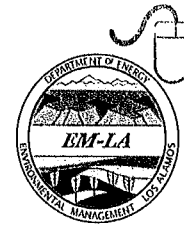




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ENTERED

Environmental Management
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Date: **JUL 31 2018**
 Refer To: N3B-18-0164

John Kieling, Bureau Chief
 Hazardous Waste Bureau
 New Mexico Environment Department
 2905 Rodeo Park Drive East, Building 1
 Santa Fe, NM 87505-6303

Subject: Submittal of the Third Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon

Dear Mr. Kieling:

Enclosed please find two hard copies with electronic files of the Third Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon. This report is being submitted to fulfill Fiscal Year 2018 Milestone 8 in Appendix B of the 2016 Compliance Order on Consent (Consent Order). The content and recommendations in this report were discussed with your staff in a pre-submission review meeting on July 19, 2018. As noted in that discussion, because of the ongoing nature of the study, this document is being submitted as a progress report rather than as a completion report.

If you have any questions, please contact Steve White at (505) 309-1370 (steve.white@em-la.doe.gov) or Cheryl Rodriguez at (505) 665-5330 (cheryl.rodriguez@em.doe.gov).

Sincerely,

Joseph A. Legare
 Program Manager
 Environmental Remediation Program

Sincerely,

David S. Rhodes, Director
 Office of Quality and Regulatory Compliance
 Environmental Management
 Los Alamos Field Office



JL/DR/SW/CR

Enclosure(s): Two hard copies with electronic files – Third Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon (EM2018-0019)

Cy: (letter with enclosure[s])
Steve White, N3B, ER Program
Danny Katzman, N3B, ER Program
Cheryl Rodriguez, DOE-EM-LA

Cy: (letter with electronic enclosure[s])
Steve Pullen, NMED-GWQB
Laurie King, EPA Region 6, Dallas, TX
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Frank Johns, N3B, ER Program

July 2018
EM2018-0019

Third Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon




Newport News Nuclear BWXT – Los Alamos, LLC (N3B), under the U.S. Department of Energy Office of Environmental Management Contract No. 89303318CEM000007 (the Los Alamos Legacy Cleanup Contract), has prepared this document pursuant to the Compliance Order on Consent, signed June 24, 2016. The Compliance Order on Consent contains requirements for the investigation and cleanup, including corrective action, of contamination at Los Alamos National Laboratory. The U.S. government has rights to use, reproduce, and distribute this document. The public may copy and use this document without charge, provided that this notice and any statement of authorship are reproduced on all copies.


Third Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon

July 2018


Responsible program director:

Bruce Robinson		Program Director	Water Program	7/23/2018
Printed Name	Signature	Title	Organization	Date

Responsible N3B representative:

Joseph A. Legare		Program Manager	N3B Environmental Remediation Program	7/23/18
Printed Name	Signature	Title	Organization	Date

Responsible DOE-EM-LA representative:

David S. Rhodes		Office Director	Quality and Regulatory Compliance	7/31/18
Printed Name	Signature	Title	Organization	Date

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1.0 INTRODUCTION

This report is the third quarterly report presenting results of two pilot-scale amendment tests being conducted to evaluate feasibility for in situ treatment of hexavalent chromium [Cr(VI)] in the regional aquifer. The study is being conducted in accordance with the “Pilot-Scale Amendments Testing Work Plan for Chromium in Groundwater beneath Mortandad Canyon” (LANL 2017, 602505) as approved by the New Mexico Environment Department (NMED 2017, 602546). The deployments occurred at regional groundwater monitoring wells R-42 and R-28. Sodium dithionite was injected into R-42 in late August 2017, and molasses was injected into R-28 in early September 2017 (Figure 1.0-1). The objectives of the tests are to evaluate (1) the ability of the amendments to reduce dissolved-phase Cr(VI) to insoluble and immobile trivalent chromium [Cr(III)] in the regional aquifer, (2) the longevity of the treatments in keeping Cr(VI) concentrations low (i.e., reduction capacity), (3) any adverse geochemical effects and their persistence, and (4) any adverse hydrological impacts of the treatments on hydraulic properties of the aquifer. The first quarterly report, issued at the end of January 2018 (LANL 2018, 602862), provided details of how the amendments were deployed and of the pumping and sampling strategies in each of the test wells, as well as the geochemistry data from the tests, through the end of calendar year 2017. The second quarterly report (LANL 2018, 603031) provided (1) an update of the geochemistry data from the two amendments tests, (2) the results of a borehole dilution tracer test that was conducted in R-42 in January 2018 to estimate the post-amendment ambient groundwater flow velocity through the R-42 screened interval, and (3) an analysis of pre- and post-amendment drawdown data from both R-42 and R-28 to evaluate the effects of the amendments on near-well hydraulic conductivity. The information provided in the two previous quarterly reports will not be repeated in this quarterly report. This quarterly report provides updated plots of geochemistry data from R-42 and R-28 that include results from additional samples collected during April through June 2018. All the new geochemistry data associated with these samples are included in Attachment 1 (on CD included with this document, plotted along with previously reported data). This report also provides some recommendations, including a qualitative discussion of expected results if R-42 is pumped for an extended period.

2.0 UPDATE OF AMENDMENT TEST GEOCHEMISTRY RESULTS

2.1 Sodium Dithionite at R-42

Figure 2.1-1 shows an updated plot of the concentration trends of selected dissolved cations and metals, including chromium, measured in samples collected from R-42 as a function of time. Results are also shown in Figure 2.1-1 for the injection batches, which are plotted to the left of the vertical dashed line that indicates when pumping of the well was initiated. Vertical dashed lines are shown in Figure 2.1-1 for when continuous pumping of R-42 stopped in September 2017, when net withdrawal of water from the well stopped in October 2017, and when 50-gal. biweekly purges were initiated after a dilution tracer test conducted in January 2018, as described in the second quarterly report (LANL 2018, 603031). After the dilution tracer test, there has been no injection or circulation of water in R-42, and every sampling event has involved an approximately 50-gal. purge. As Figure 2.1-1 shows, there was a long period of no purging/sampling that occurred from April 19 to June 13, 2018. This sampling hiatus is related to the transition from environmental work being conducted by the U.S. Department of Energy Los Alamos Environmental Management Office’s (EM-LA’s) contractor Los Alamos National Security, LLC to Newport News Nuclear BWXT – Los Alamos, LLC (N3B) beginning on April 30, 2018. Figure 2.1-2 shows concentration trends for some of the other elements of interest, including arsenic and selenium. Figure 2.1-3 shows concentration trends for selected anions. Analytical results for the oxyanions arsenic, and selenium, as well as the inductively coupled plasma mass spectrometer (ICP-MS) results for chromium, were not available for the June samples at the time of this report because the ICP-MS instrument used to conduct the analyses was out of service in late June (ICP-MS results are expected to

be complete by the end of July and available in Intellus New Mexico (<https://www.intellusnm.com/>). In lieu of the ICP-MS chromium data, chromium results obtained by ICP-optical emission spectrometry (ICP-OES) are shown in Figures 2.1-1 and 2.1-2 for the June samples and for the last three April samples to allow comparison with the ICP-MS chromium results in the April samples. (The ICP-OES generally yields higher concentrations than the ICP-MS when concentrations are as low as in these samples because of analytical interferences on the OES). Figures 2.1-1 through 2.1-3 show that there was little apparent change in any of the constituent concentration trends in the June 2018 samples that were collected after nearly a 2-mo sampling pause. Concentrations of other elements or ions not shown in Figures 2.1-1 to 2.1-3 can be found in Attachment 1 (on CD included with this document).

Although only a small number of new samples were collected during the third quarter, it is apparent that Cr(VI) concentrations (measured as total chromium) in R-42 have remained very low, well below the New Mexico groundwater standard of 0.05 mg/L. Iron concentrations remained elevated after the nearly 2-mo sampling hiatus, which suggests that groundwater in the well did not become oxidized during the hiatus. During sampling between mid-October 2017 and early January 2018, when well water was circulated instead of withdrawn for sampling, iron concentrations dropped dramatically and remained relatively low, almost certainly because the well water was being oxygenated as it circulated between the surface and the aquifer (Figure 2.1-1). Once 50-gal. purges were initiated in January 2018, iron concentrations rose steadily, consistent with the reestablishment of reducing conditions in the wellbore. These reducing conditions apparently persisted during the nearly 2-mo sampling hiatus, indicating that the oxygen mass transfer rate into the water is predictably quite slow or perhaps that the turnover rate of reduced groundwater flowing through the wellbore is faster than the oxygen mass transfer rate. Arsenic can be expected to exhibit behavior similar to that of iron, although arsenic results from the June samples are not yet available (Figure 2.1-2). Figure 2.1-3 shows that June 2018 concentrations of nitrate (NO_3^-) continued their declining trend from before the sampling hiatus, which is also consistent with the persistence of reducing conditions in the R-42 wellbore. Continued slow declines in sulfate (SO_4^{2-} , a dithionite reaction product) and bromide (the conservative tracer that was injected with dithionite) concentrations (Figure 2.1-3) suggest that groundwater was actively flowing through the well under natural flow conditions during the sampling hiatus. The fact that sulfate concentrations have remained persistently elevated over pre-test concentrations (still by a factor of about 2.5 as of late June 2018) suggests that there has been a continuous generation of sulfate near R-42, which can probably be attributed to the slow oxidation of reduced sulfur species deposited during and perhaps immediately after the dithionite deployment. Any sulfate generated in the immediate period following the deployment should have been removed by pumping in August through October of 2017, or as a result of natural groundwater flow since then (bromide tracer concentrations have decreased more rapidly than sulfate since October 2017). The slowly declining, but still significantly elevated, sulfate concentrations suggest that reduced sulfur species are being oxidized to sulfate by oxygenated groundwater that is flowing into the dithionite reaction zone near the well.

2.2 Molasses at R-28

Figure 2.2-1 shows the trends of selected cations and metals, including chromium, during the molasses test at R-28. Figure 2.2-2 shows concentration trends for some of the other elements of interest, including arsenic and selenium. Figure 2.2-3 shows trends for anions during the test. As with the R-42 dithionite test, there was a nearly 2-mo purging/sampling hiatus from April 19 to June 13, 2018. June 2018 results are not yet available for any analytes measured by ICP-MS (arsenic, selenium, nickel, and chromium). Figure 2.2-4 shows the bromide and total organic carbon (TOC) concentrations measured during the test. TOC concentrations are considered an indicator of molasses, although as the test has progressed they may increasingly reflect molasses degradation products. Naturally occurring concentrations of organic carbon in the aquifer are negligible compared with the levels of molasses introduced. Early TOC results

likely also reflect the presence of ethanol that was used in the chase water introduced downhole after the molasses.

Figures 2.2-1 through 2.2-4 indicate that the concentration trends of anions, cations, metals, and TOC in R-28 did not change significantly after the 2-mo sampling hiatus. These results suggest that the molasses amendment solution continues to linger near R-28, much longer than would have been predicted from the rate of disappearance of tracers that was observed during a tracer study conducted under natural-gradient conditions in R-28 in September 2016 (LANL 2018, 602862). Based on the results of the 2016 test, the molasses solution should have drifted out of R-28 by late November or early December 2017, over three times faster than is being observed. The persistence of elevated bromide concentrations is probably the most convincing indicator of amendment solution lingering near R-28, as bromide was a conservative tracer with a low background that was added with the molasses. However, the lingering of the amendment solution does not necessarily mean that molasses itself continues to linger; the elevated TOC concentrations could reflect molasses degradation products rather than, or in addition to, molasses. Persistent elevated concentrations of chloride, which was not added but was present in the molasses, is also a strong indicator that the amendment solution continues to linger near R-28. Concentration trends have not changed significantly since 50-gal. purges with each sampling event were initiated in early February 2018. This result suggests that the lingering of the molasses amendment solution is not a very near-wellbore effect caused by clogging or biofouling of the well screen or gravel pack. The conclusion is that the permeability of the aquifer in the vicinity of R-28 decreased as a result of the molasses injection.

As discussed in the previous quarterly reports, total chromium concentrations in R-28 have not dropped consistently below the 0.05 mg/L maximum contaminant level, but ultraviolet-visible spectroscopy and ion chromatography measurements have both indicated that essentially all of the chromium being measured by ICP-MS is Cr(III), not Cr(VI). No new Cr(VI) measurements were conducted during the past quarter, but it is assumed that the chromium being measured by ICP-MS (or ICP-OES) is still all Cr(III). Persistent elevated nickel concentrations strongly suggest that the source of Cr(III) is the stainless-steel casing in R-28, as nickel and chromium are the two primary metallic constituents besides iron in stainless steel. The mechanism(s) of liberation of Cr(III) from the stainless-steel casing is not known, but a microbially induced leaching process may be contributing. The pH in the well water has been consistently between 4.5 and 5 since the test began, and at these pHs, dissolved concentrations of Cr(III) could be as high as 30 mg/L [assuming a $\text{Cr}(\text{OH})_3$ solubility product of 6.3×10^{-31}], so the elevated concentrations of Cr(III) are not surprising provided Cr(III) can be liberated. The liberation process(es) must be relatively rapid because the 50-gal. purges are not notably decreasing the concentrations of either chromium or nickel (although both constituents decreased significantly when the 1000-gal. purge was conducted in November 2017). An extended purge would help determine if any Cr(III) is being liberated from aquifer sediments as a result of the low pH of the amendment solution.

As long as molasses persists at measureable concentrations in R-28, no Cr(VI) is expected to be detected because of the abiotic reaction of molasses with Cr(VI) to reduce the chromium to Cr(III). Although the lingering elevated TOC concentrations in R-28 do not necessarily mean that molasses is present, it would be prudent to assume that the lingering of TOC could result in abiotic reduction of Cr(VI) to Cr(III).

3.0 DISCUSSION AND RECOMMENDATIONS

As discussed above, the dithionite amendment test at R-42 still requires more time to determine Cr(VI) reduction capacity imparted to aquifer sediments because chromium concentrations have not yet begun to break through in R-42. The molasses amendment test at R-28 will also require more time to determine reduction capacity partly because of the elevated TOC concentrations that remain in the aquifer around R-28 that may be causing abiotic reduction of Cr(VI). Also, uncertainty remains at both locations regarding the effects of the amendment deployments on aquifer permeability near the wells. To address both the reduction capacity and aquifer permeability uncertainties, it would be helpful to obtain valid estimates of the groundwater flow velocity in the vicinity of the wells since the amendment deployments. This would allow the volume of aquifer water that has flowed through the treatment zones during the tests to be estimated (at R-42 it would be the volume since continuous pumping ended in October 2017), and it would also allow an assessment of changes to aquifer permeability caused by the deployments because good estimates of flow velocities near the wells were obtained before the deployments. Pumping of both wells would provide faster and more definitive estimates of reduction capacity resulting from the amendments, and at R-28 it would likely remove or reduce the uncertainty associated with the effects of elevated TOC. Therefore, the next steps of the amendments testing will involve an effort to conduct long-duration (months) pumping at R-42 and R-28 with time-series sampling. The objectives are (1) to investigate the ability to clean the area in the aquifer around each well of amendments and amendment byproducts and (2) to move more groundwater pore volumes through the treated zone to accelerate breakthrough and provide the basis for estimating reduction capacity. Before initiating long-duration pumping, a short-duration (approximately 5-d) continuous pumping activity will be conducted to collect data that can be used to guide disposition of water pumped during the long-duration tests. Details of the work plan for the short-duration pumping will be provided to the New Mexico Environment Department (NMED) before initiation of the test.

Figure 3.0-1 provides a schematic two-dimensional time-series depiction of treated/reduced zone spatial distributions at various times, assuming, for the sake of simplifying the conceptual model, that the aquifer is homogeneous and isotropic. Panel 1 shows how the treated/reduced zone would have appeared after initial deployment, after pumping in August through October 2017, and finally after 9 mo of natural flow. The reduced zone after initial deployment is evenly distributed around the well, but during pumping it becomes somewhat elongated and skewed toward the downgradient direction because reduction capacity is consumed faster in the upgradient direction where oxygenated Cr(VI)-bearing groundwater is moving toward the well at a faster rate. Once pumping stops, essentially all consumption of the reduced zone occurs in the upgradient direction, and the zone compresses from this direction. Panel 2 depicts the distribution of the reduced zone after resumption of pumping, both right at the time of Cr(VI) arrival at the well and at some later time. Soon after Cr(VI) arrival occurs, the reduced zone is entirely downgradient of the well, and it continues to shrink as pumping continues. Panel 3 shows a qualitative expected “breakthrough curve” of Cr(VI) under pumping conditions after a significant amount of preceding flow under natural gradient conditions. A relatively sharp increase in Cr(VI) can be expected as the flattened upgradient “front” reaches the well, but the rate of increase will slow as pumping slowly shrinks the downgradient reduction zone, with the fraction of reduced flow reaching the well only gradually decreasing. After Cr(VI) arrival, regardless of whether under pumping or natural flow conditions, uncertainty will remain in estimating a reduction capacity of the dithionite-treated zone because of the unquantifiable uncertainty in knowing where the zone was initially distributed and how fast the natural flow velocity is. Pumping until Cr(VI) concentrations fully return to pre-deployment levels, which seems highly impractical, would remove most of the uncertainty associated with the lack of knowledge of the initial spatial distribution of the treated zone (assuming the treated zone is entirely within the pumping capture zone), but some uncertainty will inherently remain regarding how much of the reduction capacity was consumed during the long period of natural flow.

The situation at R-28 is, in principle, similar to R-42, although the molasses-treated zone should be considerably larger than the dithionite zone at R-42 because of the larger volume of molasses injected and because R-28 was passively sampled after the deployment, except during the small purges and the 1000-gal. purge in November 2017. Also, the natural flow velocity at R-28 before the deployment was considerably faster than at R-42, so some of the molasses should have drifted a considerable distance downgradient by now, with really no expectation that it could ever be pumped back. Pumping R-28 would have the same advantages as at R-42 [i.e., it would accelerate a Cr(VI) arrival], and it would also have the advantage of removing the lingering TOC from upgradient of the well, which would eliminate the uncertainty associated with the possibility of abiotic reduction of Cr(VI) by molasses or its degradation products.

The prediction for arrival of Cr(VI) at R-42 under natural flow conditions, as discussed in the second quarterly report (LANL 2018, 603031), was at least another 4 to 5 mo after the end of March 2018 (by August or September 2018). However, this estimate assumes ideal radial flow during dithionite deployment (very unlikely) and a natural flow velocity of 0.1 m/d (uncertain), and it also assumes a similar sediment reduction capacity per mole of dithionite near R-42 as observed in laboratory column experiments (also uncertain). If the dithionite treatment radius around R-42 is truly 3 m and the flow velocity is 0.1 m/d, then a pore volume effectively moves through the upgradient zone about every 30 d. Given that the volume of dithionite solution plus chase water injected was 10,000 gal., it can be assumed that every 10,000 gal. of water pumped should result in moving 1 pore volume of upgradient groundwater through the treated zone. At a flow rate of 2 gallons per minute (the pump rate sustained in August through October 2017), 10,000 gal. would be pumped in about 3.5 d of continuous pumping, so the rate of Cr(VI) breakthrough would, in principle, be accelerated by a factor of 8.5 (30 divided by 3.5) by continuous pumping. In actuality, a greater acceleration factor can probably be expected because the thickness of the effective treatment zone has undoubtedly decreased since deployment, and the thinner the zone, the more that pumping should accelerate Cr(VI) arrival. If the August or September 2018 prediction for Cr(VI) arrival under natural flow conditions is accurate, Cr(VI) breakthrough should occur in a matter of days under pumping conditions.

Future testing may need to be conducted to evaluate whether the amendments and/or associated byproducts and geochemical reactions have had significant effects on aquifer permeability. After some data are collected from continuous pumping at R-42 and R-28, an additional field implementation plan may be necessary and will be prepared in consultation with NMED to determine the approach and objectives of additional testing.

4.0 REFERENCES AND MAP DATA SOURCES

4.1 References

The following reference list includes documents cited in this report. Parenthetical information following each reference provides the author(s), publication date, and ERID, ESHID, or EMID. This information is also included in text citations. ERIDs were assigned by the Laboratory's Associate Directorate for Environmental Management (IDs through 599999); ESHIDs were assigned by the Laboratory's Associate Directorate for Environment, Safety, and Health (IDs 600000 through 699999); and EMIDs are assigned by N3B (IDs 700000 and above). IDs are used to locate documents in N3B's Records Management System and in the Master Reference Set. The NMED Hazardous Waste Bureau and N3B maintain copies of the Master Reference Set. The set ensures that NMED has the references to review documents. The set is updated when new references are cited in documents.

LANL (Los Alamos National Laboratory), July 2017. "Pilot-Scale Amendments Testing Work Plan for Chromium in Groundwater beneath Mortandad Canyon," Los Alamos National Laboratory document LA-UR-17-25406, Los Alamos, New Mexico. (LANL 2017, 602505)

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NMED (New Mexico Environment Department), July 31, 2017. "Approval, Pilot-Scale Amendments Testing Work Plan for Chromium in Groundwater beneath Mortandad Canyon," New Mexico Environment Department letter to D. Hintze (DOE-EM) and B. Robinson (LANL) from J.E. Kieling (NMED-HWB), Santa Fe, New Mexico. (NMED 2017, 602546)

4.2 Map Data Sources

Hillshade; Los Alamos National Laboratory, ER-ES, As published;
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Unpaved roads; Los Alamos National Laboratory, ER-ES, As published, GIS projects folder;
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Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 29 November 2010.

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\\slip\gis\GIS\Projects\13-Projects\13-0065\shp\chromium_plume_2.shp; 2018.

Regional groundwater contour May 2017, 4-ft interval; Los Alamos National Laboratory, ER-ES, As published; \\slip\gis\GIS\Projects\16-Projects\16-0027\project_data.gdb\line\contour_wl2017may_2ft; 2017.

Regional groundwater contour November 2017, 2-ft interval; Los Alamos National Laboratory, ER-ES, As published; \\slip\gis\GIS\Projects\16-Projects\16-0027\project_data.gdb\line\contour_wl2017nov_2ft; 2017.

Point features; As published; EIM data pull; 2017.

Technical Area Boundaries; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; September 2007; as published 13 August 2010.

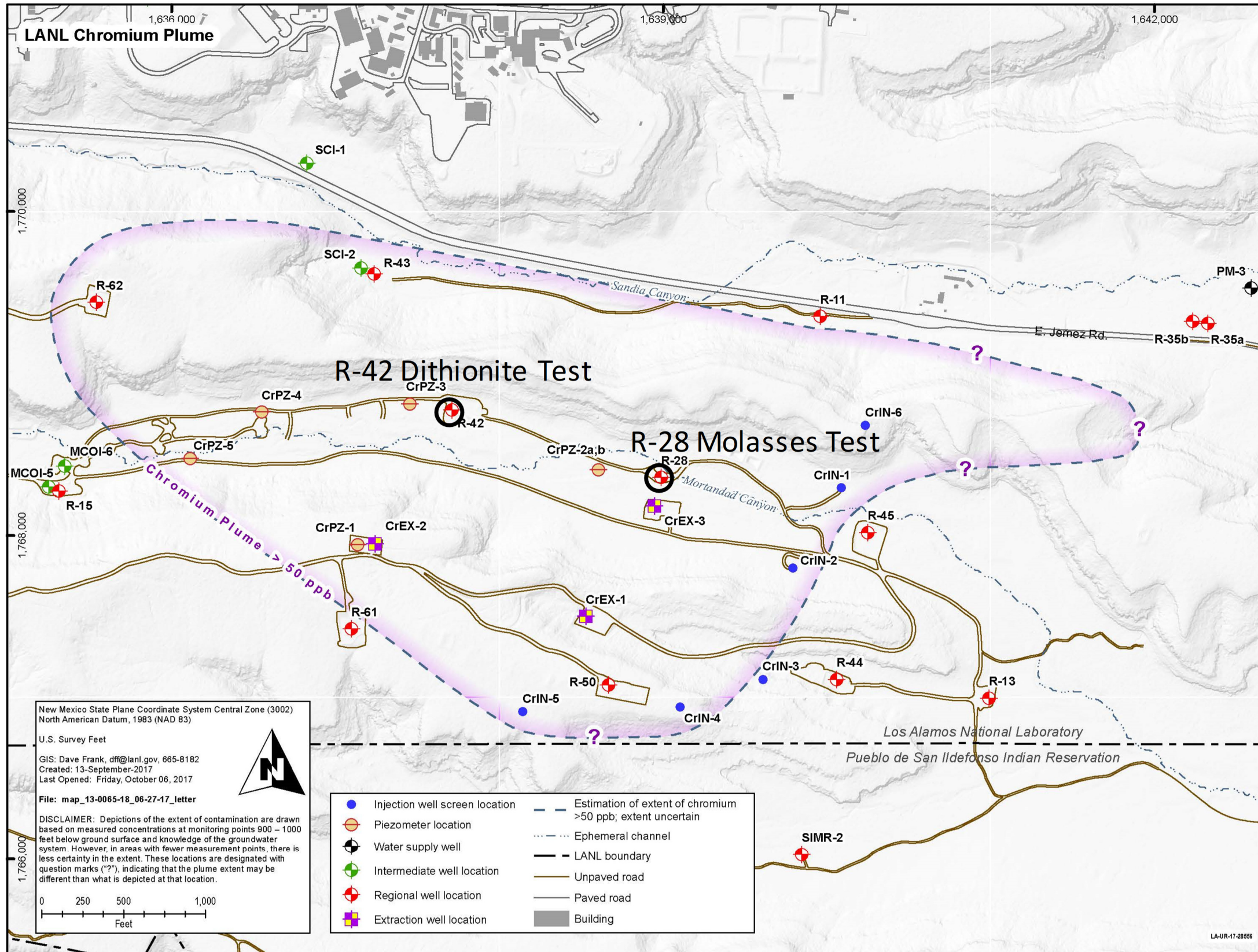
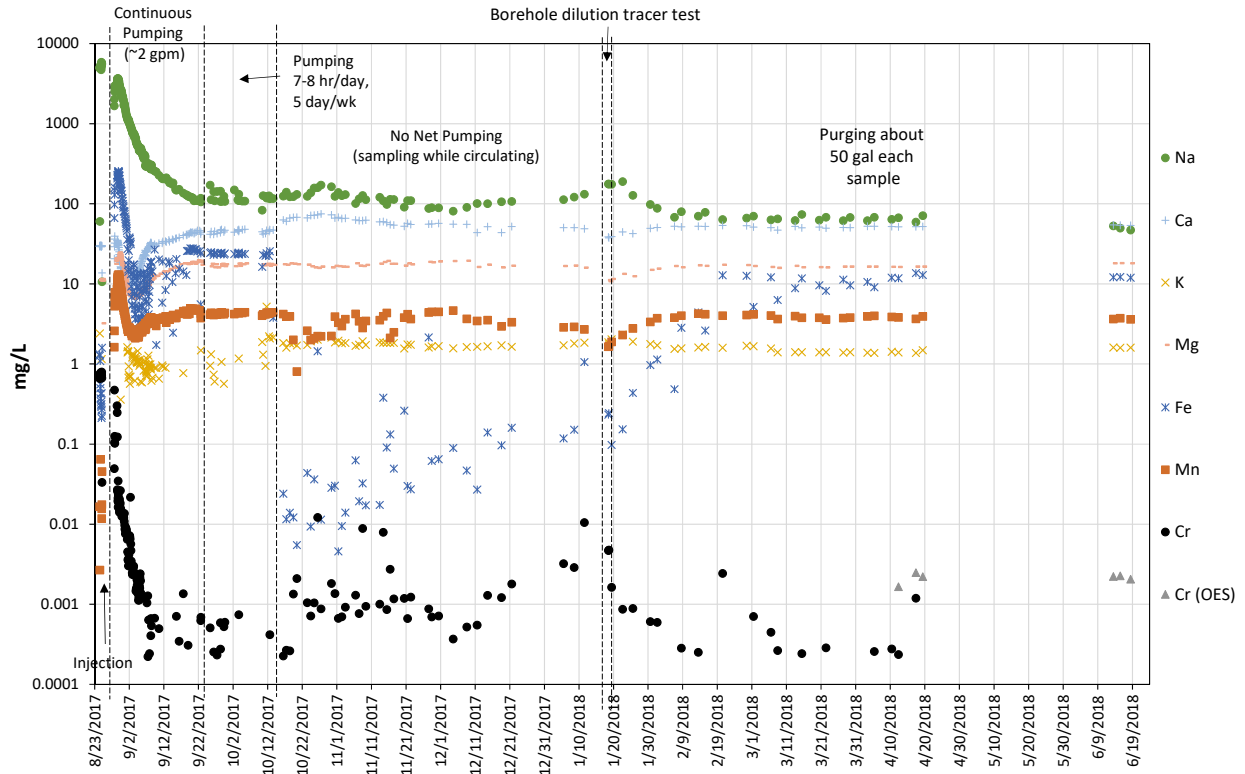
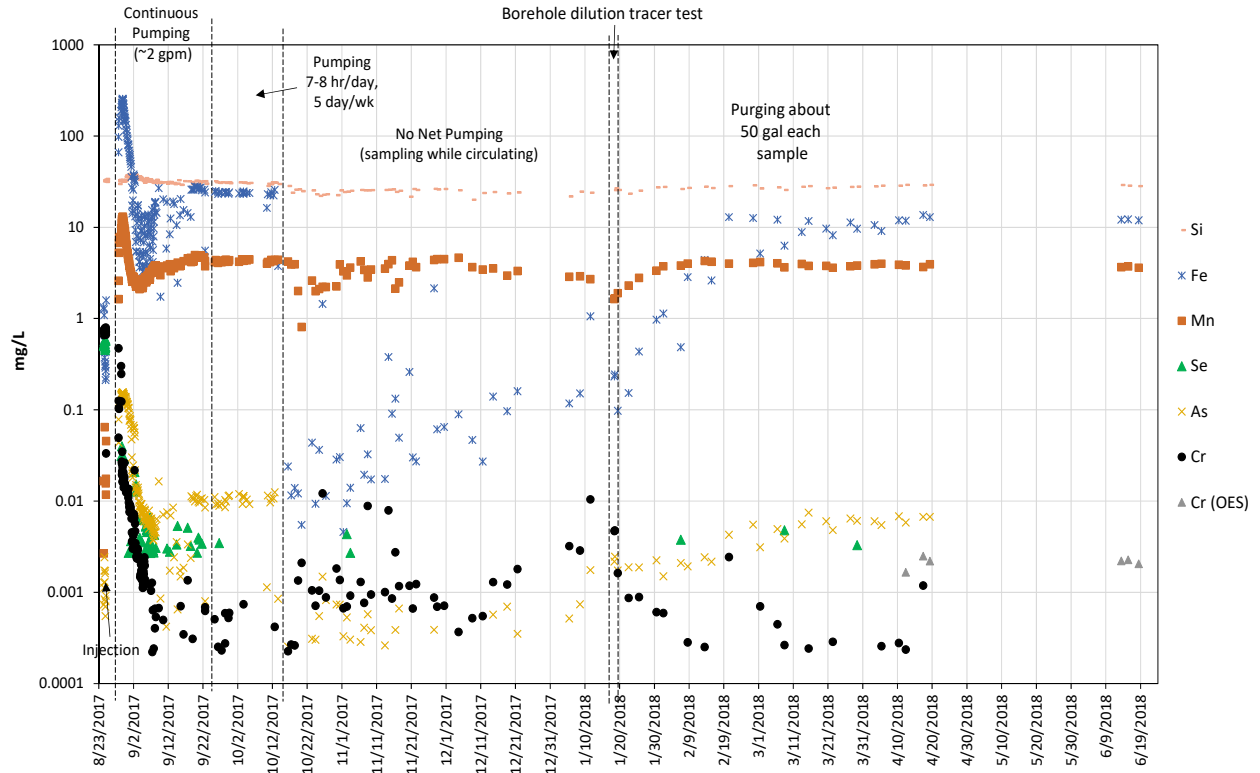


Figure 1.0-1 Map of the Cr(VI) plume showing locations of R-42 dithionite test and R-28 molasses test



Notes: Cr (OES) results are shown because Cr results from ICP-MS were not available for June 2018 samples.
 Pre-test concentration of Cr was approximately 0.8 mg/L, and pre-test concentrations of Fe and Mn were negligible.

Figure 2.1-1 Concentrations of selected cations and metals in R-42 dithionite test as a function of time



Notes: Cr (OES) results are shown because Cr results from ICP-MS were not available for June 2018 samples. Pre-test concentration of Cr was approximately 0.8 mg/L, and pre-test concentrations of Fe and Mn were negligible.

Figure 2.1-2 Concentrations of selected constituents during R-42 dithionite test as a function of time

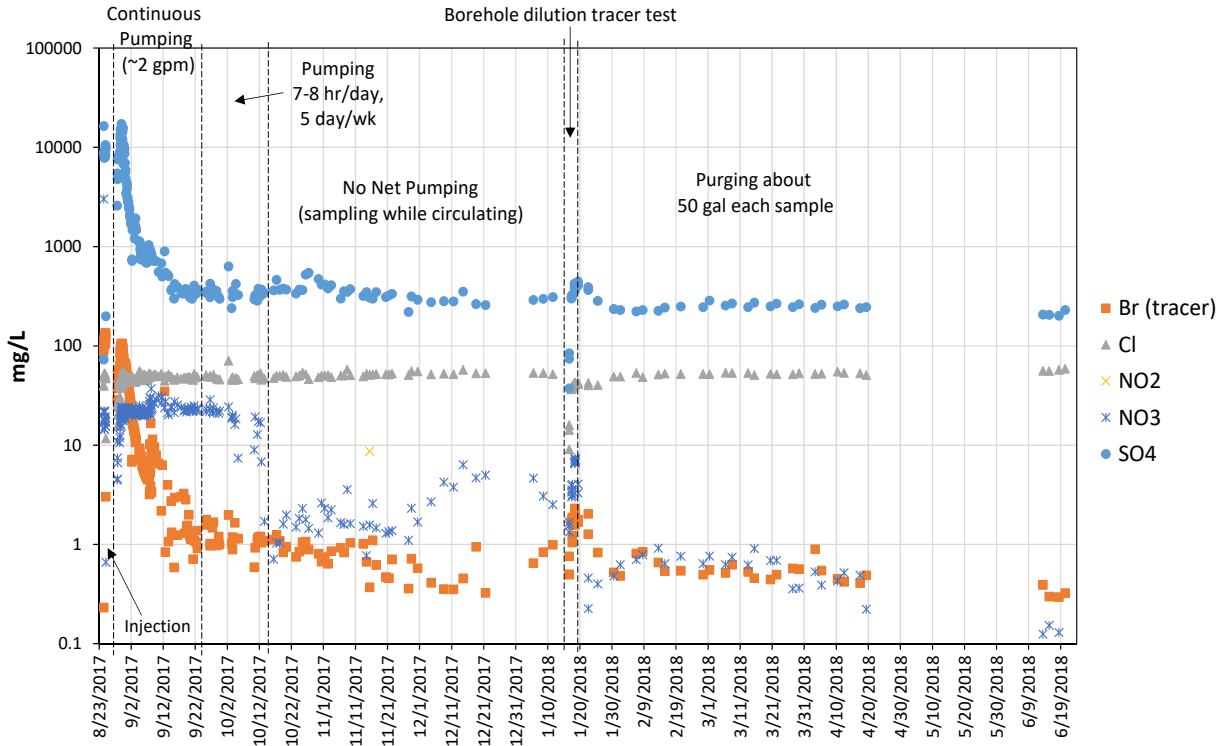
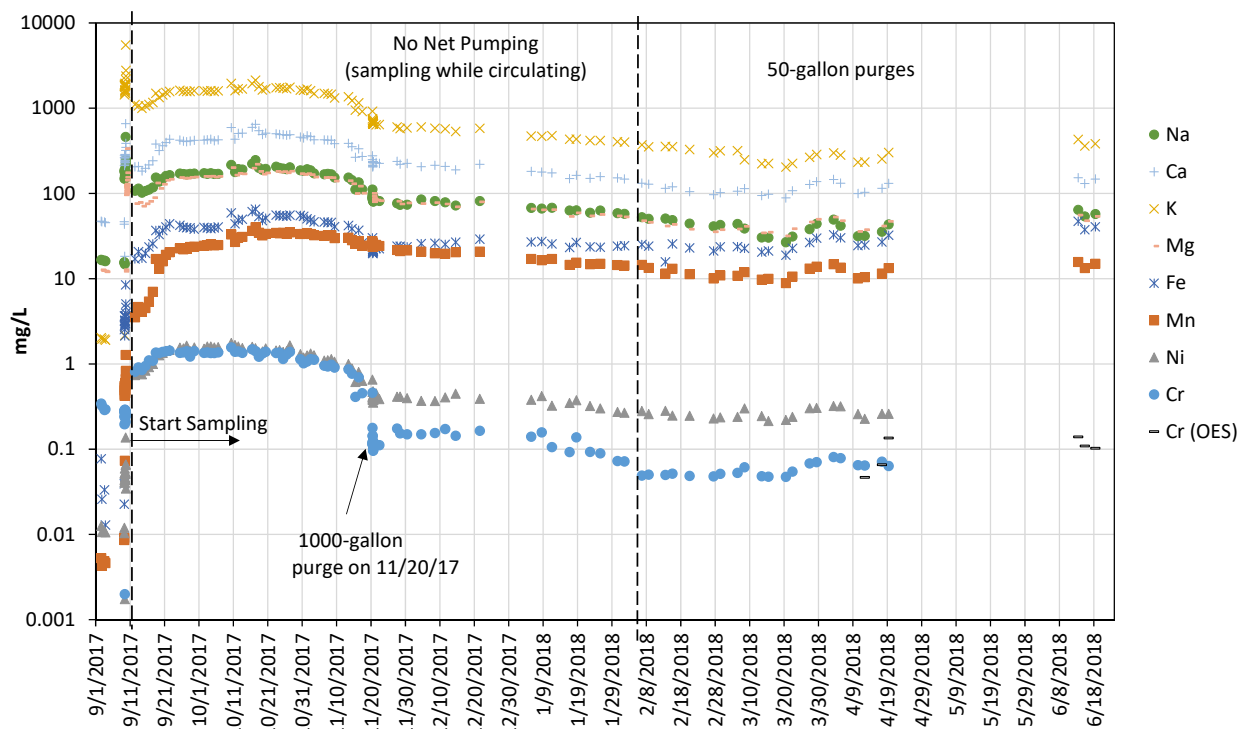
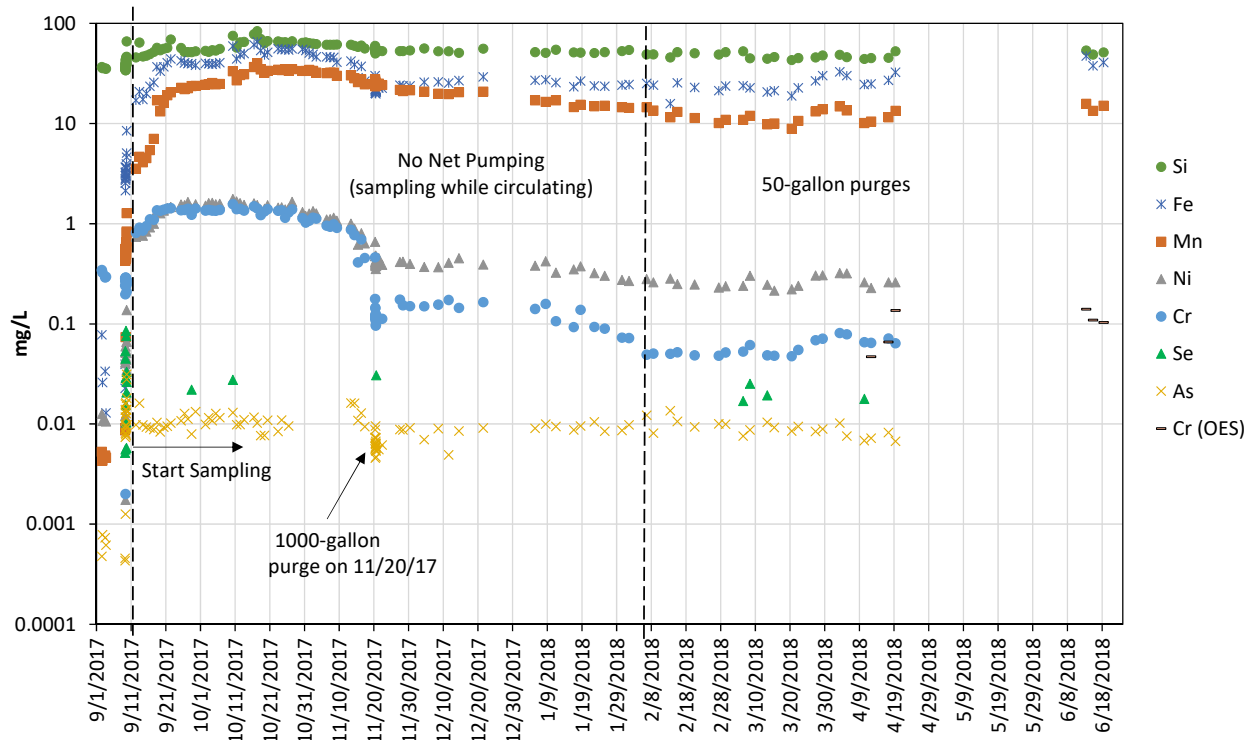


Figure 2.1-3 Concentrations of anions in R-42 dithionite test as a function of time



Notes: Cr (OES) results are shown because Cr results from ICP-MS were not available for June 2018 samples. Pre-test concentration of Cr was approximately 0.4 mg/L, and pre-test concentrations of Fe and Mn were negligible.

Figure 2.2-1 Concentrations of selected cations and metals in R-28 molasses test as a function of time



Notes: Cr (OES) results are shown because Cr results from ICP-MS were not available for June 2018 samples. Pre-test concentration of Cr was ~0.4 mg/L, and pre-test concentrations of Fe and Mn were negligible.

Figure 2.2-2 Concentrations of selected constituents during R-28 molasses test as a function of time

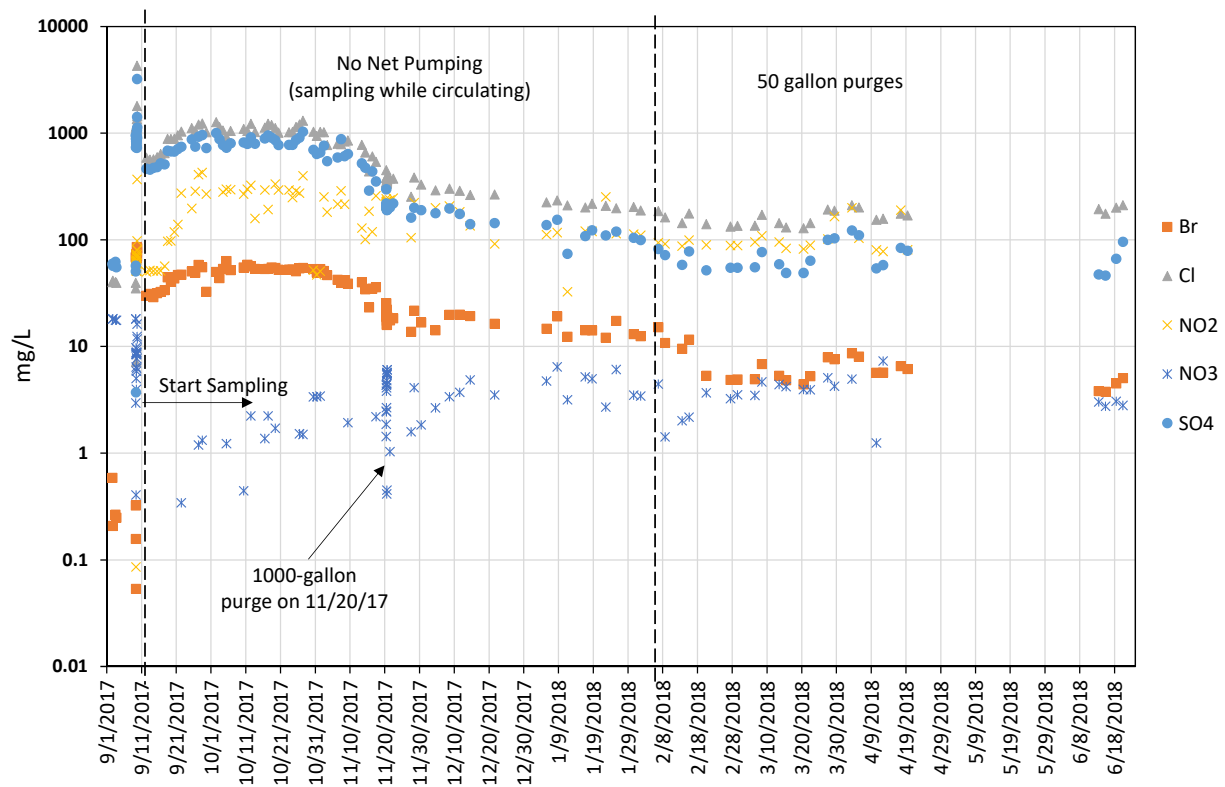
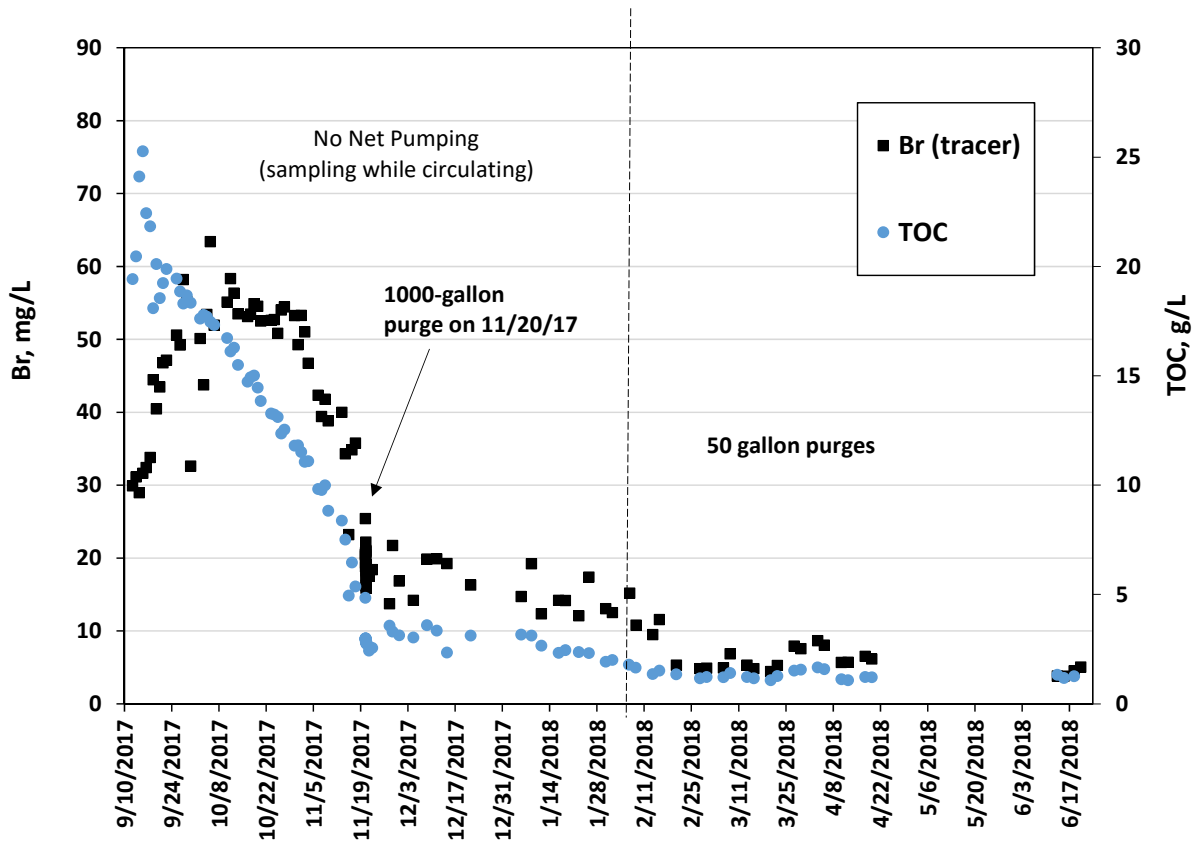


Figure 2.2-3 Concentrations of anions in R-28 molasses test as a function of time



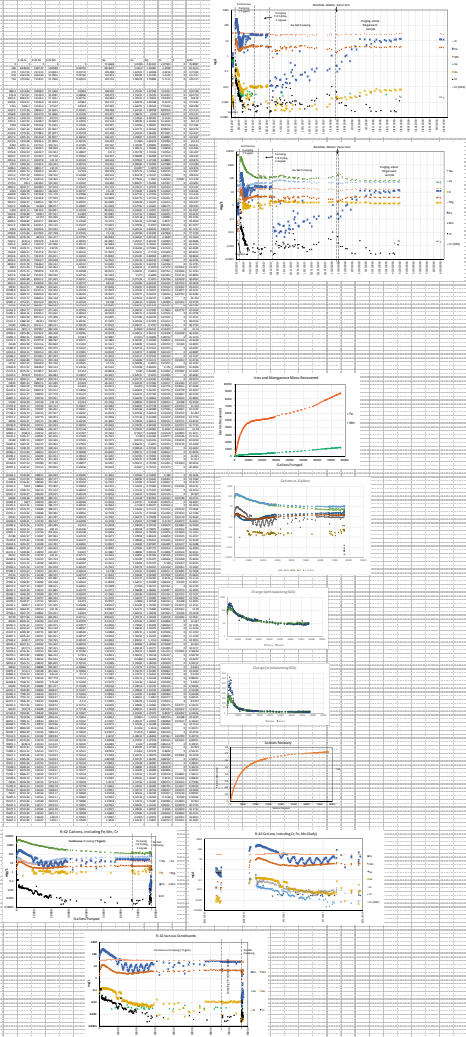
Note: Unlike other plots, concentrations scales are not logarithmic.

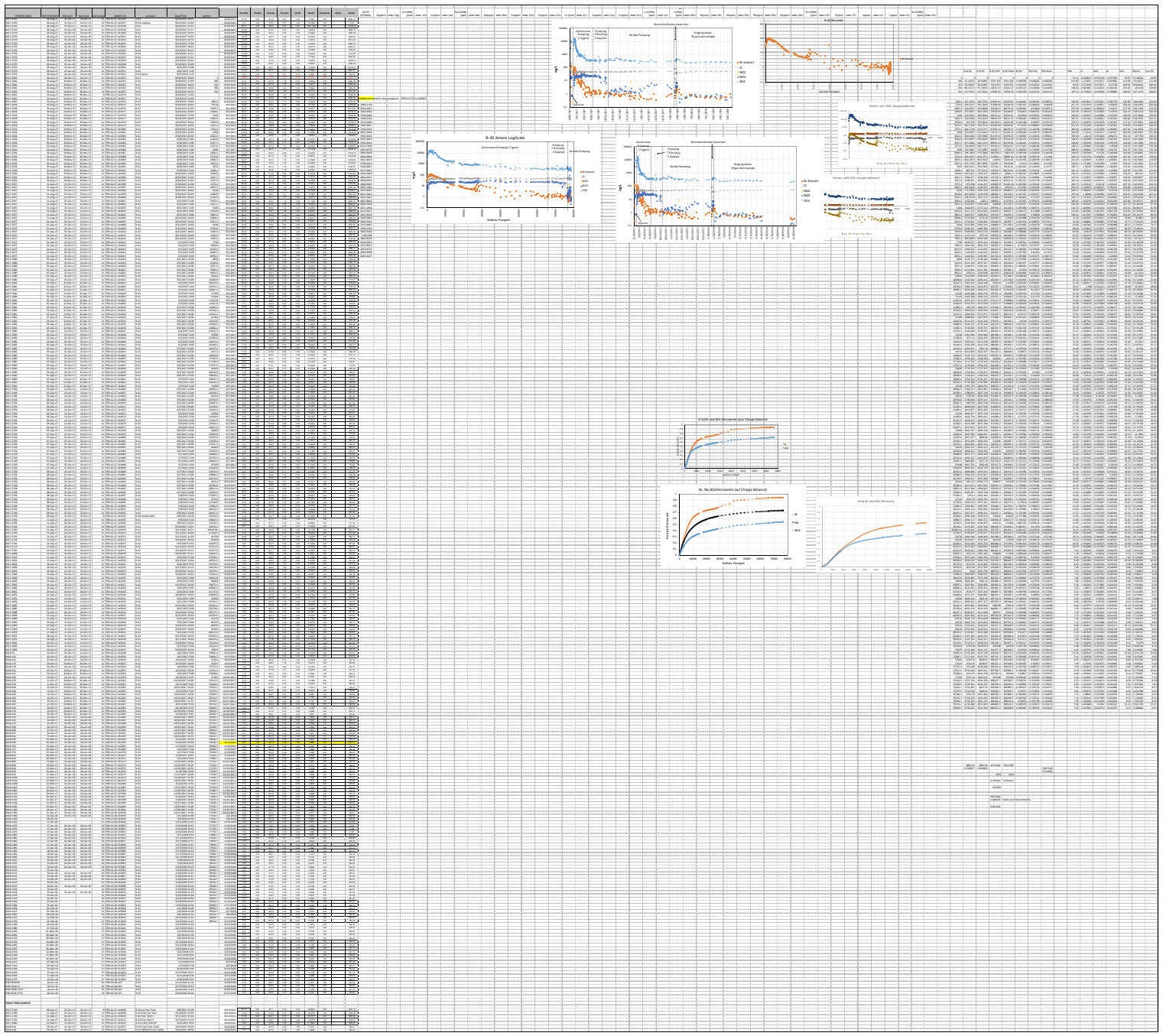
Figure 2.2-4 Concentrations of bromide and TOC in R-28 molasses test

Attachment 1

*Data Associated with Third Quarterly Report
on Pilot-Scale Amendments Testing for Chromium
in Groundwater Beneath Mortandad Canyon
(on CD included with this document)*

NO	DESCRIPTION	UNIT	QTY	AMOUNT	DATE	REMARKS
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SAMPLE ID	CoC	Collection Date	Date TOC	Comment	Conc actual method in mg/L	Conc in g/L	g/L genome equivalent
FR-28-17-142471	2017-2884	9/2/2017 24:35	9/1/2017	Water tank 6.5	1.35	0.00	0.00
FR-28-17-142479	2017-2884	9/2/2017 18:30	9/1/2017	Water tank 6.5	1.12	0.00	0.00
FR-28-17-142481	2017-2884	9/2/2017 12:30	9/1/2017		1.20	0.00	0.00
FR-28-17-142482	2017-2884	9/2/2017 18:30	9/1/2017		1.13	0.00	0.00
FR-28-17-142483	2017-2884	9/2/2017 12:30	9/1/2017		1.20	0.00	0.00
FR-28-17-142484	2017-2244	9/6/2017 7:45	9/1/2017		1.27	0.00	0.00
FR-28-17-142485	2017-2244	9/6/2017 8:45	9/1/2017	Chase Water	6301.78	0.04	0.04
FR-28-17-142486	2017-2244	9/6/2017 9:45	9/1/2017		7422.37	7.42	13.96
FR-28-17-142487	2017-2244	9/6/2017 10:45	9/1/2017		5041.39	5.04	13.96
FR-28-17-142488	2017-2244	9/6/2017 11:45	9/1/2017		6762.22	6.76	16.16
FR-28-17-142489	2017-2244	9/6/2017 12:45	9/1/2017		1.56	0.00	0.00
FR-28-17-142490	2017-2244	9/6/2017 13:45	9/1/2017		5463.63	5.49	13.73
FR-28-17-142491	2017-2244	9/6/2017 14:45	9/1/2017		6800.08	6.80	17.15
FR-28-17-142492	2017-2244	9/6/2017 15:45	9/1/2017		7188.21	7.14	17.66
FR-28-17-142493	2017-2244	9/6/2017 16:45	9/1/2017		6159.29	6.16	15.39
FR-28-17-142494	2017-2244	9/6/2017 17:45	9/1/2017		6215.34	6.22	15.54
FR-28-17-142495	2017-2244	9/6/2017 18:45	9/1/2017		6542.31	6.54	16.61
FR-28-17-142496	2017-2244	9/6/2017 19:45	9/1/2017		6225.30	6.22	15.54
FR-28-17-142497	2017-2244	9/6/2017 20:45	9/1/2017		7629.05	7.63	19.07
FR-28-17-142498	2017-2244	9/6/2017 21:45	9/1/2017		6621.69	6.63	16.61
FR-28-17-142499	2017-2244	9/6/2017 22:45	9/1/2017		6664.95	6.66	17.16
FR-28-17-142500	2017-2247	9/6/2017 15:30	9/1/2017		7241.03	7.22	18.00
FR-28-17-142501	2017-2247	9/6/2017 15:30	9/1/2017		6026.34	6.06	15.40
FR-28-17-142502	2017-2247	9/6/2017 16:25	9/1/2017		6826.51	6.83	17.07
FR-28-17-142503	2017-2247	9/6/2017 17:30	9/1/2017		1926.58	1.96	47.40
FR-28-17-142504	2017-2247	9/6/2017 17:30	9/1/2017		10162.13	10.16	25.41
FR-28-17-142505	2017-2247	9/6/2017 18:00	9/1/2017		8692.15	8.69	21.48
FR-28-17-142506	2017-2753	9/14/2017 10:20	9/1/2017		19420.82	19.42	48.55
FR-28-17-142507	2017-2753	9/14/2017 10:20	9/1/2017		20484.84	20.48	51.14
FR-28-17-142508	2017-2782	9/14/2017 10:05	9/20/2017		24112.24	24.11	60.28
FR-28-17-142509	2017-2813	9/14/2017 11:00	9/20/2017		24242.32	24.24	59.68
FR-28-17-142510	2017-2813	9/14/2017 11:00	9/20/2017		21627.75	21.63	54.08
FR-28-17-142511	2017-2815	9/14/2017 11:55	9/20/2017		18022.39	18.02	45.23
FR-28-17-142512	2017-2845	9/14/2017 10:45	9/20/2017		20111.02	20.11	50.28
FR-28-17-142513	2017-2861	9/14/2017 10:50	9/20/2017		18025.39	18.03	45.30
FR-28-17-142514	2017-2877	9/14/2017 10:55	9/20/2017		19244.47	19.24	48.10
FR-28-17-142515	2017-2887	9/14/2017 10:45	9/20/2017		19845.01	19.85	49.17
FR-28-17-142516	2017-2893	9/14/2017 11:00	9/20/2017		19445.68	19.45	48.62
FR-28-17-142517	2017-2894	9/14/2017 11:00	9/20/2017		18833.50	18.83	47.13
FR-28-17-142518	2017-2920	9/17/2017 9:50	9/20/2017		18336.55	18.31	45.77
FR-28-17-142519	2017-2949	9/17/2017 11:00	9/20/2017		18021.69	18.02	45.23
FR-28-17-142520	2017-3004	9/29/2017 15:15	10/30/2017		18344.94	18.34	45.86
FR-28-17-142521	2018-34	10/2/2017 11:00	10/18/2017		1761.13	1.76	44.01
FR-28-17-142522	2018-99	10/3/2017 10:00	10/18/2017		17780.86	17.78	44.48
FR-28-17-142523	2018-134	10/6/2017 10:00	10/18/2017		17780.86	17.78	44.47
FR-28-17-142524	2018-221	10/9/2017 10:55	10/18/2017		1468.56	1.47	43.67
FR-28-17-142525	2018-271	10/6/2017 14:30	10/18/2017		17325.54	17.33	43.31
FR-28-17-142526	2018-302	10/2/2017 9:40	10/18/2017		16726.53	16.73	42.60
FR-28-17-142527	2018-370	10/12/2017 20:45	10/18/2017		18120.10	18.12	46.10
FR-28-17-142528	2018-443	10/13/2017 15:00	10/18/2017		14625.50	14.63	36.73
FR-28-17-142529	2018-480	10/13/2017 11:15	10/18/2017		14727.00	14.73	37.00
FR-28-17-142530	2018-491	10/17/2017 9:35	10/18/2017		14027.33	14.04	37.34
FR-28-17-142531	2018-508	10/18/2017 11:00	10/18/2017		15011.32	15.01	37.53
FR-28-17-142532	2018-532	10/19/2017 11:30	11/6/2017		14427.00	14.46	36.14
FR-28-17-142533	2018-542	10/20/2017 8:00	11/6/2017		13844.00	13.84	34.63
FR-28-17-142534	2018-543	10/24/2017 10:35	11/6/2017		13370.88	13.37	33.18
FR-28-17-142535	2018-544	10/24/2017 10:35	11/6/2017		13224.47	13.22	32.07
FR-28-17-142536	2018-572	10/25/2017 10:30	11/6/2017		13116.16	13.12	31.79
FR-28-17-142537	2018-590	10/26/2017 10:40	11/6/2017		12386.82	12.39	30.89
FR-28-17-142538	2018-600	10/27/2017 10:30	11/6/2017		12461.92	12.44	31.36
FR-28-17-142539	2018-627	10/29/2017 10:30	11/6/2017		11877.80	11.81	29.52
FR-28-17-142540	2018-645	10/31/2017 10:30	11/6/2017		11623.60	11.62	28.96
FR-28-17-142541	2018-669	11/1/2017 10:10	11/6/2017		11514.89	11.52	28.80
FR-28-17-142542	2018-684	11/2/2017 10:00	11/6/2017		11069.24	11.07	27.66
FR-28-17-142543	2018-705	11/3/2017 10:20	11/6/2017		11025.09	11.10	27.74
FR-28-17-142544	2018-717	11/6/2017 9:45	11/6/2017		8654.45	8.65	24.88
FR-28-17-142545	2018-735	11/7/2017 10:00	11/6/2017		8777.41	8.78	24.44
FR-28-17-142546	2018-802	11/9/2017 10:00	11/6/2017		8992.82	8.99	24.88
FR-28-17-142547	2018-836	11/9/2017 8:45	11/6/2017		8627.07	8.63	22.07
FR-28-17-142548	2018-866	11/21/2017 10:00	11/6/2017		8373.75	8.37	20.03
FR-28-17-142549	2018-889	11/21/2017 10:30	11/6/2017		7512.63	7.51	18.78
FR-28-17-142550	2018-920	11/21/2017 10:30	11/6/2017		6485.53	6.49	16.26
FR-28-17-142551	2018-949	11/21/2017 10:30	11/6/2017		6465.79	6.47	16.16
FR-28-18-130057	2018-952	11/21/2017 10:40	11/28/2017		5369.80	5.37	13.42
FR-28-18-130058	2018-955	11/20/2017 10:40	11/28/2017		4822.00	4.82	12.13
FR-28-18-130040	2018-955	11/20/2017 10:40	11/28/2017		2981.73	2.98	7.45
FR-28-18-130041	2018-955	11/20/2017 10:40	11/28/2017		2992.87	2.99	7.41
FR-28-18-130042	2018-955	11/20/2017 10:40	11/28/2017		2972.92	2.97	7.43
FR-28-18-130043	2018-955	11/20/2017 11:40	11/28/2017		2944.23	2.94	7.36
FR-28-18-130044	2018-955	11/20/2017 11:40	11/28/2017		3000.77	3.00	7.50
FR-28-18-130045	2018-955	11/20/2017 11:40	11/28/2017		2984.07	2.98	7.48
FR-28-18-130046	2018-955	11/20/2017 12:00	11/28/2017		2987.74	2.99	7.22
FR-28-18-130047	2018-955	11/20/2017 12:20	11/28/2017		2975.10	2.98	7.44
FR-28-18-130048	2018-955	11/20/2017 12:40	11/28/2017		2958.81	2.94	7.35
FR-28-18-130049	2018-955	11/20/2017 13:00	11/28/2017		2989.50	2.99	7.25
FR-28-18-130050	2018-955	11/20/2017 13:20	11/28/2017		2935.48	2.94	7.09
FR-28-18-130051	2018-955	11/20/2017 13:40	11/28/2017		2999.68	2.99	7.24
FR-28-18-130052	2018-955	11/20/2017 14:00	11/28/2017		2971.96	2.97	7.29
FR-28-18-130053	2018-955	11/20/2017 14:20	11/28/2017		2839.32	2.84	7.10
FR-28-18-130054	2018-955	11/20/2017 14:40	11/28/2017		2915.01	2.92	7.04
FR-28-18-130055	2018-955	11/20/2017 15:00	11/28/2017		2846.19	2.85	7.12
FR-28-18-130056	2018-955	11/20/2017 15:20	11/28/2017		2971.40	2.97	6.88
FR-28-18-130057	2018-955	11/20/2017 15:40	11/28/2017		2624.77	2.62	7.08
FR-28-18-130058	2018-955	11/20/2017 16:00	11/28/2017		2783.72	2.78	6.98
FR-28-18-130059	2018-955	11/20/2017 16:20	11/28/2017		2625.26	2.61	7.02
FR-28-17-130055	2018-2084	11/22/2017 10:50	13/20/18		2453.90	2.45	6.08
FR-28-17-130056	2018-2027	11/22/2017 10:50	13/20/18		2465.97	2.46	6.40
FR-28-17-130054	2018-2042	11/22/2017 13:35	13/20/18		3070.63	3.07	8.93
FR-28-17-130053	2018-2044	11/22/2017 20:40	13/20/18		3026.96	3.03	7.58
FR-28-17-130052	2018-1113	11/16/2017 20:40	13/20/18		3137.48	3.14	7.84
FR-28-17-130051	2018-1214	12/1/2017 14:10	13/20/18		3569.93	3.56	8.99
FR-28-17-130050	2018-1283	12/14/2017 14:10	13/20/18		3344.15	3.34	8.36
FR-28-17-130049	2018-1283	12/14/2017 14:10	13/20/18		2338.42	2.34	5.85
FR-28-17-130048	2018-1357	12/15/2017 8:45	13/20/18		3124.44	3.12	7.81
FR-28-17-130047	2018-1389	1/1/2018 12:15	13/20/18		3168.38	3.17	7.9

Days	1,6 NDS, mg/L
	0.002
5.722222	26.62322
5.722222	
6.760417	36.80631
6.760417	
7.75	26.31745
7.75	
8.989583	23.40903
8.989583	
9.743056	32.62933
9.743056	
10.98958	39.80755
10.98958	
11.75347	41.72587
11.75347	
12.8125	65.73754
12.8125	
13.73958	123.8604
13.73958	
14.72917	74.628
14.72917	
15.65625	92.70256
15.65625	
16.64583	89.90441
16.64583	
17.78125	80.75369
17.78125	
18.69792	93.24925
18.69792	
19.76389	125.4674
19.76389	
20.71181	159.9196
20.71181	
21.72917	136.1967
21.72917	
23.00486	108.0778
23.00486	
23.94514	114.1412
23.94514	
24.72917	106.8652
24.72917	
25.76736	131.9523
25.76736	
26.72222	132.3313
26.72222	
27.89236	133.3166
27.89236	
28.70486	144.458
28.70486	
29.89583	135.3956
29.89583	
30.89861	85.33958
30.90208	
31.71528	135.4757
31.71528	
32.72222	131.9518
32.72222	
33.71875	123.5424
33.71875	
34.78125	117.3935
34.78125	
35.74653	117.0843
35.74653	
36.95139	102.8582
36.95139	
37.96875	101.3892
37.96875	
38.72569	84.37977
38.72569	
39.71181	84.08056
39.71181	
40.73958	97.67596
40.73958	
41.72222	101.6381
41.72222	
42.92014	88.81953
42.92014	
45.74653	38.71077
45.74653	
46.71528	24.8823
46.71528	
47.71875	65.02342
47.71875	
48.75	67.78389
48.75	
49.74653	55.40381
49.74653	
52.75	59.68278
52.75	
53.93056	55.64745
53.93056	
54.72222	47.01337
54.72222	
59.77431	40.47309
59.77431	
60.72222	16.99966
60.72222	
61.76389	32.07504
61.76389	
	15.416
	12.812
66.79861	14.495
66.79861	
67.74653	17.674
67.74653	
68.79167	16.672
68.79167	
69.73958	13.62719
69.73958	
70.77431	
73.78819	8.204439
73.78819	
74.85764	7.662369
74.85764	
75.77778	11.21332
75.77778	
76.80208	24.094
76.80208	
77.87153	
77.87153	
80.87847	
80.87847	
81.79167	
81.79167	
82.92708	
82.92708	

R-42					R-28					
15 - 600 gallon batches					20 -1500 gallon batches					
9000	gallons	1000 gallon chase			30000	gallons	1500 gallons of 10% ethanol as chase			
	lb	kg	moles	mol/L	NaBr	10 kg total				
Na2SO3	555	251.859	1998.881	0.058678						
Na2S2O4	750	340.35	1956.034	0.057421						
NaBr	11.025	5.003145								
Moles NaBr		48.59086	97.18173							
Molarity NaBr		0.001426	0.000856							