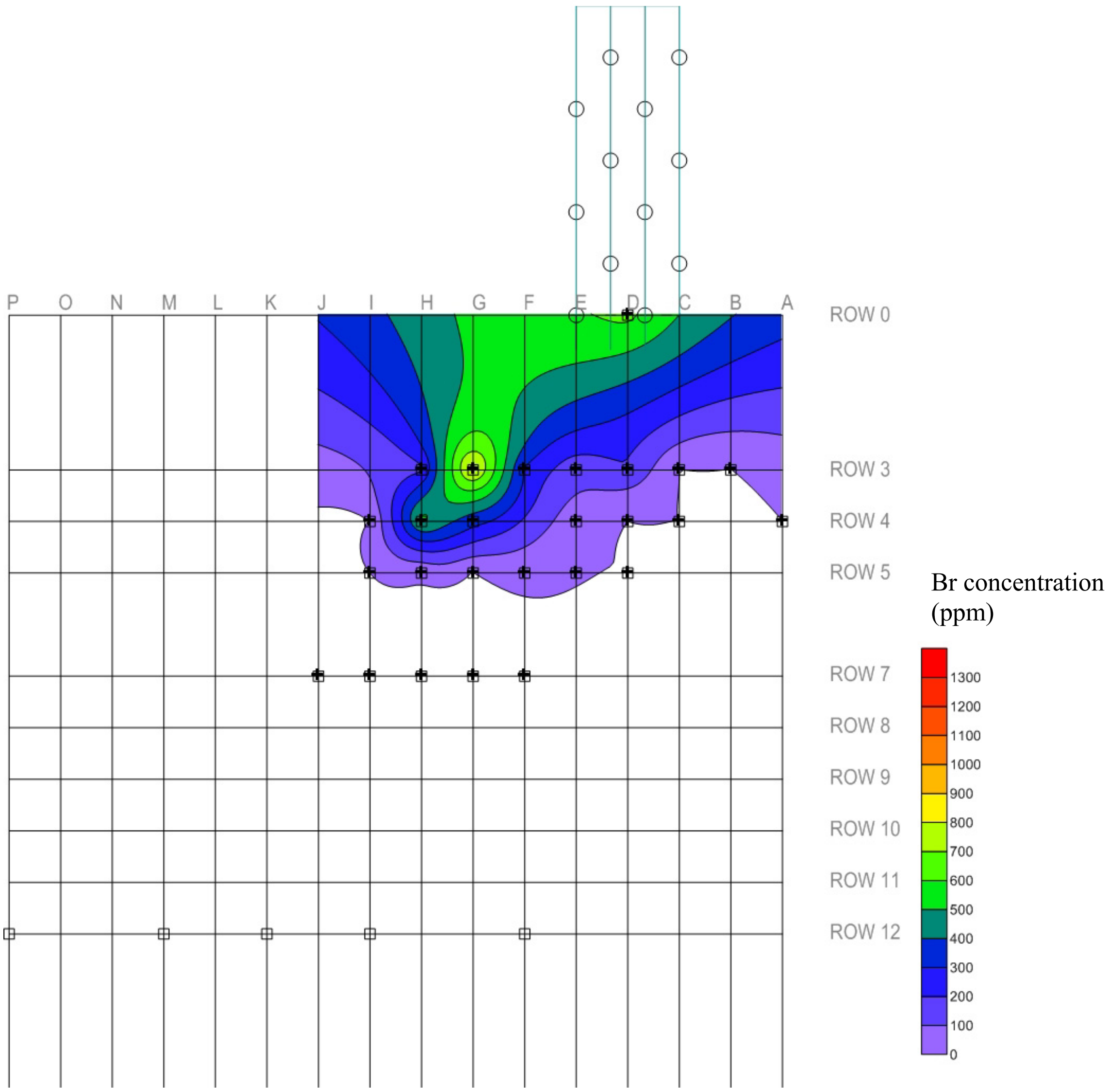

Figure A-7
November 24th 8am
360 hours, pumped samples

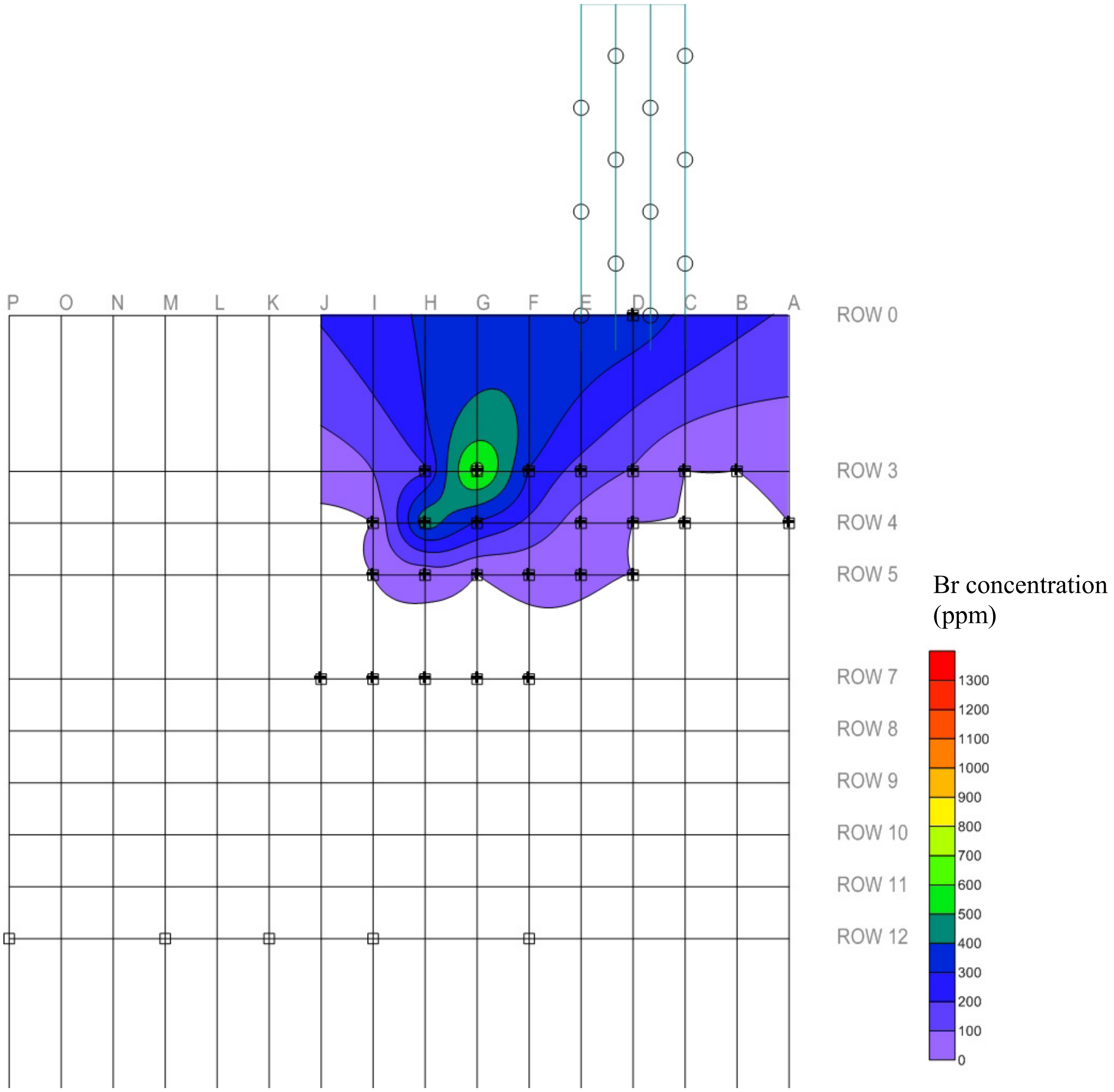

Figure A-8
November 24th 12pm
364 hours, pumped samples

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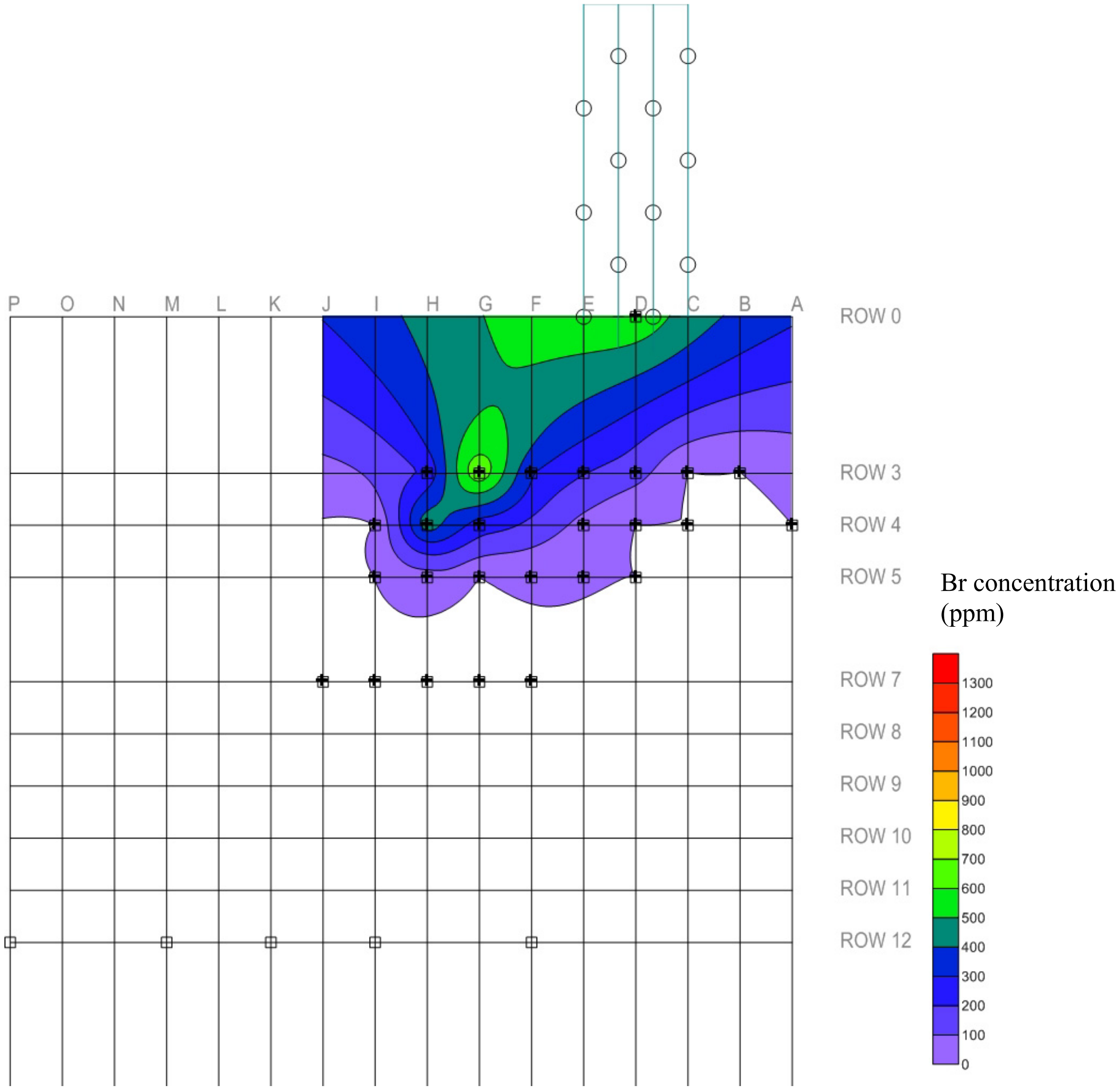

Figure A-9
November 24th 4pm
368 hours, pumped samples

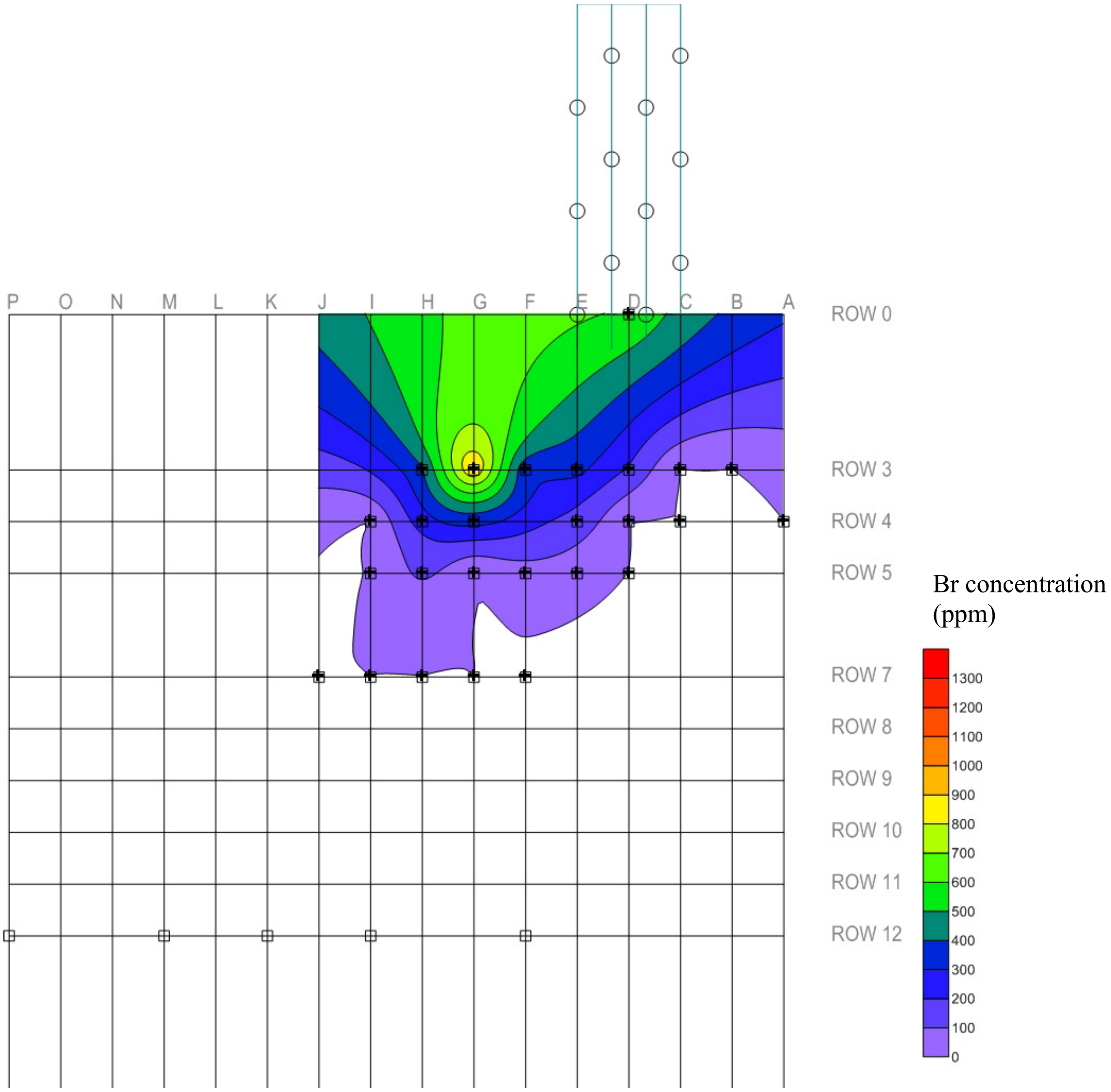

Figure A-10
November 25th 8am
384 hours, pumped samples

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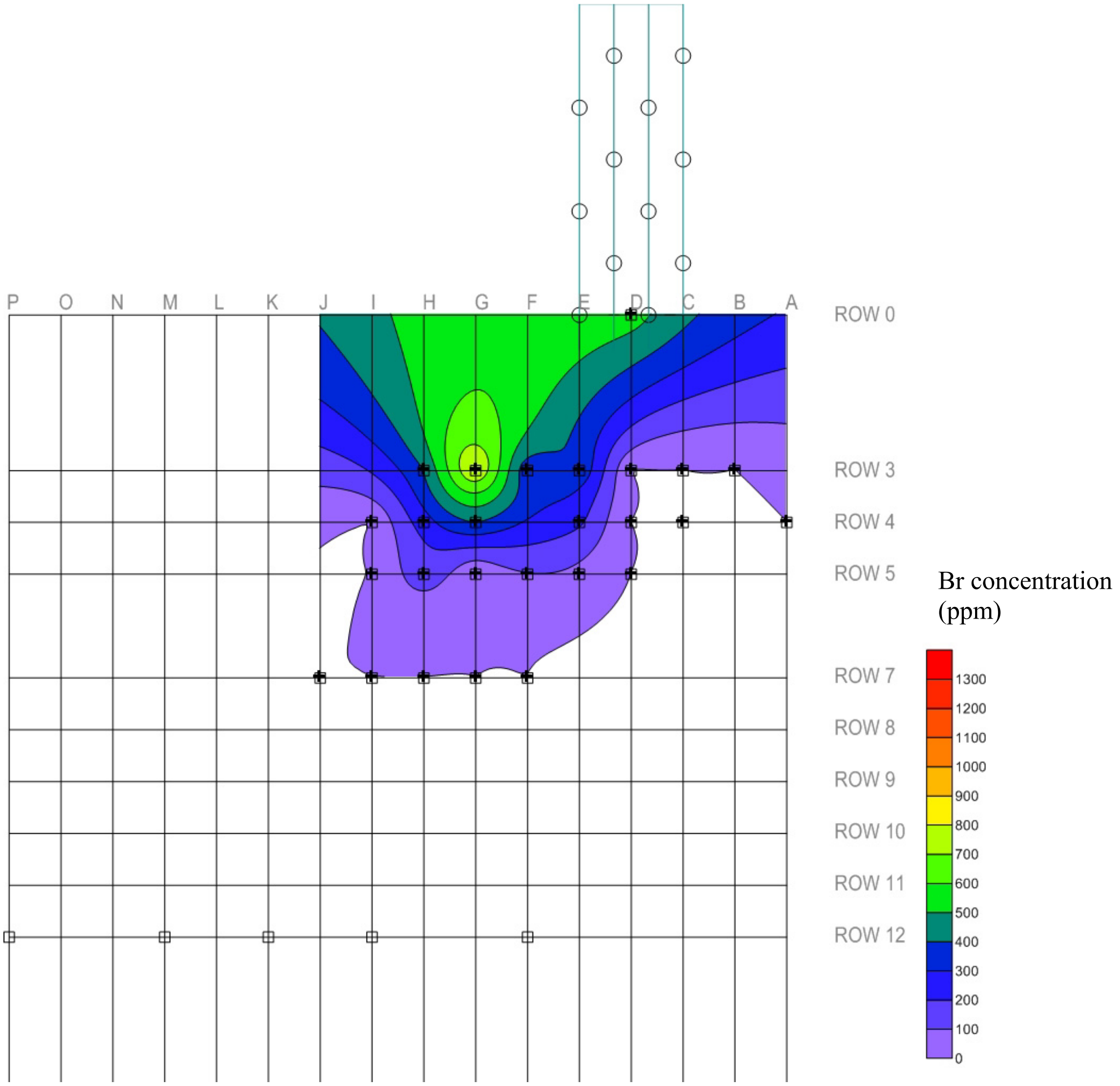

Figure A-11
November 25th 4pm
392 hours, pumped samples

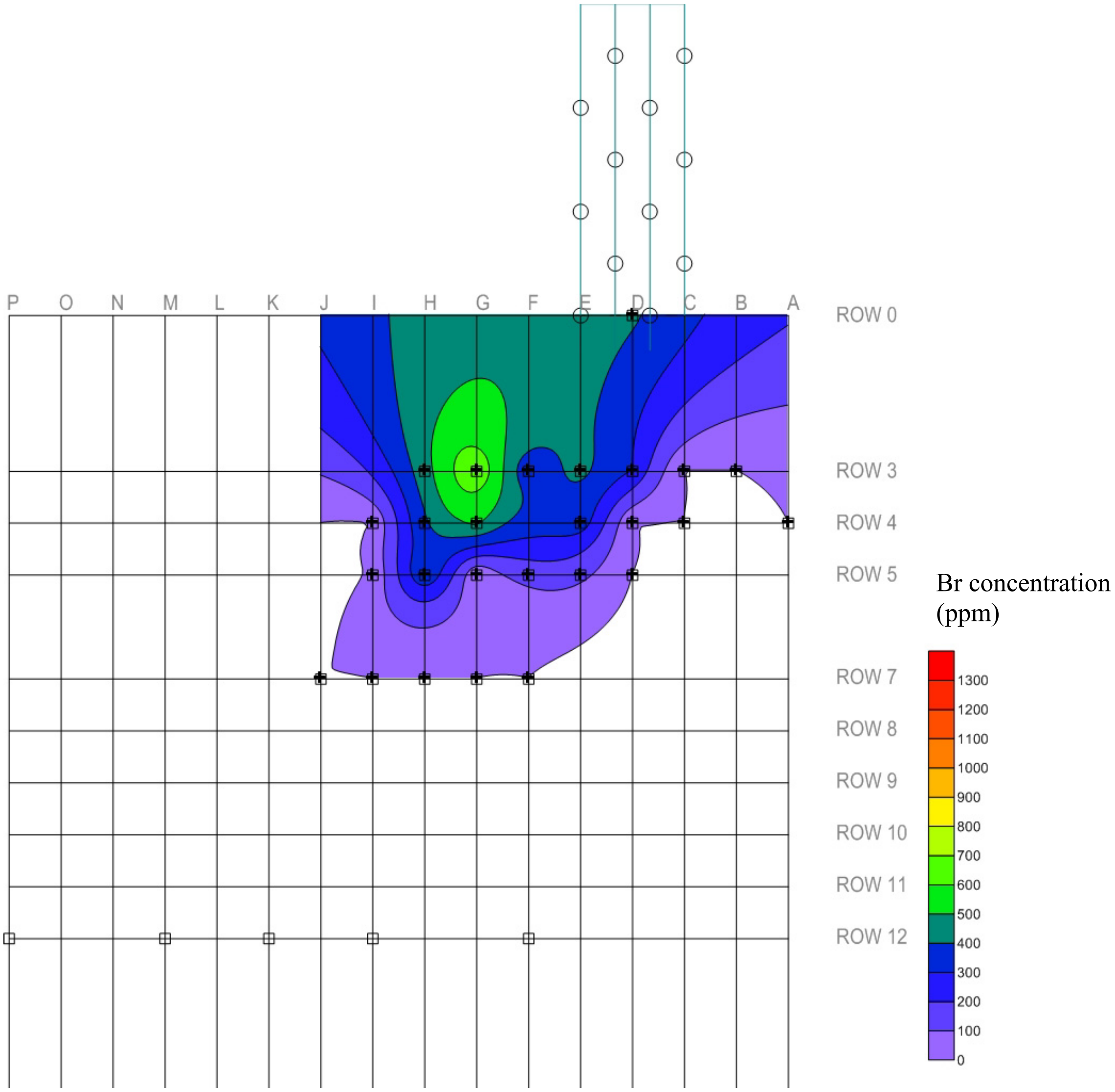

Figure A-12
November 26th 8am
408 hours, pumped samples

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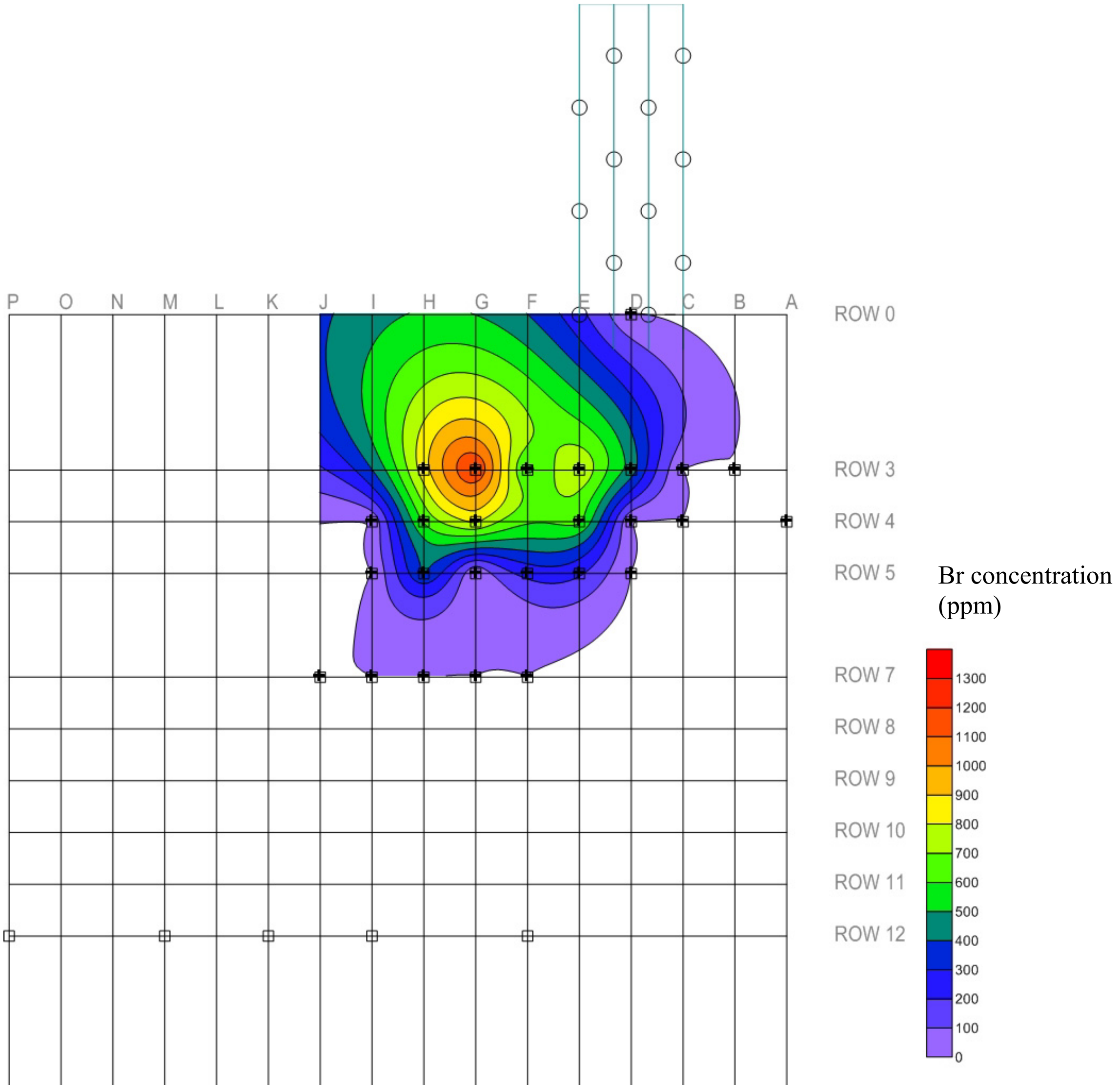

Figure A-13
November 26th 12pm
412 hours, pumped samples

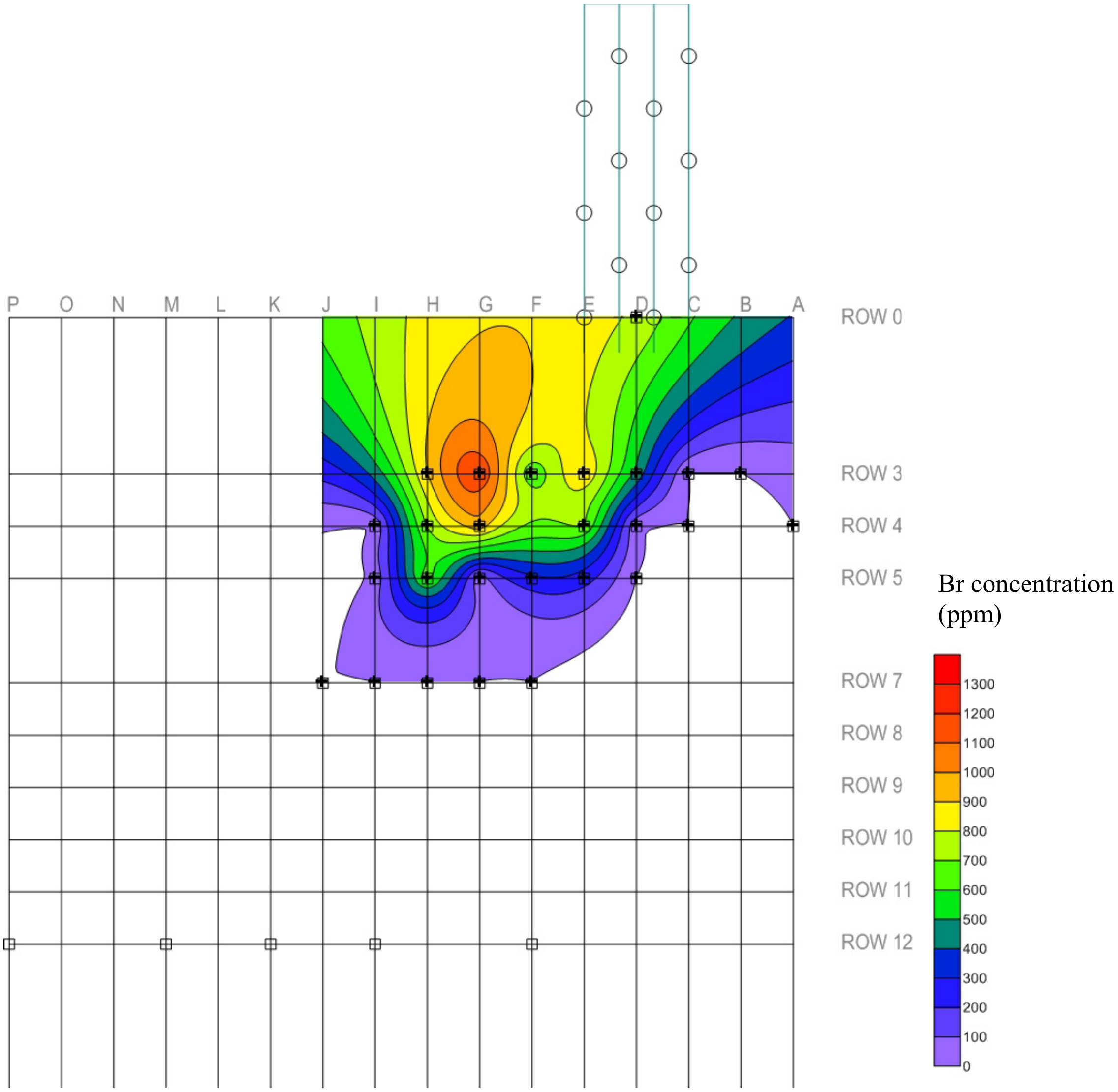

Figure A-14
November 26th 4pm
416 hours, pumped samples

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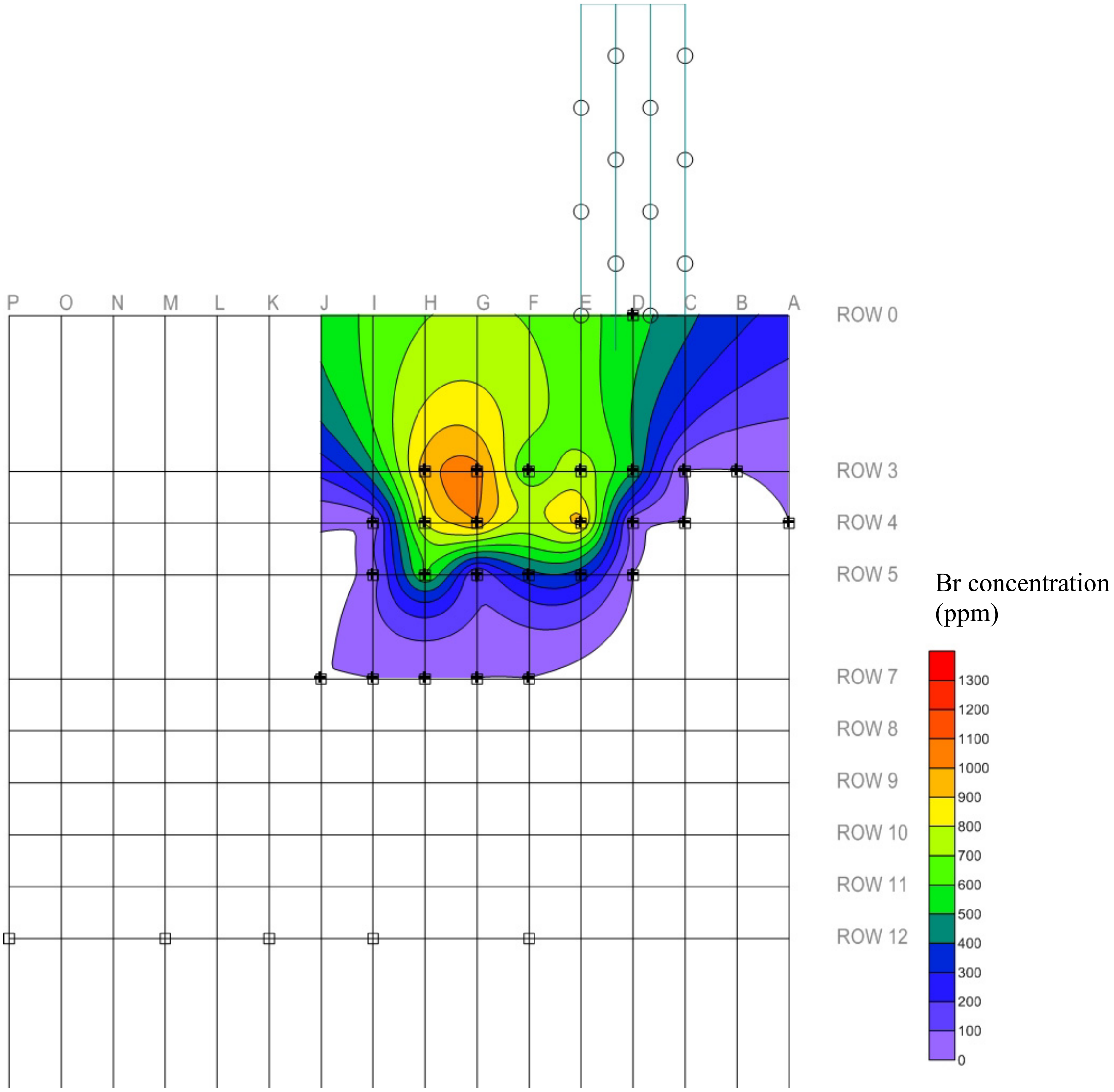

Figure A-15
November 27th 8am
432 hours, pumped samples

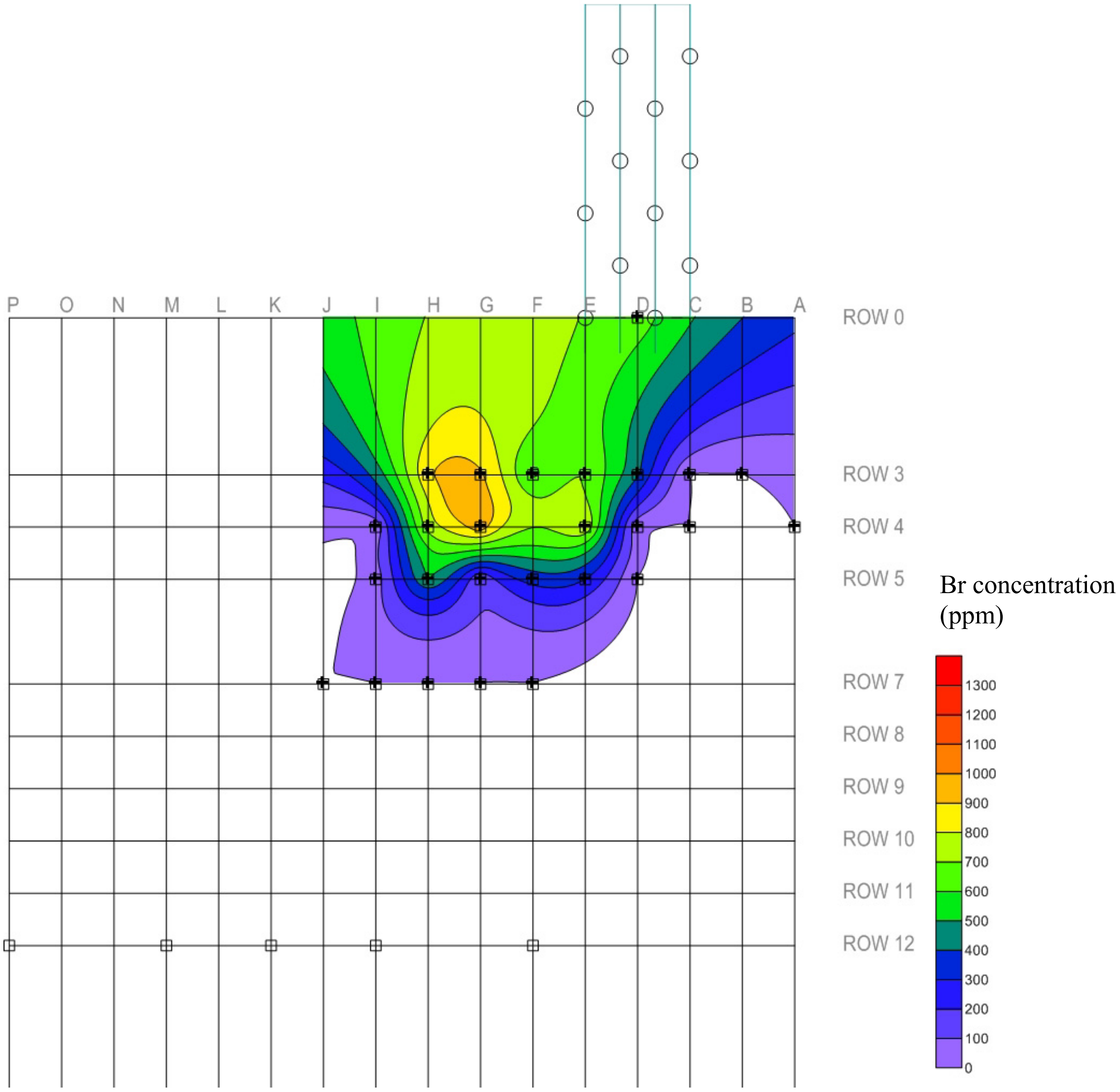

Figure A-16
November 27th 12pm
436 hours, pumped samples

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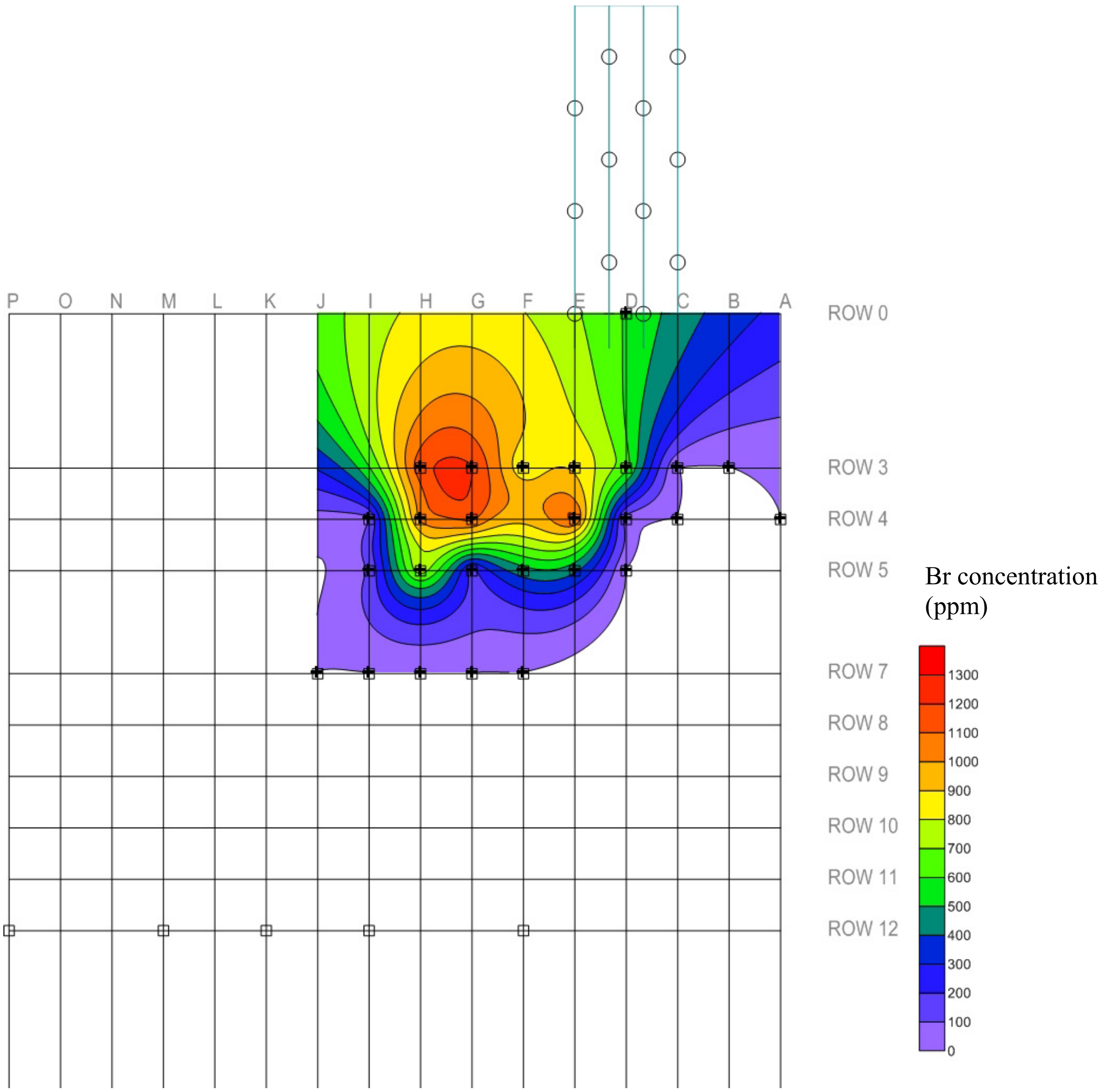

Figure A-17
November 28th 8am
456 hours, pumped samples

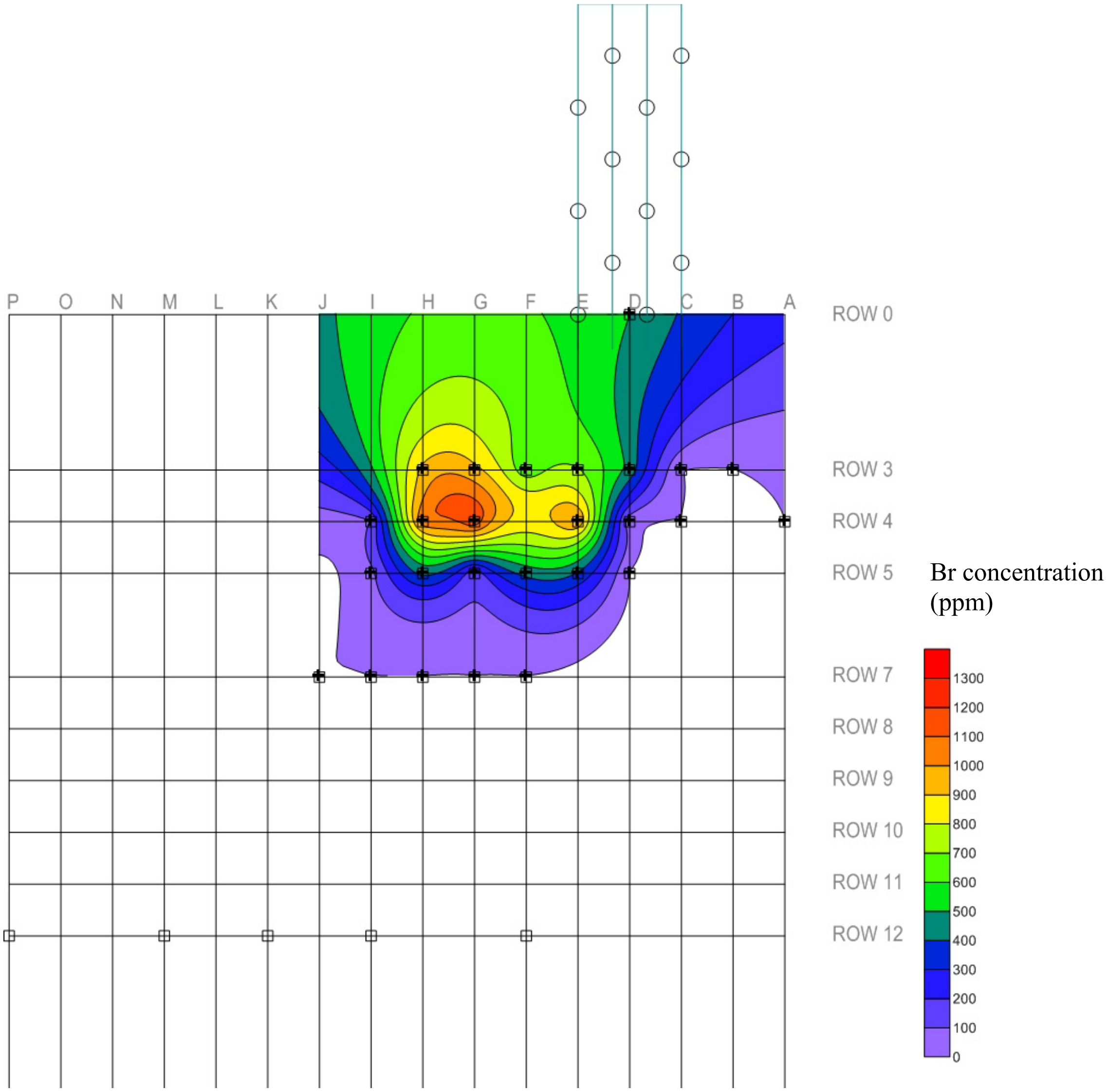

Figure A-18
November 28th 12pm
460 hours, pumped samples

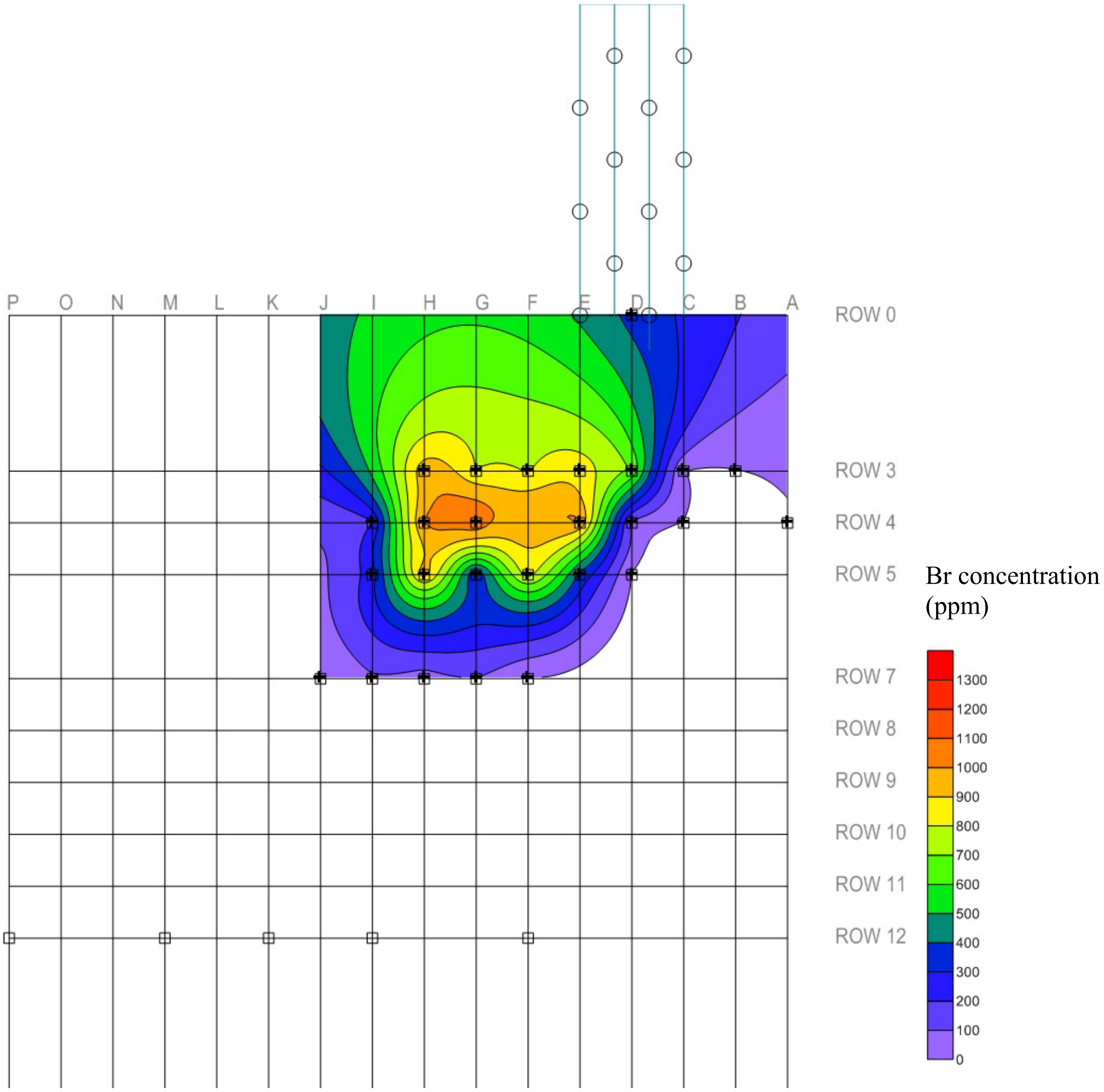

Figure A-19
November 29th 8am
480 hours, pumped samples

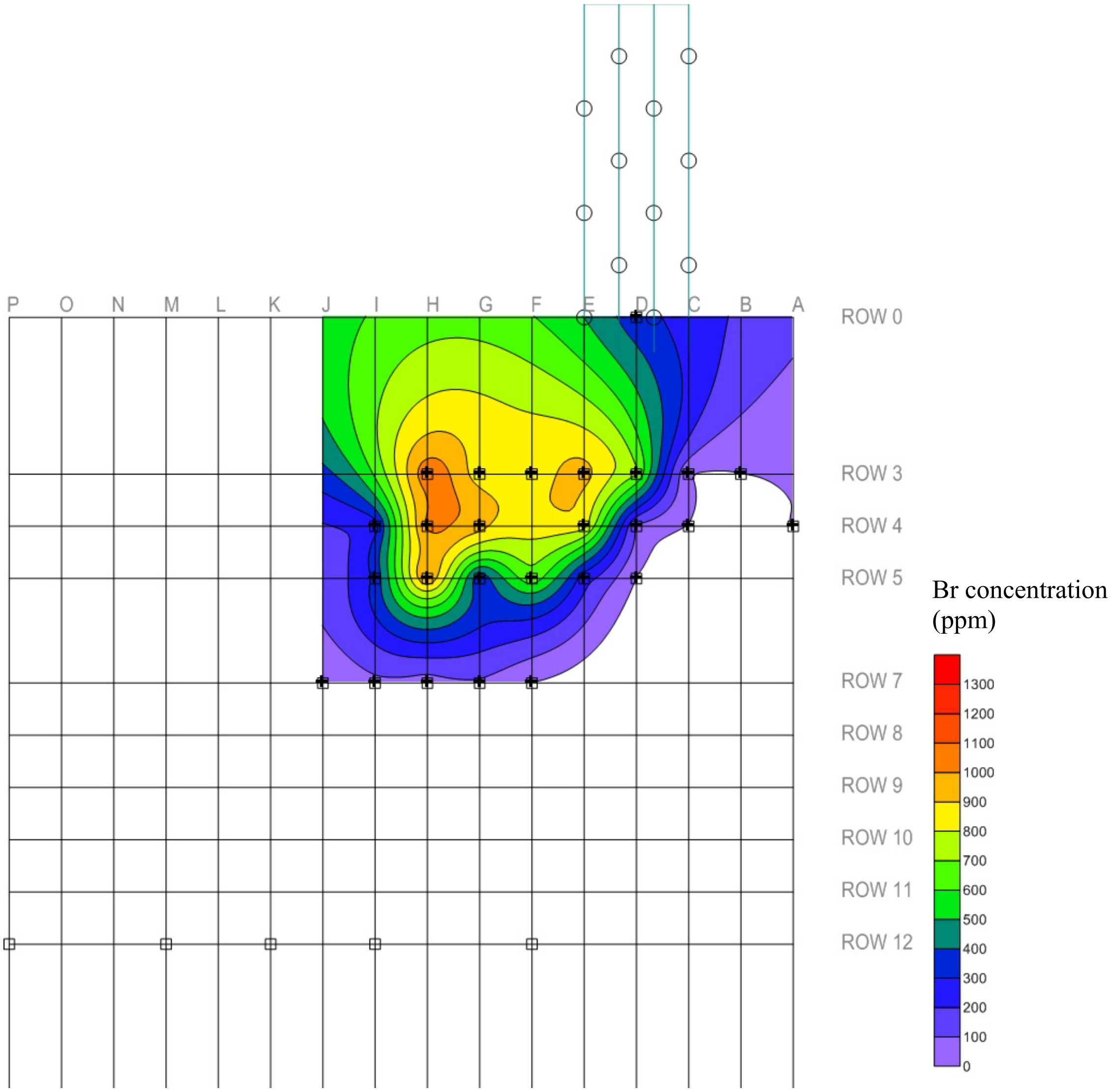

Figure A-20
November 29th 4pm
488 hours, pumped samples

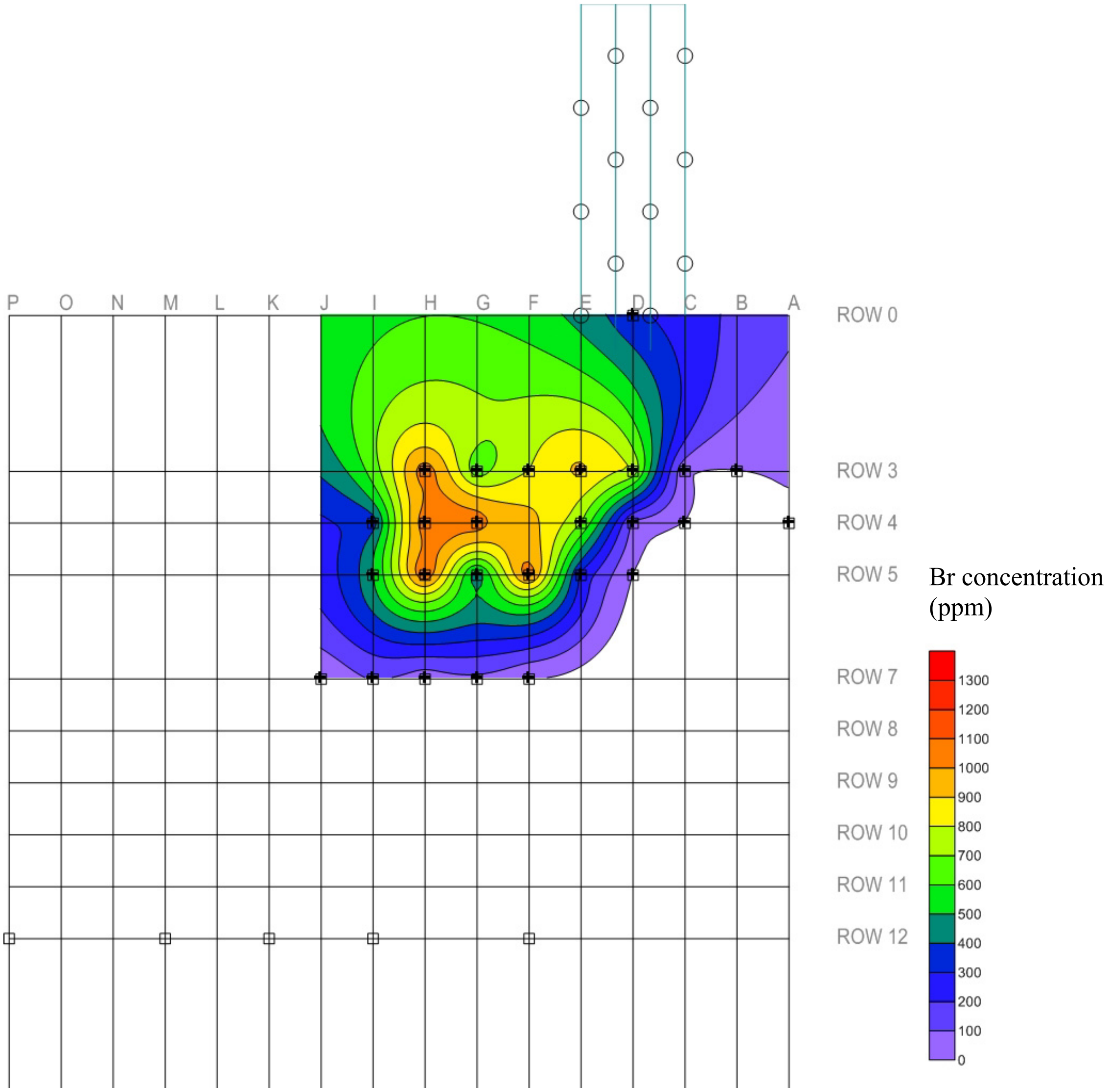

Figure A-21
November 30th 8am
504 hours, pumped samples

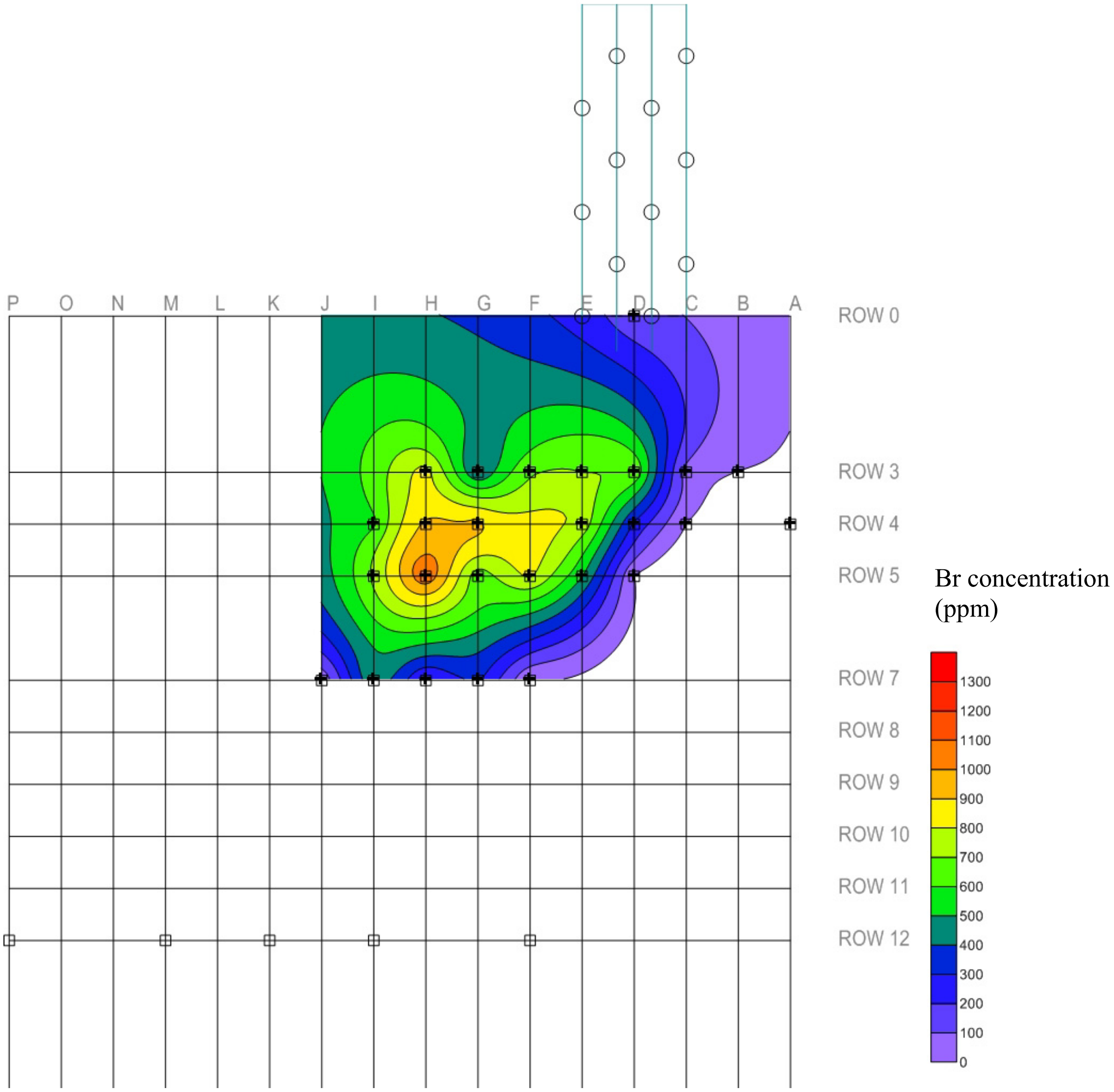

Figure A-22
December 1st 8am
528 hours, pumped samples

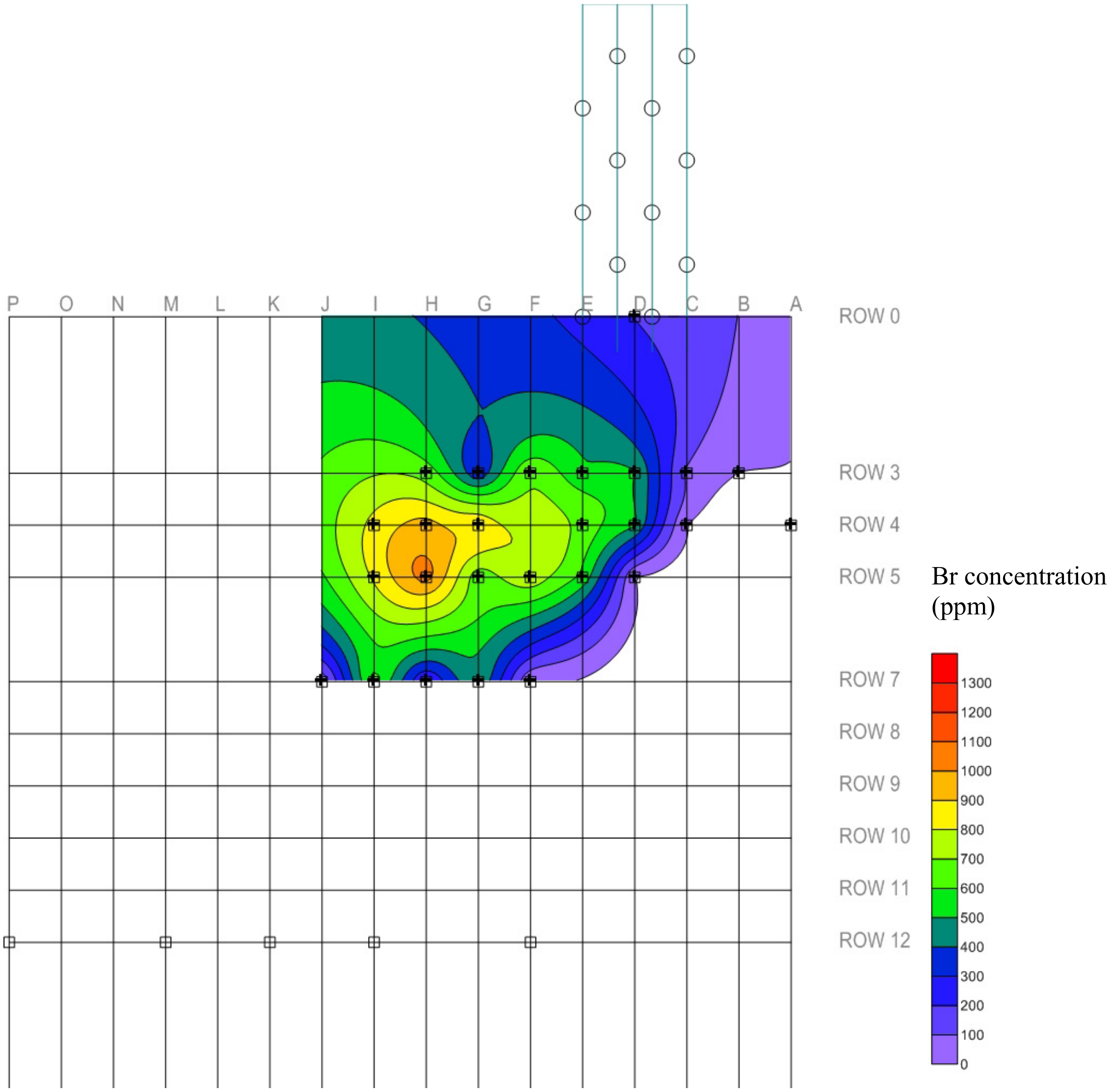

Figure A-23
December 2nd 8am
552 hours, pumped samples

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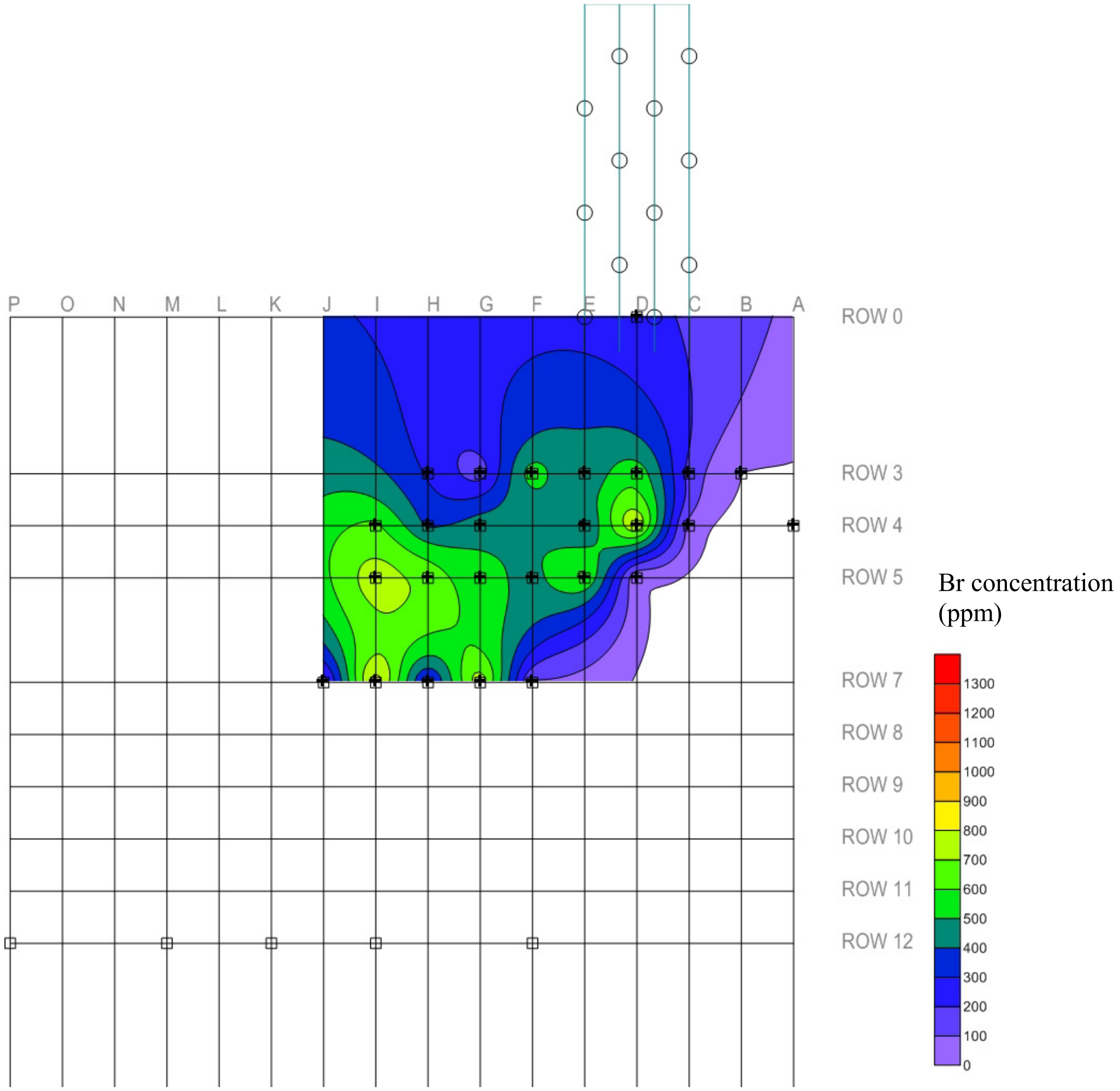

Figure A-24
December 4th 8am
600 hours, pumped samples

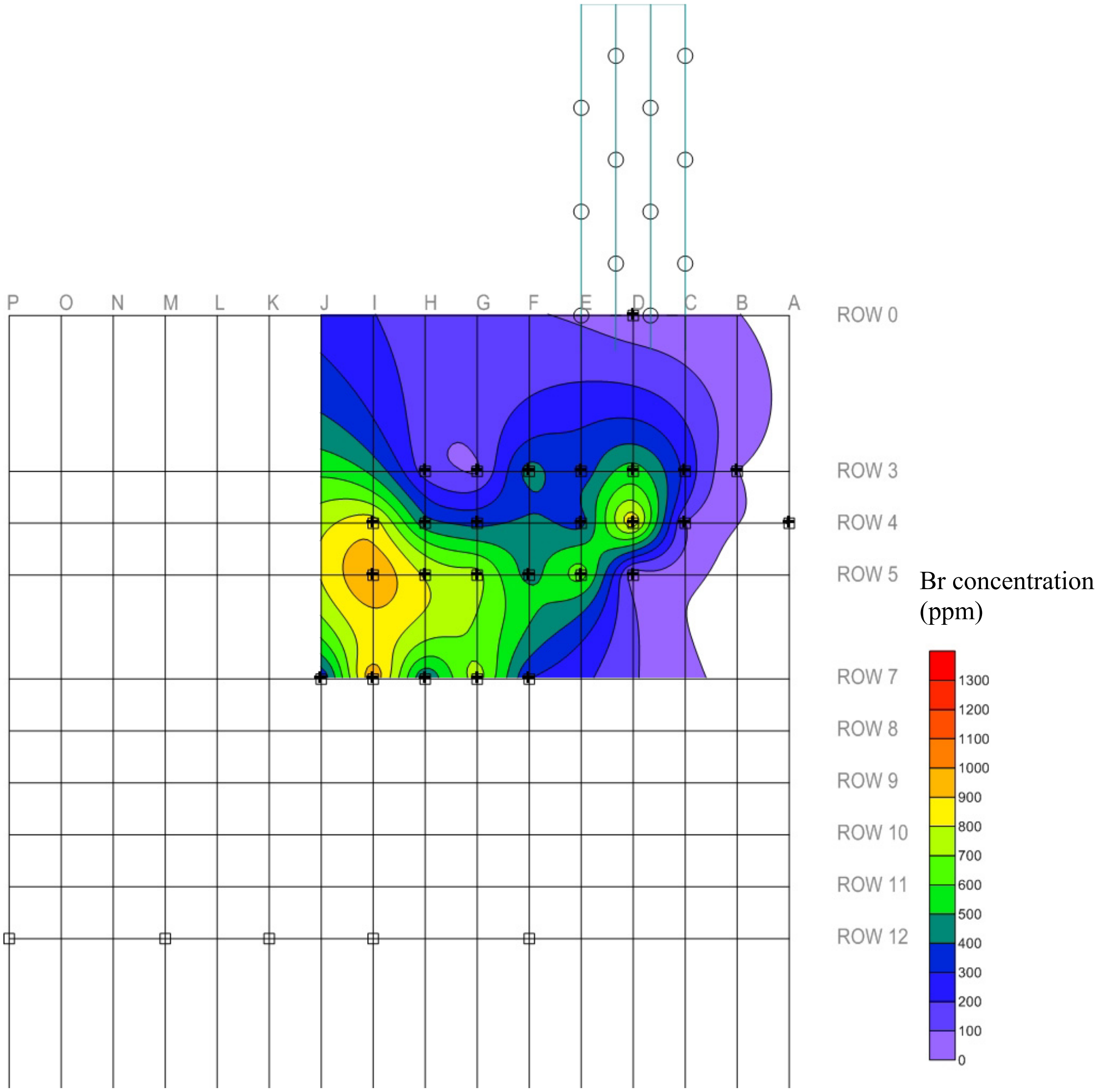

Figure A-25
December 5th 8am
624 hours, pumped samples

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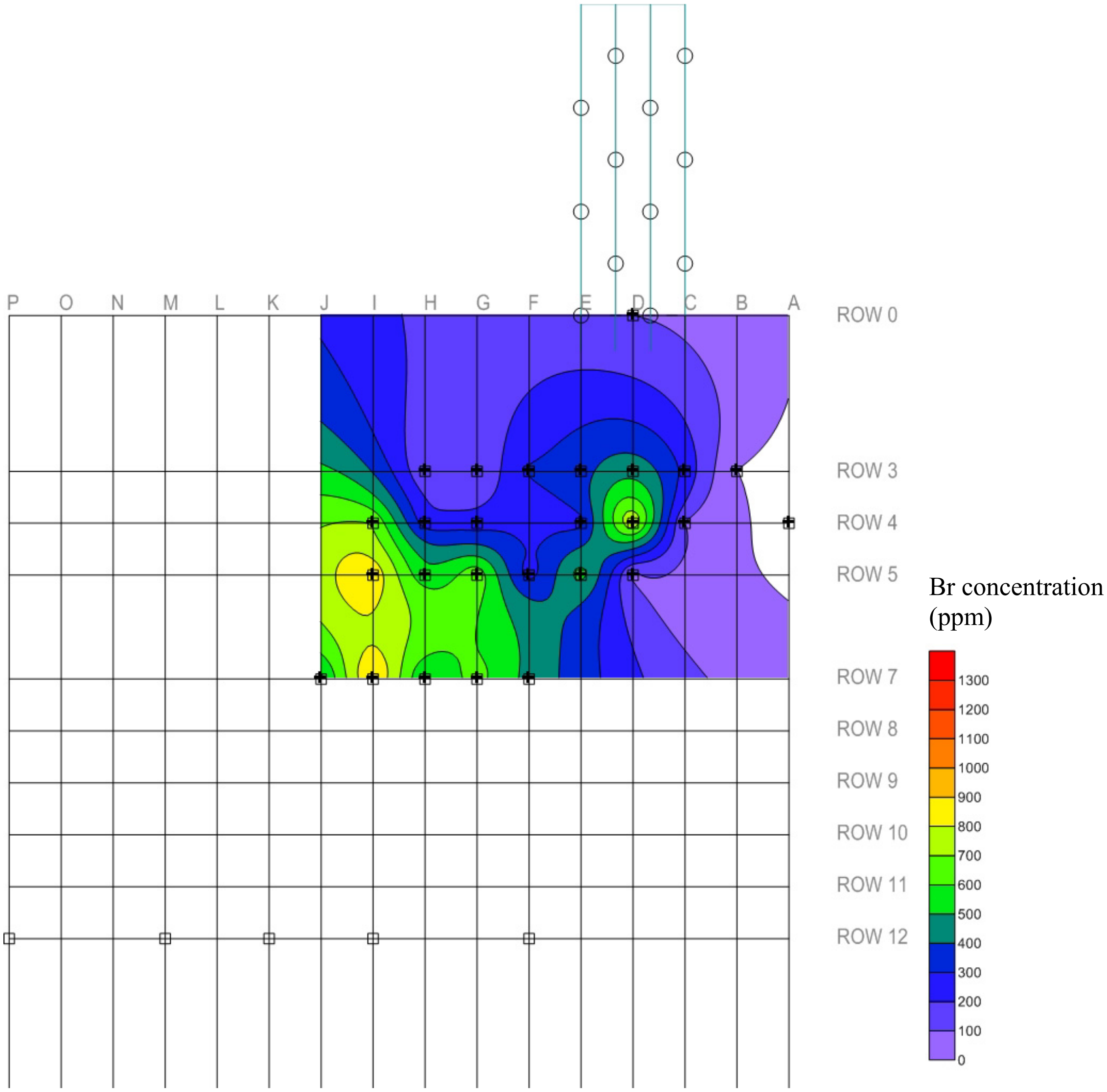

Figure A-26
December 6th 8am
648 hours, pumped samples

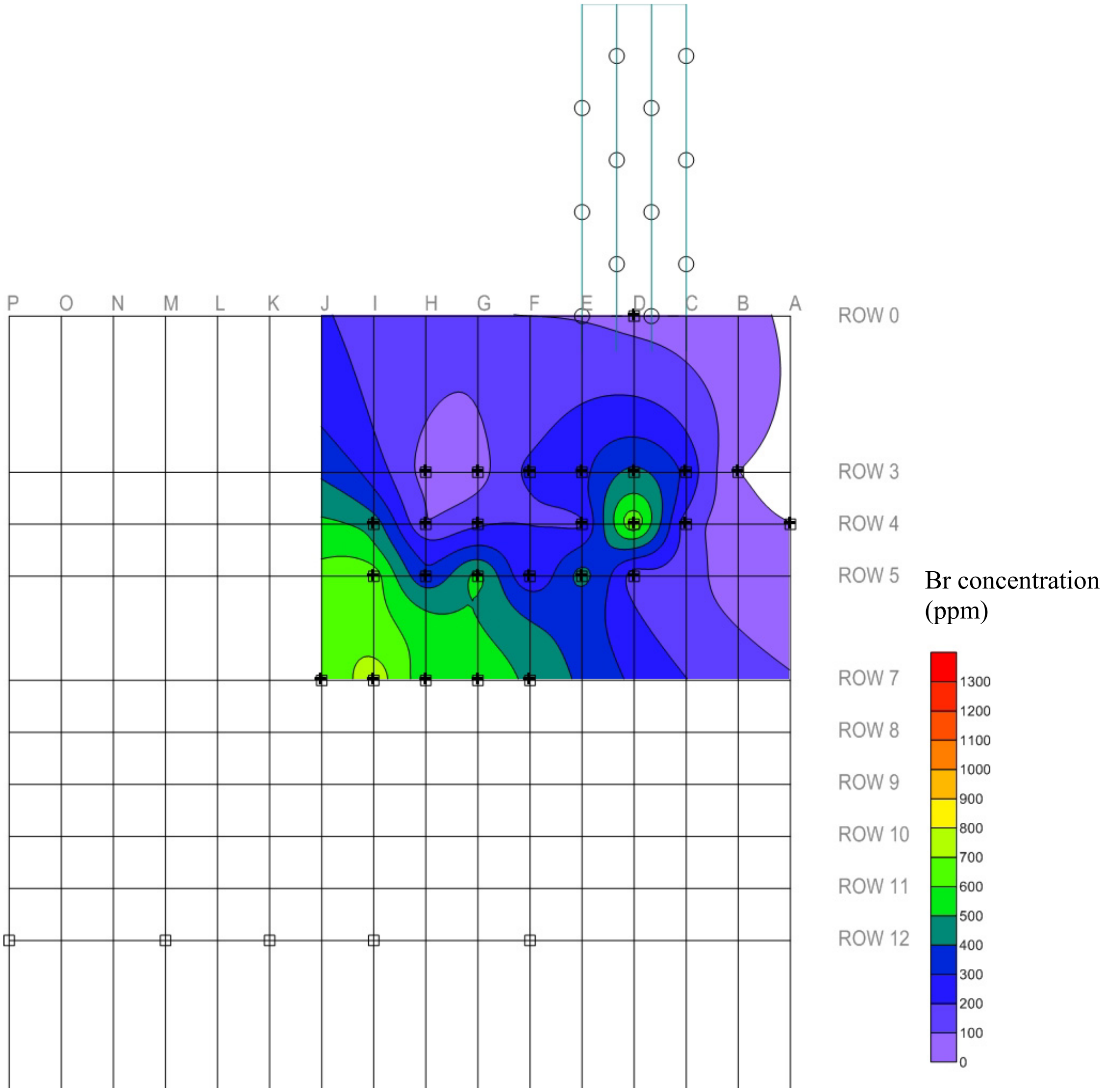

Figure A-27
December 7th 8am
672 hours, pumped samples

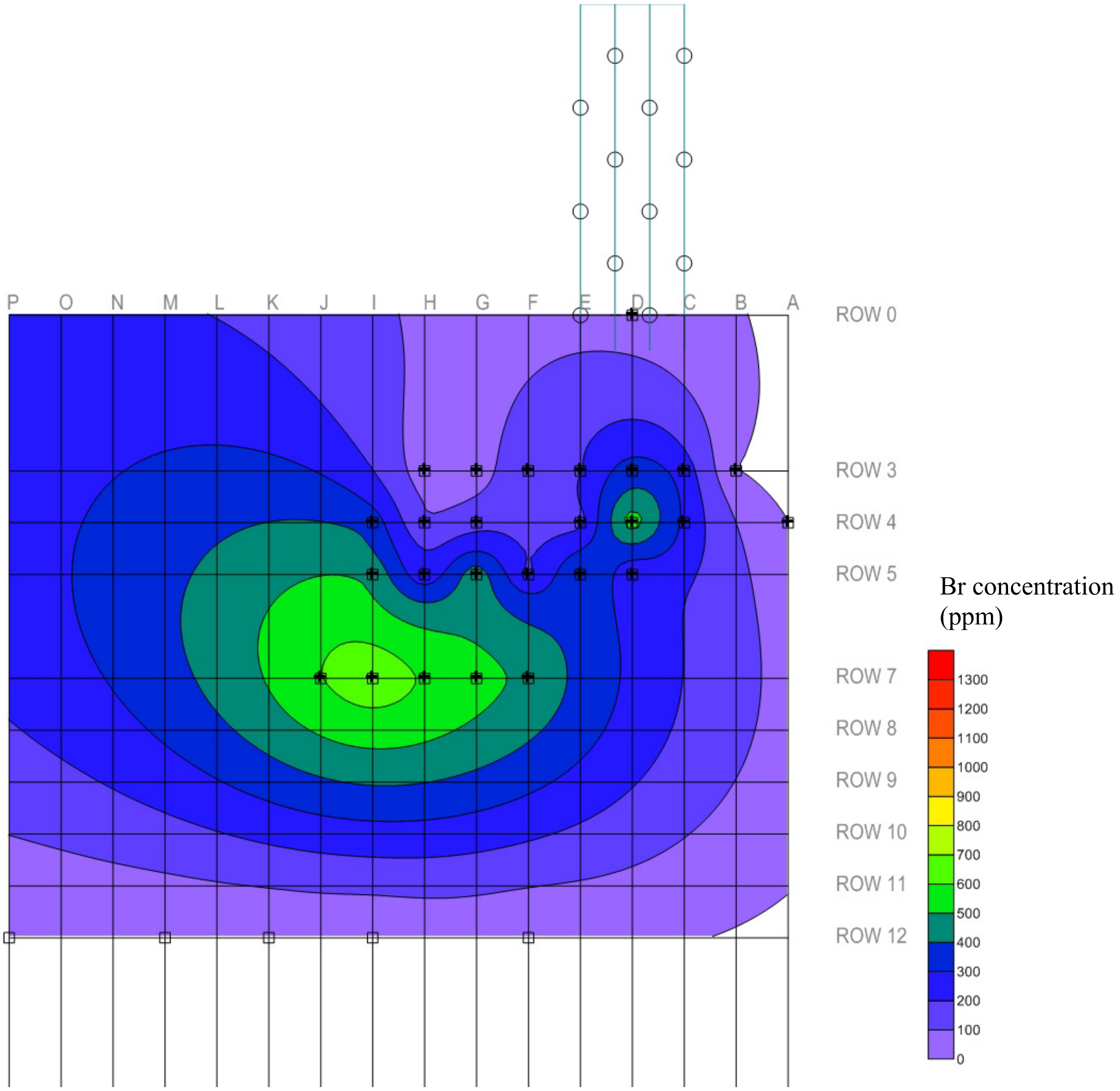

Figure A-28
December 8th 8am
696 hours, pumped samples

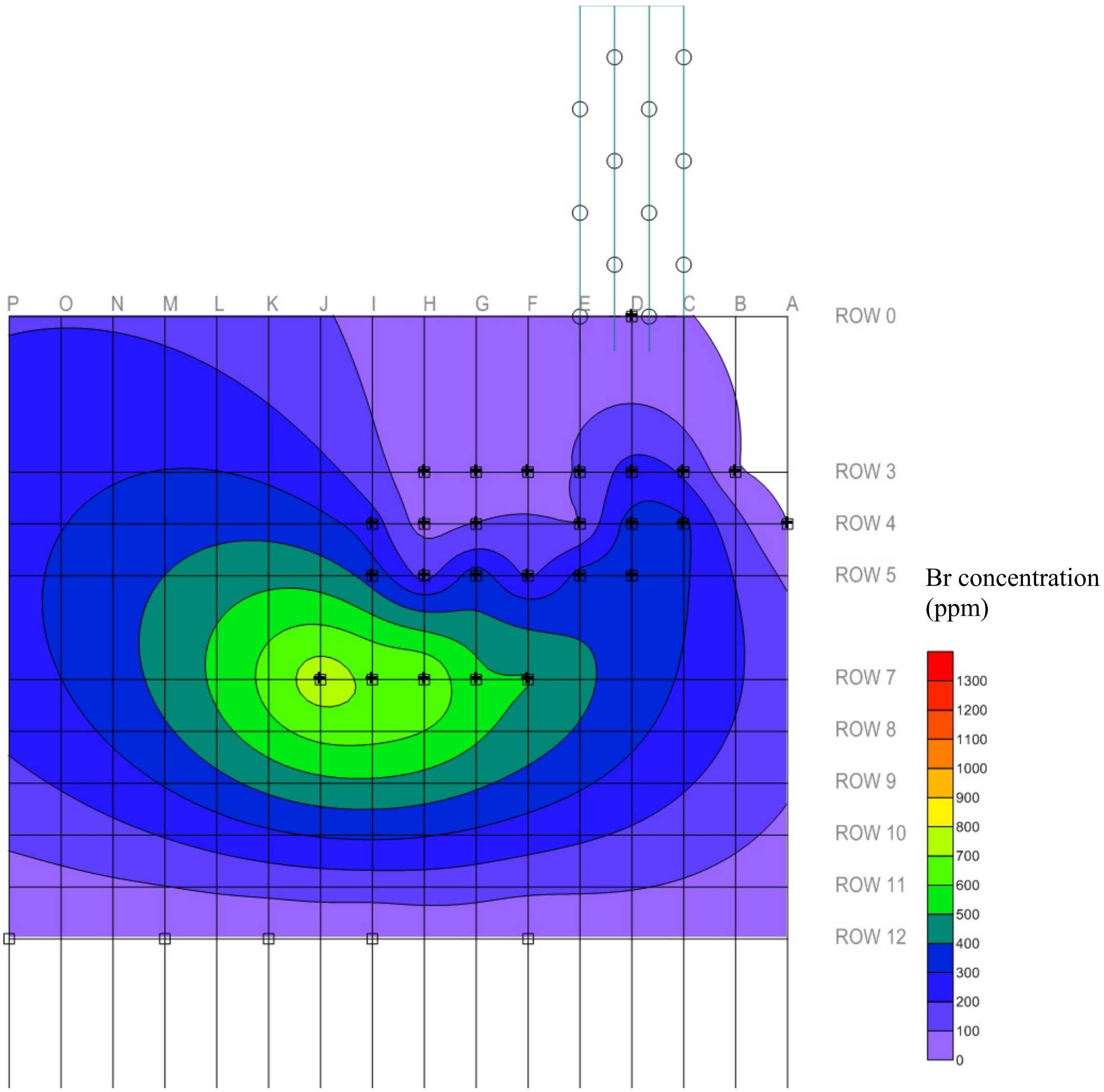

Figure A-29
December 9th 8am
720 hours, pumped samples

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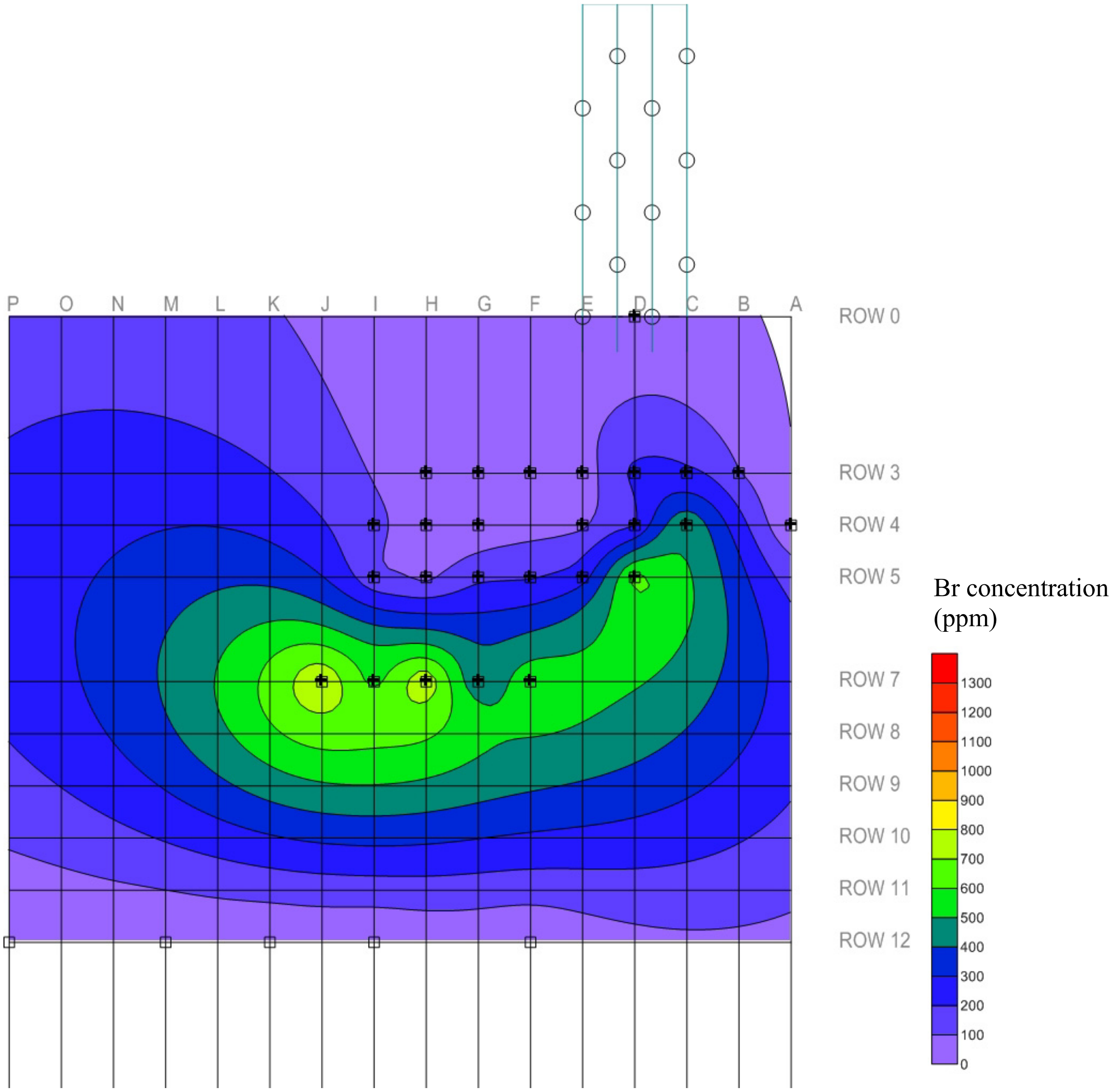

Figure A-30
December 12th 10am
794 hours, pumped samples

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