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DEPARTMENT OF ENERGY
Environmental Management Los Alamos Field Office (EM-LA)
Los Alamos, New Mexico 87544

EMLA-2020-1472-02-001

June 25, 2020

Mr. Kevin Pierard
Bureau Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505-6313

Subject: Submittal of the Eighth Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon, October 2019 to March 2020

Dear Mr. Pierard:

Enclosed please find two hard copies with electronic files of the “Eighth Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon, October 2019 to March 2020.” This report includes updates to the ongoing study at regional groundwater monitoring wells R-42 and R-28 as discussed with the New Mexico Environment Department in a pre-submission meeting held on April 29, 2020.

If you have any questions, please contact Danny Katzman at (505) 309-1371 (danny.katzman@em-la.doe.gov) or Cheryl Rodriguez at (505) 414-0450 (cheryl.rodriguez@em.doe.gov).

Sincerely,

Arturo Duran
Digitally signed by Arturo Duran
Date: 2020.06.24 06:32:36 -06'00'

Arturo Q. Duran
Compliance and Permitting Manager
Environmental Management
Los Alamos Field Office

Enclosures:

1. Two hard copies with electronic files – Eighth Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon, October 2019 to March 2020 (EM2020-0253)

CC (letter and enclosure[s] emailed):
Laurie King, EPA Region 6, Dallas, TX
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Pamela T. Maestas

From: Martinez, Cynthia, NMENV <cynthia.martinez1@state.nm.us>
Sent: Thursday, June 25, 2020 12:00 PM
To: Pamela T. Maestas
Subject: RE: Submittal to NMED on 6/25/2020 of 8th Cr Amendments Testing Rpt

received

From: Pamela T. Maestas <pamela.maestas@em-la.doe.gov>
Sent: Thursday, June 25, 2020 11:44 AM
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Subject: [EXT] Submittal to NMED on 6/25/2020 of 8th Cr Amendments Testing Rpt

Mr. Pierard,
Attached for submittal is the following:

- Submittal of the Eighth Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon, October 2019 to March 2020 (pdf of letter and enclosure; zip file of Attachment 1 to the enclosure)

Please acknowledge receipt of this submittal by responding to this email.
Let me know if you have any questions.
Thank you.

Pamela T. Maestas
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June 2020
EM2020-0253

Eighth Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon, October 2019 to March 2020

EM2020-0253

Eighth Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon, October 2019 to March 2020

June 2020

Responsible program director:

Bruce Robinson		Program Director	Water Program	6/12/20
Printed Name	Signature	Title	Organization	Date

Responsible N3B representative:

Kim Lebak	Kimberly D Lebak	Program Manager	N3B Environmental Remediation Program	6/12/20
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Responsible DOE EM-LA representative:

Arturo Q. Duran	Arturo Duran Digitally signed by Arturo Duran Date: 2020.06.24 06:33:09 -06'00'	Compliance and Permitting Manager	Office of Quality and Regulatory Compliance	
Printed Name	Signature	Title	Organization	Date

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Attachment 1	Data Associated with Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon, October 2019 to March 2020 (on CD included with this document)

Acronyms and Abbreviations

Cr(III)	trivalent chromium
Cr(VI)	hexavalent chromium
EIM	Environmental Information Management (system)
gpm	gallons per minute
LANL	Los Alamos National Laboratory
LANS	Los Alamos National Security, LLC
N3B	Newport News Nuclear BWXT-Los Alamos, LLC
NMED	New Mexico Environment Department
ppb	parts per billion
ROI	radius of influence
TOC	total organic carbon

1.0 INTRODUCTION

This eighth report presents results of two pilot-scale amendment tests 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 amendment treatments 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 deployment 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 amendment treatments on near-well hydraulic conductivity. The third and fourth quarterly reports (N3B 2018, 700032; N3B 2018, 700108) provided an update of the geochemistry data from the two amendments tests. The fifth quarterly report provided updates on the geochemistry at R-42 and R-28, including data from extended purge events conducted in October and November 2018 (the "October 2018 purge"), and additional samples collected in December 2018 (N3B 2019, 700214).

The sixth quarterly report (N3B 2019, 700420) provided an evaluation of groundwater geochemistry from the first sampling event conducted in March 2019 as the beginning of a series of events that employed time-series sampling during 350-gal. or 1000-gal. purges at R-42 and R-28. The report also included an updated analysis of hydraulic behavior at the two wells to explore insights into whether there have been reductions in aquifer permeability associated with the tests. An analysis providing estimates of the amount of chromium reduction to date at each of the two test wells was also presented.

The seventh report (N3B 2019, 700723) provided updates and evaluations of ongoing geochemical conditions at both R-42 and R-28. The report summarized results and analysis of a cross-hole tracer test executed between CrPZ-1 and CrEX-2, in March through April of 2019, as a candidate location for potential future cross-hole amendment testing. Laboratory tests and results related to studies of the geochemical conditions at CrEX-3 were also presented.

This eighth report provides an update of geochemical conditions at both R-42 and R-28, based on three sampling events conducted from October through December of 2019. An update of the estimated amounts of Cr(VI) reduced at each of the two amendment test locations through the end of December 2019 is also presented. Potential hydrological impacts of the amendment deployments on the aquifer were discussed in the second and sixth reports on pilot-scale amendments testing for chromium (LANL 2018, 603031; N3B 2019, 700420). Further evaluation of hydrologic conditions at both wells will be provided in a future report after pending workover/rehabilitation activities and borehole dilution tracer tests at R-42 and R-28 are conducted in accordance with the NMED-approved Supplemental Amendments Testing Work Plan, (N3B 2019, 700698). The workover/rehabilitation activities are intended to reduce or eliminate potential near-well or in-well conditions (e.g., screen or filter-pack biofilms) that could adversely affect permeability or create near-well geochemically reducing conditions that are not representative of conditions further into the aquifer.

An update of the evaluation of geochemical conditions at CrEX-3 and how those conditions might be influenced by the molasses deployment at R-28 is not included in this report because no new sampling has been conducted at CrEX-3 since the previous report. An update will be provided in the next report after the pending workover/rehabilitation of CrEX-3 (N3B 2019, 700723), which is expected to yield new information to assess geochemical and biological conditions at CrEX-3.

All of 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).

2.0 UPDATE OF AMENDMENT TEST GEOCHEMISTRY RESULTS FOR R-42 AND R-28

2.1 Sodium Dithionite at R-42

Overall, conditions at R-42 through December 2019 remain similar to those presented in the previous amendments testing report (N3B 2019, 700723). Some trends are apparent and are described below. This section provides details, including observations made regarding amendment test objectives during this reporting period. Conditions continue to show Cr(VI) reduction. In addition to the very low concentrations of total filtered chromium that are observed, a few other chemical indicators also suggest the persistence of reducing conditions. These include significantly elevated dissolved-phase iron and manganese. Persistence of ancillary geochemical effects has also been observed. For example, the concentration of arsenic briefly rose to approximately 0.16 mg/L following the September 2017 amendment deployment. Although concentrations significantly fell within a few weeks of the deployment, arsenic has persisted and been observed at concentrations up to approximately 0.02 mg/L as recently as the summer of 2019. Concentrations decreased to around a few parts per billion (ppb) from August to December 2019. Although manganese concentrations continue to fall from significantly elevated levels immediately following the amendment deployment, they also persist above pre-amendment concentrations. Similarly, although sulfate levels have been falling following elevated deployment levels, they are still elevated above pre-amendment concentrations.

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. Operational timelines and operational descriptions are shown in Figure 2.1-1. The approximate timeline for the August 2017 injection batches is plotted as the earliest of the vertical dashed timelines. Operational activities following the amendment injection included the start of continuous pumping of R-42 in August 2017, and then the subsequent transition in September 2017 to pumping 5 days/wk (8 hr/day) from the well. This pumping was stopped in October 2017 when samples were collected by circulating water to the surface and returning it to the screened interval employing a closed-loop sampling mode and affecting minimal net withdrawal from the aquifer. Biweekly 50-gal. purges (sampling after withdrawal of 50 gal. with none of the purge water being returned to the aquifer) were initiated after a dilution tracer test was conducted in January 2018, as described in the second quarterly report (LANL 2018, 603031). There was no purging/sampling from April 19 to June 13, 2018. This hiatus is a result of the transition of environmental work conducted by the U.S. Department of Energy Environmental Management Los Alamos Field Office's contractor Los Alamos National Security, LLC (LANS) to Newport News Nuclear BWXT-Los Alamos, LLC (N3B) beginning on April 30, 2018. From October 22 and until November 2, 2018, an extended semi-continuous purge and sampling event was conducted at approximately 3 gallons per minute (gpm) (2.9 gpm) for 170 hr during the period. This 3-gpm purge and sampling event was conducted to obtain samples representing groundwater at greater distance from the well than is achieved during the 50-gal. purges. Starting on March 19, 2019, time-series sampling over purges of either 1000 gal. or 350 gal. were performed. In the case of 1000-gal. purges, four samples were taken at times spread throughout each purge (at 50, 350, 700, and 1000 gal.). Similarly, in the case of 350-gal. purges, two samples were taken over each purge (one after 50 gal. and the other after 350 gal.). The goal of time-series sampling over longer purging periods is to obtain samples representing groundwater both near the well and further into the aquifer than is achieved during 50-gal. purges. The most recent sampling event included in this reporting period was performed on December 10, 2019. Additional sampling was paused during preparations for the planned workover/rehabilitation of R-42 and, more recently, because of the cessation of field activities associated with the COVID-19 pandemic shutdown, which began formally during the week of March 23, 2020.

Figures 2.1-2 through 2.1-7 provide concentration histories of selected constituents along with operational timelines and descriptive text. Some figures represent periods that, like those shown in Figure 2.1-1, started approximately 1 mo before amendment injections. Other figures focus on briefer, more recent periods.

Cr(VI) concentrations (measured as total chromium) in R-42 decreased to below the New Mexico groundwater standard of 0.05 mg/L soon after the dithionite deployment and have remained well below this level. Since the beginning of 2018, chromium concentrations have remained at levels below 0.01 mg/L (Figure 2.1-1), which suggests that the aquifer in the vicinity of R-42 maintains sufficiently reducing conditions to reduce and immobilize Cr(VI). The pH before, during, and following the October 2018 purge ranged from approximately 6.6 to 7.6 standard units. This value remains significantly lower than pre-deployment values that were near 8.0. The persistence of these lower pH values is indicative of a continued influence from geochemical reactions following the dithionite deployment.

Dissolved iron was initially generated after the dithionite injection (Figure 2.1-1). There was a period in late 2017 when iron was lower, likely because of the use of a closed sampling circulation loop. The loop drew water from the well and up to the surface sampling point and then returned water back down into the well. In the process, atmospheric oxygen was likely introduced into the well causing downhole oxidation of iron, thus decreasing iron concentrations in samples. Concentrations of dissolved iron increased to over 10 mg/L in early 2018 after 50-gal. purges were initiated and persisted at similarly elevated levels until about March 2019 when 350-gal. and 1000-gal. purges began to consistently draw concentrations below 10 mg/L (Figure 2.1-2). Time-series samples from each purge started with higher iron concentrations, which fell during the extended purging. Most recently, as seen for samples taken from August through December 2019, the first sample collected at the beginning of each purge showed iron at a concentration of several milligrams per liter and the latter purge sample fell below that in each case. These intra-purge drops in iron concentration suggest that geochemically reducing conditions are more reducing inside or near the well than outside of it. There also appears to be a trend during the same period wherein the concentration fell from month to month. Although these decreases, both in terms of the trend during any single purge and from month to month, may indicate a trend back towards pre-amendment conditions, concentrations are still significantly above pre-amendment iron levels of approximately 0.01 to 0.1 mg/L.

Like iron, arsenic exhibited elevated levels up to approximately 0.16 mg/L, shortly after dithionite amendment injection, and has generally trended with iron since then (Figure 2.1-2). The highest arsenic concentrations since the first few weeks after the deployment were observed following the October 2018 extended purge (~0.02 mg/L), and, like iron, arsenic concentrations have decreased during the most recent sampling events. Concentrations of manganese have fallen in the 350-gal. and 1000-gal. purges from March to December 2019 (Figures 2.1-1 and 2.1-3). Like iron, the recent manganese level (approaching 2 mg/L) remains well above pre-amendment levels (approximately 0.001 mg/L) and indicates persistent reducing conditions. Unlike iron, the manganese concentration has increased slightly over the individual course of each 350-gal. or 1000-gal. time-series purge.

Figures 2.1-4 presents sodium and sulfate trends. The amendment solution, containing sodium dithionite and sodium sulfite (and to a lesser extent sodium bromide), was the origin of the elevated sodium. These chemicals also provided the sulfur that acted as the primary sulfur source that produced sulfate through oxidation reactions. Sulfate has been the most prominently elevated anion measured in R-42 since the amendment deployment. Sodium helped ionically balance sulfate (i.e., maintain charge balance) in samples following the time of the deployment. Sulfate and sodium levels initially concurrently spiked upwards following amendment deployment and then subsequently trended downwards, the rate of decrease in their concentrations slowed over time as the concentrations asymptotically approached pre-amendment levels. The October 2018 extended purge drew increasing levels of sodium and sulfate during the beginning of the purge period followed by falling concentrations. The 350-gal. and 1000-gal. purges from March to December 2019 have each acted like the beginning of the October 2018 extended purge, as both sodium and sulfate have risen over the course of each of these more recent, shorter purges. Month-to-month concentrations of both have remained relatively steady from June to December 2019.

Since June 2019, sodium concentrations at the end of purges have been falling to levels below those observed immediately preceding the amendment deployment (i.e., approximately 50 mg/L). Concentrations appear to be slowly trending towards lower values that may be representative of earlier well history (i.e., towards approximately 16 mg/L). Sodium concentrations just before the 2017 amendment deployment were already elevated above 2014–2015 levels from the lingering effects of a 2016 injection of sodium carbonate and bicarbonate into R-42. Calcium and magnesium concentrations appear to have stabilized at levels that exceed pre-deployment concentrations but are close to 2014–2015 concentrations measured before the perturbations associated with the sodium carbonate and bicarbonate injection in 2016.

Figures 2.1-5 and 2.1-6 illustrate the long-term and recent trends for both nitrate and nitrite. The nitrate has been depressed below pre-deployment levels since the end of the post-amendment pumping in 2017, consistent with continued reducing conditions in the R-42 samples from October 2017 to mid-October 2018. With the exception of a single outlying data point, nitrite was not detected during this period. As shown in Figure 2.1-6, upon the start of the October 2018 purge, nitrite appeared while nitrate nearly disappeared. The nitrate-to-nitrite flip appears to represent a shift that was close to stoichiometric in regard to nitrogen. In the recent time-series purges from March to December 2019, nitrate has risen to a similar level as before the October 2018 purge; nitrite has, during the period, continued a month-to-month drop back towards its pre-October 2018 value. These trends potentially indicate a return towards a more oxidative environment. However, nitrate is still at levels <1 mg/L, which is well below the pre-amendment level of approximately 20 mg/L. Increases in nitrate concentrations during each recent purging/sampling event suggest that the geochemical conditions inside R-42 are somewhat more reducing than just outside the well, consistent with the inferences from intra-purge iron concentration trends.

Figures 2.1-5 and 2.1-7 show long-term and recent trends for bromide. Bromide originated from the co-deployed amendment tracer (i.e., sodium bromide). The bromide was predominantly captured during the initial post-deployment months when continuous pumping was conducted. Bromide levels steadily trailed off until August 2018, when the concentration essentially reached pre-deployment levels of approximately 0.2 mg/L, indicating a return to ambient groundwater conditions with respect to conservative anions. Like sodium and other analytes previously described, bromide exhibited a modest increase in concentration during the October 2018 purge. The concentration held relatively stable in the sample following the purge. Although the increase in bromide was modest (from approximately 0.22 to 0.45 mg/L), the increase indicates that the October 2018 purge effectively reached further into the radius of influence (ROI) and possibly also into downgradient migration zones, or into low permeability zones adjacent to the well that the previous 50-gal. purges did not access. In the recent time-series purges from March to December 2019, bromide has held in a similar range (approximately 0.3 to 0.4 mg/L) as was observed during the October 2018 purge. With one exception, each of the purges since March 2019 has started at a higher value in the range and then fallen as the purge progressed.

Concentrations of other constituents either remain close to pre-amendment levels (e.g., potassium and chloride) or levels that were observed in 2014/2015 before the 2016 injection of sodium carbonate and sodium bicarbonate into R-42 (e.g., calcium and magnesium) (Figures 2.1-1 and 2.1-5).

The 350-gal. and 1000-gal. purges from March through September 2019 suggest that ROI region(s) in the R-42 vicinity are still exhibiting reducing conditions; chromium and nitrate concentrations remain low while iron and manganese remain elevated. Additionally, dissolved oxygen remains low, at roughly 3.5 mg/L or lower, further indicative of continued reducing conditions.

Concentrations of other elements or ions not shown in Figures 2.1-1 through 2.1-7 can be found in Attachment 1 (on CD included with this document).

2.2 Molasses at R-28

Overall, conditions in purges through December 2019 remain similar to those following the extended purge in October 2018 (N3B 2019, 700214). Some modest trends following the purge are apparent and are described below. This section provides details, including observations regarding amendment test objectives made during this report period. Conditions continue to show Cr(VI) reduction. As at R-42, in addition to the very low concentrations of total filtered chromium that are observed, a few other chemical indicators suggest the persistence of reducing conditions. This includes a significant elevation in dissolved-phase iron. Persistence of some ancillary geochemical effects was also noted. Arsenic persists above pre-amendment levels. It appears to be exhibiting a moderate trend with declining concentrations following the October 2018 purge. Manganese concentrations persist above pre-amendment concentrations and may be exhibiting a moderate declining trend following the October 2018 purge. With the exception of one elevated result in October 2019, nickel levels have fallen to and stayed at pre-amendment levels. The pH rose significantly and achieved circum-neutral values during the October 2018 purge. It has not noticeably changed following that time and remains at values between approximately 6 and 7 standard units that are below pre-amendment values (approximately 8 standard units).

Figure 2.2-1 shows an updated plot of the concentration trends of selected dissolved cations and metals, including chromium, measured in samples collected from R-28 as a function of time. Operational timelines or other operational descriptions are also provided in Figure 2.2-1 (and in subsequent R-28 Figures 2.2-2 through 2.2-8). The approximate timeline for injection batches are plotted as the earliest of the vertical dashed lines presented on each figure. The other vertical dashed lines shown to the right indicate subsequent dates when operational activities were conducted. Chronologically, following the amendment injection, these operational activities included sampling while circulating water to the surface and returning it to the screened interval in a closed loop with no net withdrawal from the aquifer, sampling during a 1000-gal. purge, and a transition to 50-gal. purge sampling. Figure 2.2-1 shows no purging/sampling occurred from April 19 to June 13, 2018. This gap in sampling is a result of the transition of environmental work from LANS to N3B. From October 22 until November 2, 2018, an extended purge and sampling event was conducted at approximately 2.6 gpm for 170 hr. Starting on March 19, 2019, time-series sampling over purges of either 1000 gal. or 350 gal. were performed. In the case of 1000-gal. purges, four samples were taken at times spread throughout each purge (at 50, 350, 700, and 1000 gal.). Similarly, in the case of 350-gal. purges, two samples were taken over each purge (one after 50 gal. and the other after 350 gal.). The goal of time-series sampling over longer purging periods is to obtain samples representing groundwater both near the well and further into the aquifer than is achieved during 50-gal. purges. The last sampling event included in this reporting period was performed on December 10, 2019. Additional sampling was paused during preparations for the planned workover/rehabilitation of R-42 and, more recently, because of the cessation of field activities associated with the COVID-19 pandemic shutdown.

Figure 2.2-1 includes chromium and other cations and metals. Figures 2.2-2 and 2.2-3 focus on chromium, pH, total organic carbon (TOC), and oxalate. Following the injection, chromium concentrations increased to greater than 1.5 mg/L (Figure 2.2-1), likely associated with small-scale leaching of the stainless-steel well screen and casing when pH was initially very low. Following the 1000-gal. purge in November 2017, chromium concentrations declined from approximately 0.15 mg/L following the purge to approximately 0.065 mg/L in April 2018 (Figure 2.2-2). During this period, pH was low (less than 5.5, with two exceptions) likely because of the production of organic acids from fermentation. At these lower pH levels, organic acid concentrations are assumed to correlate with the concentration of TOC, which remained elevated, at approximately 1000 mg/L in April 2018. The data indicate that Cr(III) was produced from leaching of the stainless-steel well screen and/or casing at the observed pH levels, possibly complemented by complexation of Cr(III) by organic acids. The pH data were not collected from April until the October 2018 purge event. During this period, as TOC (and organic acids, by inference) declined, reaching a minimum of 102 mg/L on September 17, 2018 (Figure 2.2-3), and pH presumably increased, chromium concentrations decreased to below 0.05 mg/L. The concentrations of many constituents, including chromium, dropped sharply in July 2018, suggesting that a large fraction of the residual amendment solution drifted out of the R-28 well at that time. The chromium concentration has remained below 0.05 mg/L since then. During the October 2018 extended purge (Figure 2.2-2), chromium concentrations fell to the lowest levels yet observed (approximately 0.01 mg/L), while pH increased to above 6, indicating diminishing levels of organic acids. TOC concentration initially increased during the purge and then fell back towards pre-purge levels (Figure 2.2-3); concentrations have remained relatively stable since falling after the October 2018 purge. The data obtained during the extended purge indicated that there was a small amount of residual molasses solution lingering close to R-28 that was drawn out by the purge, after which concentrations trended back toward pre-purge levels (and below for many constituents). The rise in observed pH and fall in chromium levels over the October 2018 purge suggested falling concentrations of organic acids that would solubilize chromium (Figure 2.2-2). The 350-gal. and 1000-gal. time-series purges conducted from March through December of 2019 continued with trends similar to the October 2018 purge wherein chromium decreased over the course of each purge (while field pH typically increased). These results suggest ongoing Cr(VI)-reducing conditions generated by the injected molasses.

The concentration of potassium, which was a significant component in the molasses amendment, since the October 2018 purge, has continued to gradually fall towards pre-amendment levels. At approximately 50 mg/L in September 2019, it is still well above pre-amendment levels of approximately 2 mg/L (Figure 2.2-1). Potassium values also fall over the course of each 350-gal. and 1000-gal. time-series purge sampling. Potassium concentrations are expected to remain elevated for a long time at R-28 because potassium is a strong cation exchanger that readily displaces many other cations on sediment cation-exchange sites—this will result in a very slow decline in concentrations because potassium is slowly being displaced from cation-exchange sites by more abundant groundwater cations like sodium, calcium, and magnesium flowing into the amendment-treated zone.

Figure 2.2-4 focuses on iron and manganese data. Dissolved iron and manganese were initially elevated by high concentrations of these elements in the injected molasses solution as well as the low pH of the injected solution. Concentrations of both elements decreased significantly as the molasses solution drifted out of the well (most notably during the summer of 2018). Even following decreasing concentrations, values remain elevated presumably because of reducing conditions induced by the molasses biostimulation that remain in the aquifer near the well. This concept will be further evaluated as part of the redevelopment activities planned at R-28. Both iron and manganese remain at about three orders of magnitude higher than pre-amendment levels. Iron and manganese concentrations were observed to rise at the beginning of the October 2018 extended purge, although they steadily decreased as the purge progressed and dropped to their lowest levels to date by the end of the purge. These trends are consistent with a small amount of residual molasses solution lingering close to R-28 that was drawn out by the purge, after which concentrations trended below pre-purge levels. Subsequent purges (both 350-gal. and 1000-gal.) from March to December 2019 have prompted lower iron and manganese concentrations over the course of each purge; these trends are similar to the decreasing trends during the October 2018 purge.

Figure 2.2-5 shows concentration trends for some of the other elements of interest, including arsenic and selenium. Arsenic demonstrated a slow and steady decline after February 2018. The October 2018 purge accelerated the rate of its decline, when it fell from 0.007 to 0.004 mg/L. Its concentration has remained steady since that purge and through September 2019. Selenium has remained undetected since a couple of exceptions were detected at approximately 0.015 mg/L in early 2018. Nickel levels continue to gradually fall, consistent with increasing pH values that result in less leaching/dissolution of nickel from the stainless-steel well screen and/or casing. The recent samples exhibit the lowest nickel concentrations to date and are at near pre-amendment levels.

Figure 2.2-6 shows concentration trends for selected anions. Chloride concentrations starting from elevated levels above 1000 mg/L in the molasses amendment are now approaching historical pre-amendment background levels in the most recent sample set. The October 2018 purge accelerated the rate of decline, and concentrations have remained low and at approximately pre-amendment levels since the end of the purge. The shorter 350-gal. and 1000-gal. purges from March through August 2019 have typically drawn concentrations down further towards pre-amendment level (approximately 45 mg/L) over the course of each purge.

Figure 2.2-7 illustrates bromide, sulfate, and TOC trends. Sodium bromide is the tracer that was introduced with molasses. Sulfate may come from either of two potential sources: (1) from the aquifer outside of the ROI that contains approximately 60 mg/L or (2) from the molasses amendment itself, which contained approximately 1000 mg/L of sulfate. The TOC represents molasses and/or ethanol and metabolic reaction products from each, such as organic acids (as described previously in this section). The levels of all three (i.e., TOC, bromide, and sulfate) were elevated following the molasses deployment and ethanol chase. Both the bromide and sulfate levels decreased following the ethanol chase and then rebounded to an extent, reflecting the higher levels in the molasses amendment solution than in the chase. TOC levels were higher in the ethanol chase than in the molasses amendment solution. TOC, bromide, and sulfate levels generally fell over the subsequent period as upgradient water flowed through the well and purges were conducted. Sulfate levels fell to below pre-amendment concentrations in July 2018, indicating action of sulfate-reducing bacteria in conjunction with a general washout of the amendment solution, which contained elevated levels of sulfate. Sulfate concentrations rose significantly during the October 2018 extended purge, consistent with the drawing in of lingering amendment solution from just outside the well at the start of the purge. Sulfate concentrations since then have remained lower than pre-amendment concentrations (approximately 60 mg/L), although they have increased with each of the 350-gal. and 1000-gal. purges from March through December 2019. In these purges, samples started at lower sulfate levels (as low as 5 mg/L upon starting a purge) and climbed to levels reaching as high as 45 mg/L at the end of purges. The rising values over each of the time-series purges suggests that geochemical conditions are more strongly sulfate-reducing inside the well than in the aquifer surrounding the well. The bromide concentration has been gradually falling towards its pre-amendment levels since the October 2018 purge and through the December 2019 purge. This is indicative that the pumping has drawn out the majority of amendment solution that was still lingering in the vicinity of R-28 at the time of the October 2018 purge. Bromide concentrations have typically fallen over individual time-series purge sampling. TOC levels have fallen gradually after the October 2018 purge. The rate of decrease appears to have slowed down in the fall of 2019, with the concentration approaching approximately 10 mg/L between August and December 2019. Like bromide, and with a few exceptions, the time-series purging samples each exhibit decreasing TOC values from early purge samples to later ones. Even the lowest TOC levels, which are approximately 10 mg/L, are still well above the pre-amendment levels of approximately 1 mg/L.

Figure 2.2-8 illustrates the nitrate and nitrite trends during the test progression. Nitrate has been reduced below pre-deployment levels since deployment of the molasses and ethanol. Nitrite exhibited an initial spike following molasses deployment because of the presence of nitrite in the molasses mixture, but it gradually fell in trends similar to other molasses constituents as the amendment solution drifted out of the well. Following about July 2018, both nitrite and nitrate have decreased more rapidly, as shown in Figure 2.2-8. The levels of both nitrate and nitrite fell to nondetect during the October 2018 extended purge event. Nitrite has remained at near-nondetect concentrations since the purge and through the most recent sample in December 2019. Nitrate levels have risen only subtly and at <0.3 mg/L have remained very low compared with pre-amendment levels of approximately 20 mg/L. These low nitrate/nitrite values are consistent with the persistence of microbially induced reducing conditions near the well that are also reflected by other geochemical trends discussed in this section.

The 350-gal. and 1000-gal. purges from March through December 2019 suggest that ROI region(s) in the R-28 vicinity are still exhibiting reducing conditions; chromium and nitrate concentrations remain low while iron, manganese, and TOC remain elevated. Additionally, potassium and bromide from the amendment deployment linger and dissolved oxygen remains low, at approximately <2 mg/L, further indicative of continued reducing conditions. However, reestablishment of pre-amendment levels for some species that are not susceptible to reducing ROI conditions (e.g., chloride) continues to be evident.

Concentrations of other constituents have held reasonably steady since the October 2018 purge. Sodium and magnesium, after reaching near pre-amendment levels in mid-2018, have remained at similar levels.

Concentrations of other elements or ions not shown in the figures can be found in Attachment 1 (on CD included with this document).

2.3 Updated Estimates of Chromium Reduced in R-42 and R-28 Pilot Amendment Tests

In the sixth quarterly report (N3B 2019, 700420), estimates of the amount of Cr(VI) reduced as a result of the amendment additions at R-42 and R-28 through March 2019 were provided. These estimates are updated here through December 2019, the month of the last samples collected from R-42 and R-28 (each of which showed no evidence of Cr(VI) concentration increases above approximately background levels in each well).

The methodologies used for estimating the amounts of Cr(VI) reduced at R-42 and R-28 are described in detail in section 3 of the sixth quarterly report (N3B 2019, 700420); these descriptions are not repeated here. In summary, separate calculations were employed to estimate the amount of Cr(VI) reduced as a result of (1) drawing Cr(VI) into/through the amendment-treated zones near the wells by pumping either R-42 or R-28 and (2) natural flow causing Cr(VI) to flow into the amendment-treated zones. The contribution from pumping is obtained by multiplying the volume pumped from each well by the Cr(VI) concentration that existed in the wells before the addition of amendments.

- R-42: (gallons pumped)(3.785 L/gal.)(0.0007 g Cr(VI)/L)
- R-28: (gallons pumped)(3.785 L/gal.)(0.0005 g Cr(VI)/L)

As of the end of March 2019, approximately 110,000 gal. were pumped from R-42 and approximately 30,000 gal. were pumped from R-28, resulting in pumping contributions of approximately 291 g and approximately 57 g of Cr(VI) reduced for R-42 and R-28, respectively (N3B 2019, 700420). During the period from April through December 2019, an additional approximately 6100 gal. were pumped from R-42 (four sampling events of approximately 1000 gal. purged, and six events of approximately 350 gal. purged), and an additional approximately 6750 gal. were pumped from R-28 (five sampling events of approximately 1000 gal. purged, and five events of approximately 350 gal. purged). This pumping resulted in an additional 16.2 g of Cr(VI) being drawn into/through the amendment treated zone near R-42 and an additional 12.8 g being drawn into/through the treated zone near R-28. Thus, the estimates of Cr(VI) reduced as a result of pumping have increased to approximately 307 g at R-42 and approximately 70 g at R-28 as of December 2019.The contributions to Cr(VI) reduction as a result of natural flow through the amendment-treated zones are less certain than those attributed to pumping, as discussed in the sixth quarterly report (N3B 2019, 700420). The estimates of these contributions are as follows:

- R-42: (number of days)(163 L/day of natural flow)(0.0007 g Cr(VI)/L)
- R-28: (number of days)(487 L/day of natural flow)(0.0005 g Cr(VI)/L)

As of the end of March 2019, these estimates were approximately 57 g of Cr(VI) reduced at R-42 and approximately 107 g of Cr(VI) reduced at R-28. Since the end of March 2019, there were an additional 275 days through the end of December 2019. Using the above formulas, the estimated amounts of additional Cr(VI) reduced as a result of natural flow at R-42 and R-28 between the end of March 2019 to the end of December 2019 are as follows:

- R-42: 31.5 g
- R-28: 66.9 g

These estimates assume that there have been no changes in the permeability of the amendment-treated zones surrounding the wells since March 2019 [i.e., the natural flow rate estimates in L/day reported in the sixth quarterly report, (N3B 2019, 700420) are assumed to apply through December 2019]. The updated estimates of the total amounts of Cr(VI) reduced as a result of natural flow since the start of the amendments tests are as follows:

- R-42: approximately 89 g
- R-28: approximately 174 g

The updated estimates of total Cr(VI) reduced as a result of both pumping and natural flow at the two wells since the start of the amendments tests are as follows:

- R-42: approximately 396 g
- R-28: approximately 244 g

The larger values at R-42 are primarily the result of the much greater volume of water pumped from R-42 than R-28, approximately 116,000 gal. versus approximately 37,000 gal. The rate of increase of Cr(VI) reduced by natural flow is more than 2 times greater at R-28 than at R-42, so, over time, in the absence of pumping, the estimates of Cr(VI) reduced at R-28 will approach those at R-42. Table 2.3-1 summarizes the estimated amounts of Cr(VI) reduced at the two locations at the end of March 2019, from April to December 2019, and at the end of December 2019, including the contributions from both pumping and natural flow.

As discussed in the sixth quarterly report (N3B 2019, 700420), the estimates of Cr(VI) reduced at both amendment testing locations have inherent uncertainty; therefore, the estimates should only be considered accurate to within 50% of the stated values (that is, they could be higher or lower by 50% of the stated values, based on scientific judgement). This uncertainty is dominated by the uncertainty in the estimates of natural flow rates through the amendment treated zones, which could easily be more than a factor of 2 too high or too low. Some of the uncertainty in natural flow rate estimates will likely be reduced after borehole dilution tracer tests are conducted at R-42 and R-28, which are planned after the rehabilitation of both wells later this year per the Supplemental Pilot-Scale Amendments Testing Work Plan (N3B 2019, 700698). After those tests, revised and updated estimates of Cr(VI) reduced at both locations will be provided in a future report.

2.4 Conclusions and Recommendations

Regarding the study’s first two (of four) objectives, the results in this report continue to show evidence of geochemical reduction of dissolved-phase Cr(VI), although further resolution of whether the reduction is occurring near the well or in the aquifer ROI surrounding the well is a goal of the supplemental field work involving well redevelopment. Regarding the third objective, some potential adverse geochemical effects in the form of moderately elevated metals and total dissolved solids were observed following the amendment’s initial application. Metals concentrations and total dissolved solids fell significantly typically during the several months following amendments applications and have persisted. Oxidation reduction-sensitive indicators such as iron and manganese remain elevated above screening levels in samples collected from the deployment wells. However, no nearby or downgradient monitoring or extraction wells show indications of amendment byproducts above applicable screening levels. In regard to R-28, nitrite concentrations were observed to initially have increased for the months following amendment application. After trending downward during 2018, nitrite concentrations have remained low. The pH at R-28 initially fell to values that may (likely in conjunction with organic acids) have caused minor but detectable leaching of some metals from its stainless-steel well casing. The pH returned upwards to circum-neutral values in 2018. These higher pH values have been maintained since that time. Finally, regarding the fourth objective, no additional information was available during this period to evaluate hydrological impacts of the treatments on hydraulic properties of the aquifer. Data to address this fourth objective will be obtained through implementation of the pending dilution tracer tests and comparative analysis to initial hydrologic test results.

Mechanical well redevelopment will be conducted for both R-42 and R-28 following the restart of field activities after the shutdown caused by the COVID-19 pandemic. A principle objective of the redevelopment work is to remove significant fouling materials from each well screen, filter pack, and possibly from the aquifer close to each well. Because redevelopment is not expected to reach far into the aquifer, it is unknown to what extent it will accelerate the timeframe for chromium breakthrough at each well, but it should improve confidence in the interpretation of the nature of persistent reducing conditions at each well. Data collected following redevelopment will help inform the nature of reducing conditions in the ROI by removing the potential influence of perturbed conditions close to the well. Redevelopment will also enable a better determination of whether decreases in specific capacity observed at each well are because of conditions in the well or filter pack or in the aquifer. Following redevelopment, borehole dilution tracer tests will be conducted in a manner consistent with pre-amendment borehole dilution tracer tests to generate estimates of local groundwater flow rates that may provide insights into whether changes in aquifer hydrologic conditions associated with the amendments testing have occurred.

As discussed above, the dithionite amendment test at R-42 still requires more time to determine Cr(VI) reduction capacity imparted to the aquifer in the ROI. Chromium has not yet begun to break through into R-42. Other indicators, such as iron and manganese, continue to decrease towards, but remain significantly above, pre-amendment levels indicating that, although the reducing conditions near the well have been diminishing, they are still significant and are effectively reducing chromium.

The molasses amendment test at R-28 similarly requires more time for Cr(VI) breakthrough to occur. As discussed above, significant reduction capacity is apparently still present in the ROI around R-28. Following the initial purges, reducing conditions in the aquifer have resulted in chromium concentrations that are significantly below the pre-deployment level of approximately 0.5 mg/L. Following amendment deployment, slightly elevated chromium [as dissolved Cr(III)] was attributed to low pH conditions that caused leaching of Cr(III) from stainless-steel components in the well, and chromium concentrations did not drop below the New Mexico groundwater standard level (0.05 mg/L) until mid-2018 when the pH had significantly rebounded and a majority of the molasses amendment solution had drifted away from R-28. Following the October 2018 extended purge, the dissolved chromium concentrations fell to less than 10 ppb, where they have since remained. As mentioned in the first paragraph of this section, after rising back to circum-neutral values, the pH has remained rather static from March to December 2019 and has not fully recovered to pre-deployment levels. Iron and manganese levels and other indicators such as elevated TOC, depressed dissolved oxygen, and depressed oxidation-reduction potential indicate the persistence of reducing conditions amenable to reducing Cr(VI).

The data from recent purges continue to show concentrations of byproduct constituents (e.g., iron and manganese) that do not allow direct land application of produced water without treatment and are incompatible with the current ion-exchange-based chromium treatment system. Therefore, continuous pumping at R-42 and R-28 creates significant logistics challenges related to management of produced water. A new sampling protocol, including frequency, purge volume and analyte suite, will be implemented for each well following completion of redevelopment and the borehole dilution tracer tests.

The schedule for the next report on amendments testing at R-42 and R-28 will be governed, in part, by the schedule of restart activities following the COVID-19 shutdown and through discussions with NMED. Updates and ongoing evaluation of periodic sampling, geochemical modeling, and evaluation of new data collected in support of characterization at CrEX-3 will be also discussed through technical team meetings with NMED and documented in the next report. Because of uncertainties in the post-COVID fieldwork start date and efficiency of field activities, it is recommended that the schedule for the next amendments testing report be unspecified at this time. A due date for the report will be established with NMED after details of the resumption of field activities are better understood.

3.0 REFERENCES AND MAP DATA SOURCES

3.1 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)

LANL (Los Alamos National Laboratory), January 2018. "Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater beneath Mortandad Canyon," Los Alamos National Laboratory document LA-UR-18-20467, Los Alamos, New Mexico. (LANL 2018, 602862)

LANL (Los Alamos National Laboratory), April 2018. "Second Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon," Los Alamos National Laboratory document LA-UR-18-23418, Los Alamos, New Mexico. (LANL 2018, 603031)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), July 2018. "Third Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon," Newport News Nuclear BWXT-Los Alamos, LLC, document EM2018-0019, Los Alamos, New Mexico. (N3B 2018, 700032)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), October 2018. "Fourth Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon," Newport News Nuclear BWXT-Los Alamos, LLC, document EM2018-0069, Los Alamos, New Mexico. (N3B 2018, 700108)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), December 2019. "Supplemental Work Plan for Pilot-Scale Amendments Testing for Chromium in Groundwater beneath Mortandad Canyon, Revision 1," Newport News Nuclear BWXT-Los Alamos, LLC, document EM2019-0455, Los Alamos, New Mexico. (N3B 2019, 700698)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), January 2019. "Fifth Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon," Newport News Nuclear BWXT-Los Alamos, LLC, document EM2019-0011, Los Alamos, New Mexico. (N3B 2019, 700214)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), April 2019. "Sixth Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon," Newport News Nuclear BWXT-Los Alamos, LLC, document EM2019-0133, Los Alamos, New Mexico. (N3B 2019, 700420)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), December 2019. "Seventh Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon, April to September 2019," Newport News Nuclear BWXT-Los Alamos, LLC, document EM2019-0427, Los Alamos, New Mexico. (N3B 2019, 700723)

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)

3.2 Map Data Sources

Hillshade; Los Alamos National Laboratory, ER-ES, As published; \\slip\gis\Data\HYP\LiDAR\2014\Bare_Earth\BareEarth_DEM_Mosaic.gdb; 2014.

Unpaved roads; Los Alamos National Laboratory, ER-ES, As published, GIS projects folder; \\slip\gis\GIS\Projects\14-Projects\14-0062\project_data.gdb\digitized_site_features\digitized_roads; 2017.

Drainage channel; Los Alamos National Laboratory, ER-ES, As published, GIS projects folder; \\slip\gis\GIS\Projects\15-Projects\15-0080\project_data.gdb\correct_drainage; 2017.

Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 29 November 2010.

Paved Road Arcs; Los Alamos National Laboratory, FWO Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 29 November 2010.

Chromium plume > 50 ppb; Los Alamos National Laboratory, ER-ES, As published; \\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

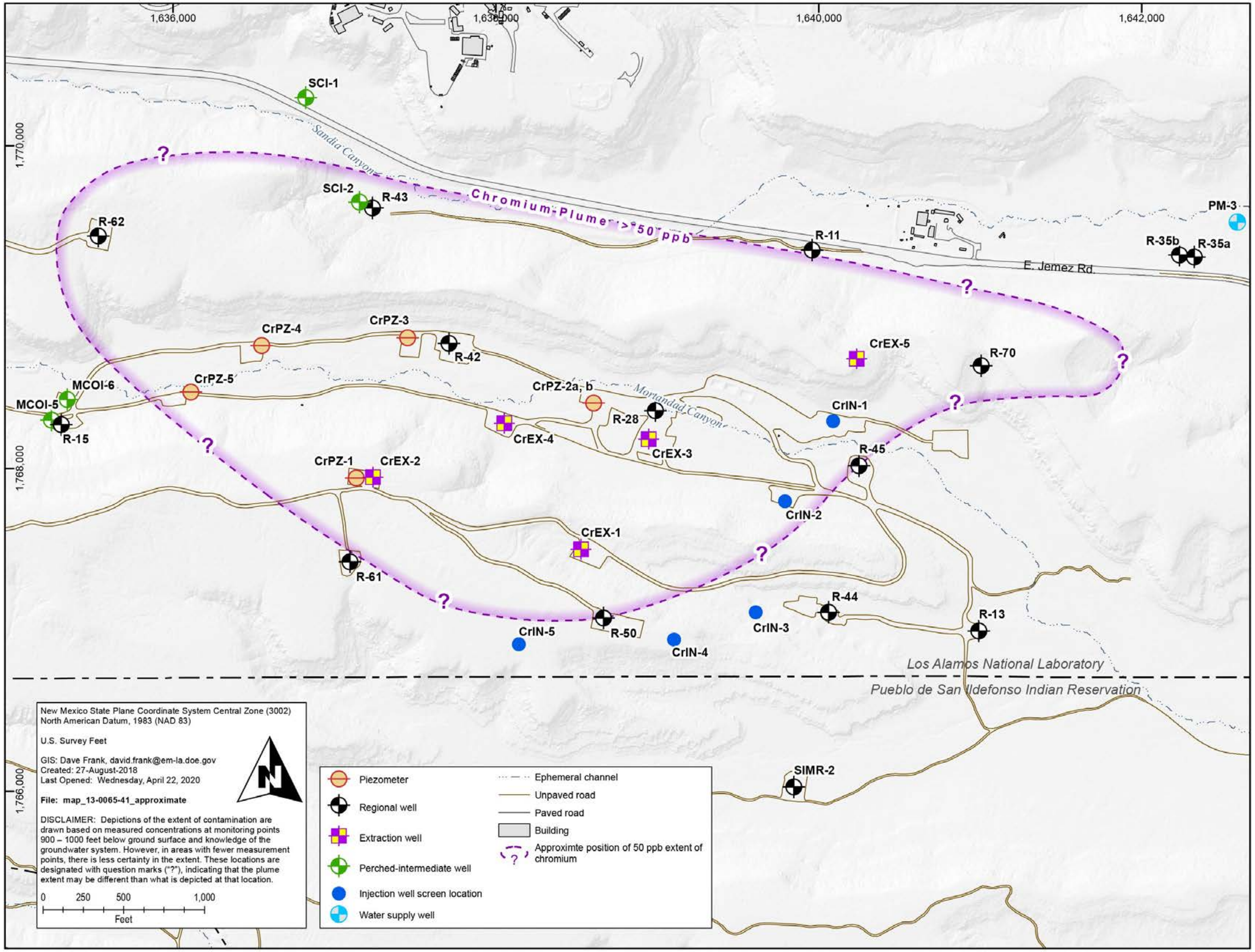
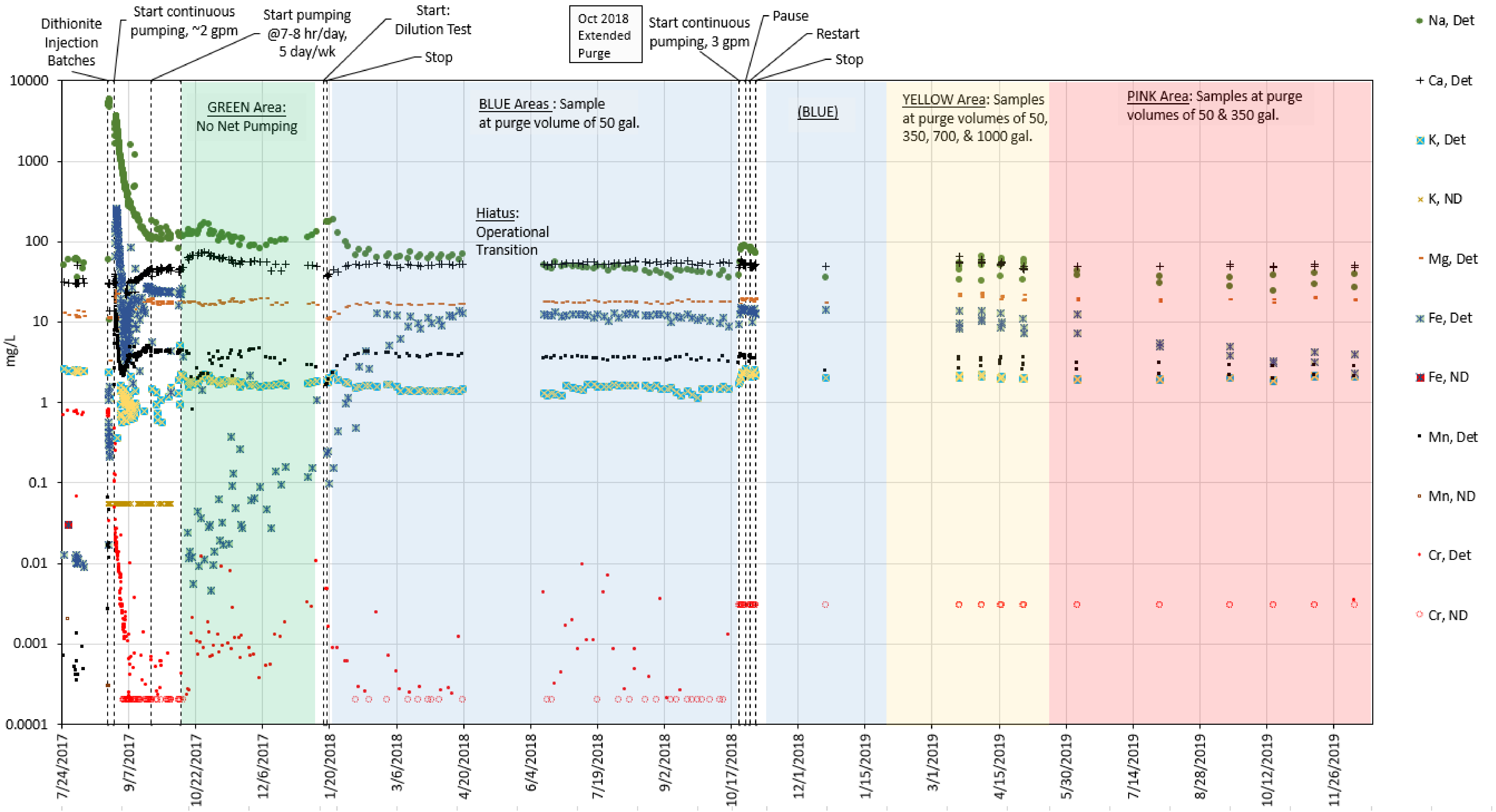
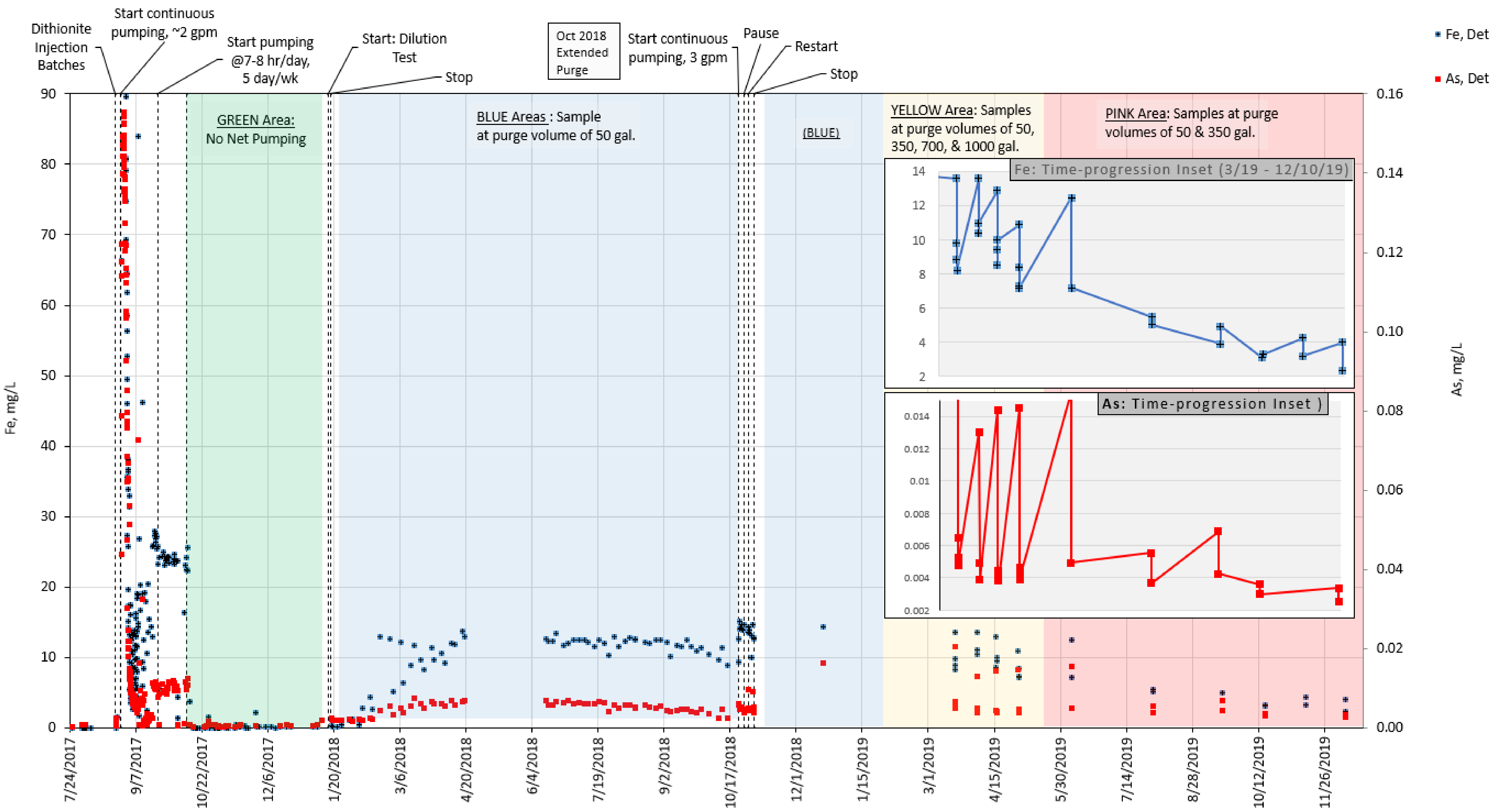


Figure 1.0-1 Locations of estimated 50 ppb extent of the Cr(VI) plume and monitoring wells (including R-42 and R-28), piezometers, and interim measure infrastructure wells



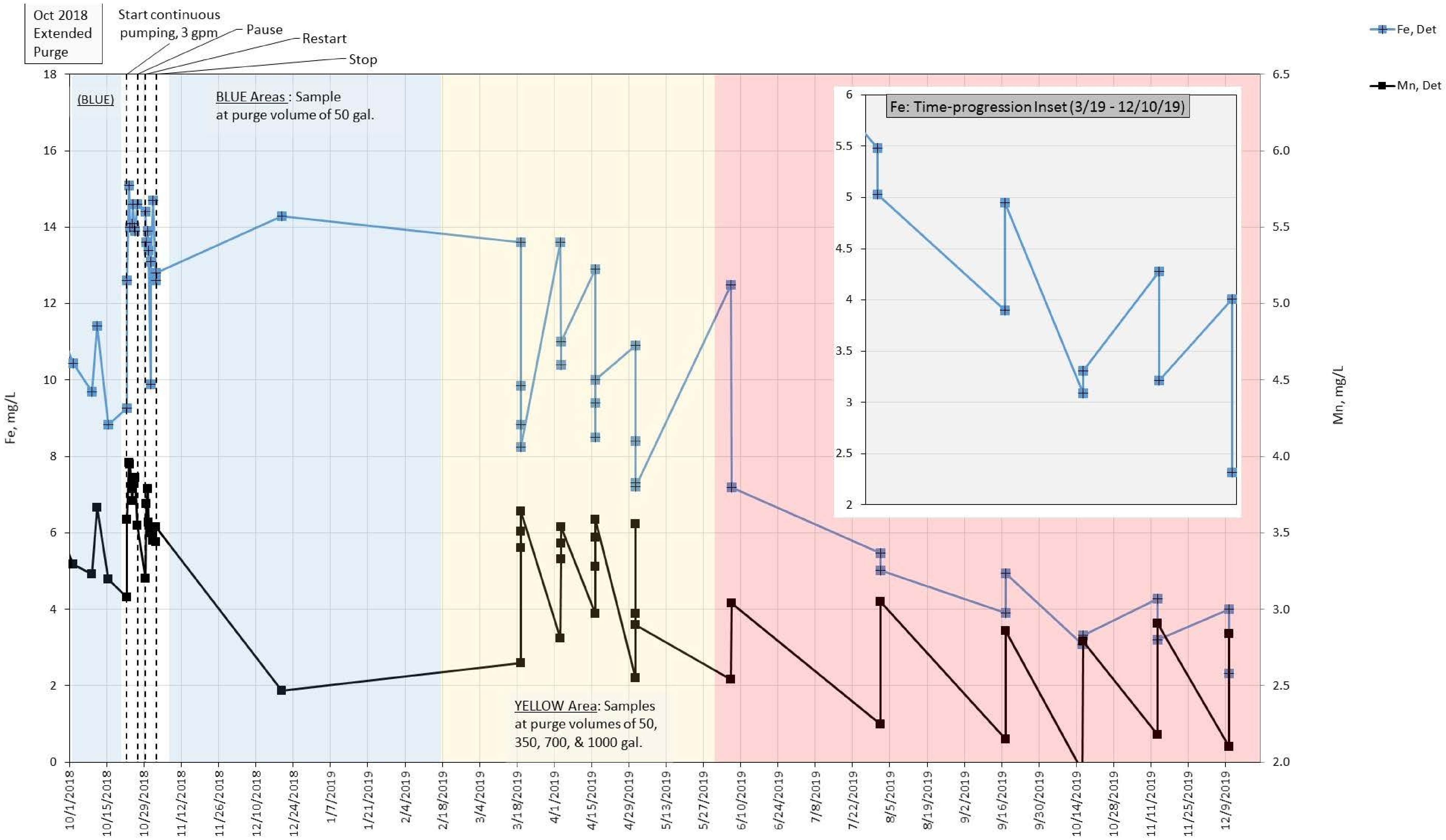
Notes: The pre-test concentrations were approximately as follows: Na = 50–60 (16), Ca = 30 (55), K = 2, Mg = 12 (15), Fe = 0.01 (0.1), Mn = 0.001, and Cr = 0.7. Pre-amendment values are shown in mg/L. Also, if different, values for 2014/2015 period are shown in parentheses. All results are from filtered samples. Det = Detected, ND = Not detected.

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



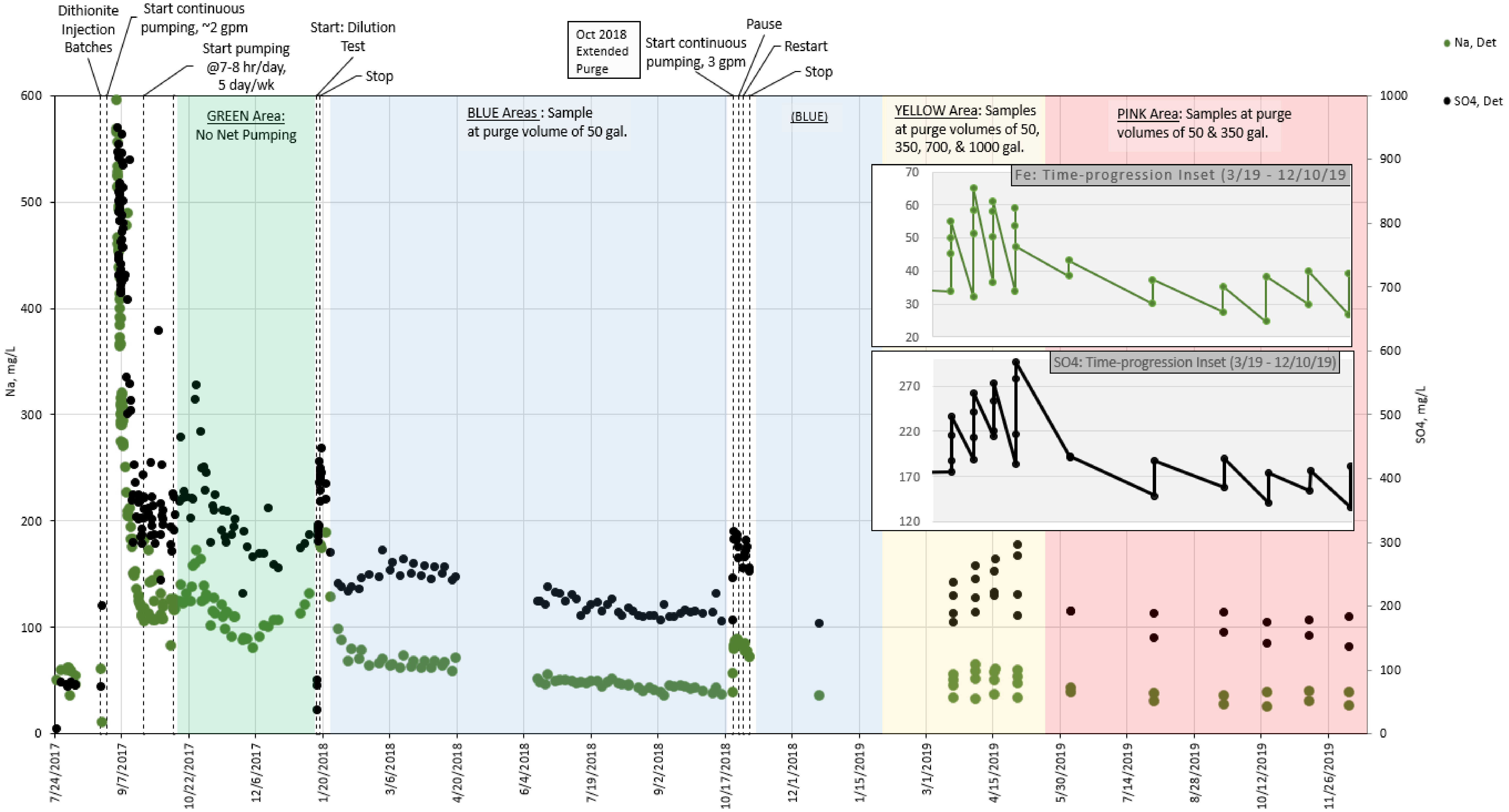
Notes: The pre-test concentrations were approximately as follows: Fe = 0.01 (0.1), As = 0.001 (0.002). Pre-amendment values are shown in mg/L. Also, if different, values for 2014/2015 period are shown in parentheses.
All results are from filtered samples. Det = Detected.

Figure 2.1-2 Concentrations of iron and arsenic in R-42 dithionite test as a function of time



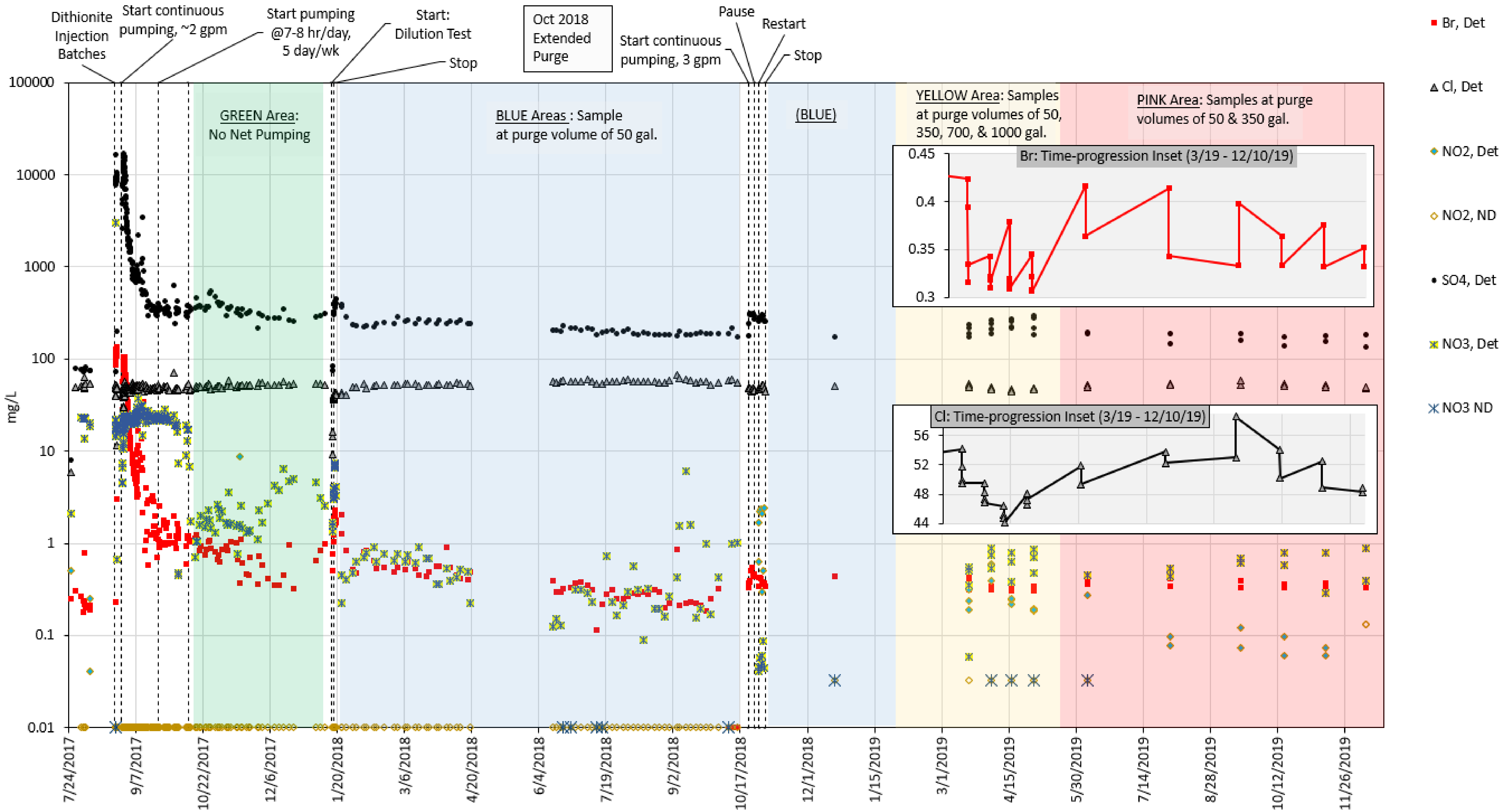
Notes: The pre-test concentrations were approximately as follows: Fe = 0.01 (0.1), Mn = 0.001. Pre-amendment values are shown in mg/L. Also, if different, values for 2014/2015 period are shown in parentheses. All results are from filtered samples. Det = Detected.

Figure 2.1-3 Concentrations of iron and manganese in R-42 dithionite test as a function of time



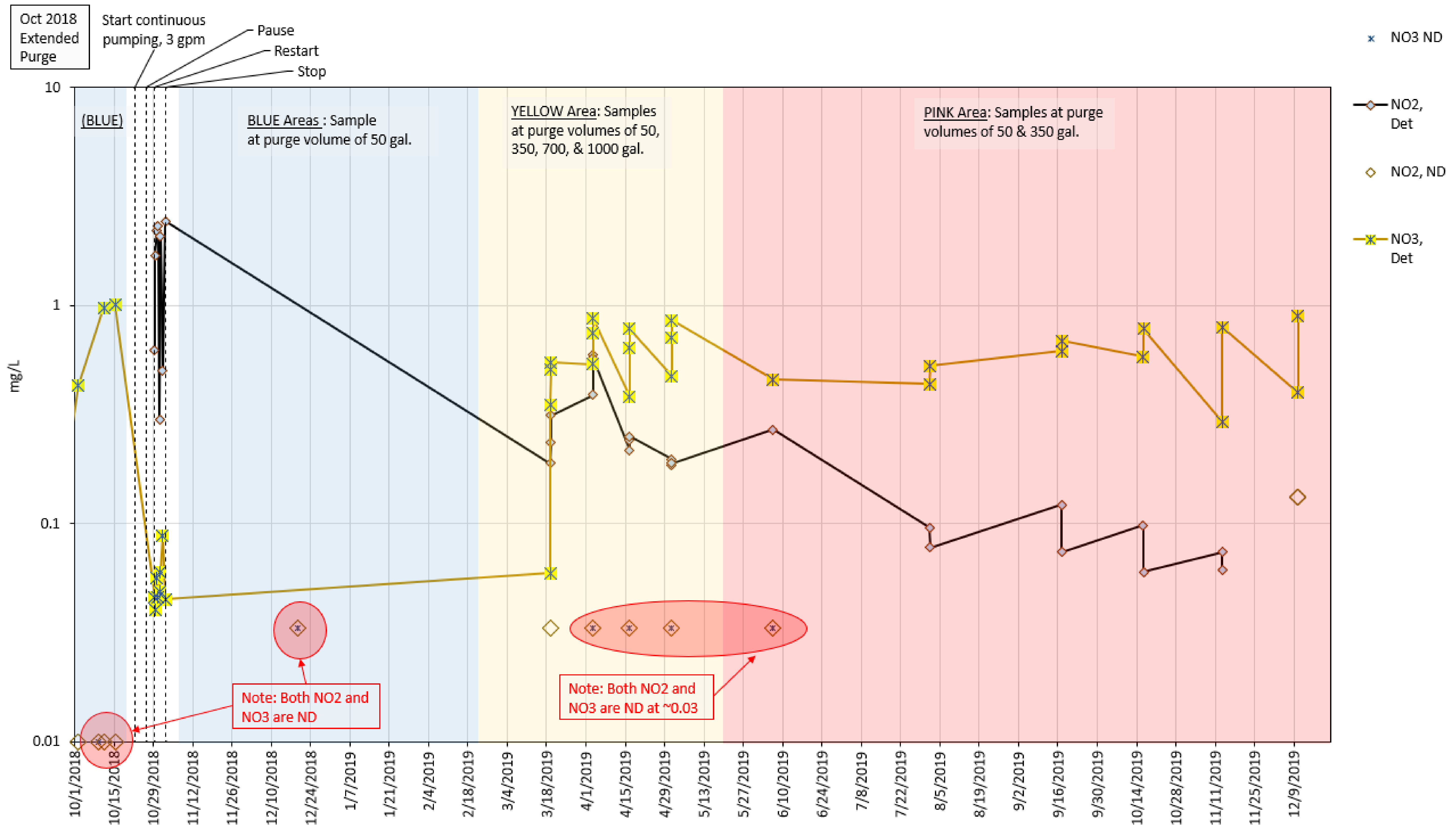
Notes: The pre-test concentrations were approximately as follows: Na = 50–60 (16), SO4 = 80. Pre-amendment values are shown in mg/L. Also, if different, values for 2014/2015 period are shown in parentheses. Na results are from filtered samples. Det = Detected.

Figure 2.1-4 Concentrations of sodium and sulfate in R-42 dithionite test as a function of time



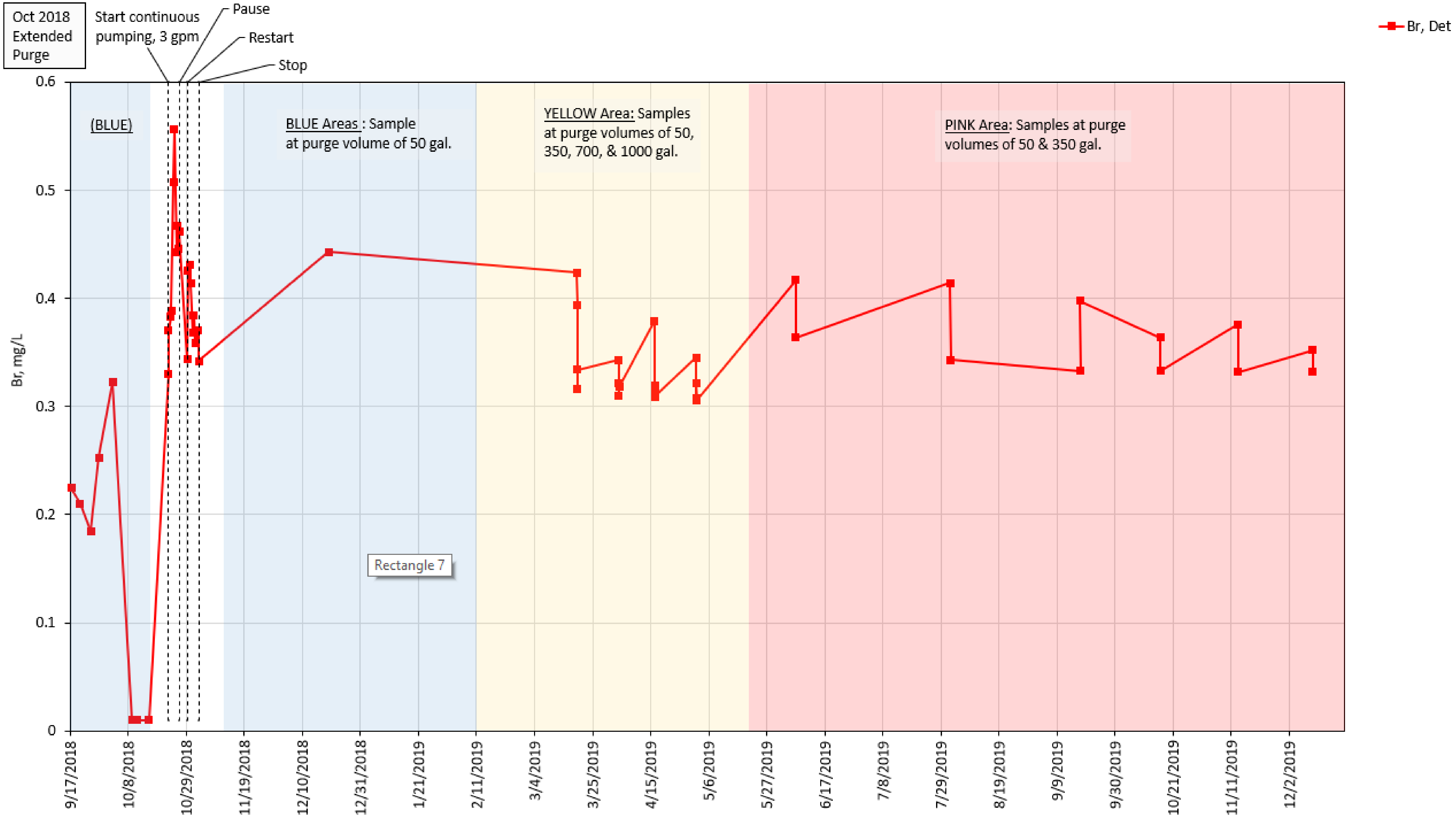
Notes: The pre-test concentrations were approximately as follows: Br ~0.2 Cl = 50–60 (45), NO2 <0.2, NO3 = 20 (25), SO4 = 80. Pre-amendment values are shown in mg/L. Also, if different, values for 2014/2015 period are shown in parentheses. Det = Detected, ND = Not detected.

Figure 2.1-5 Concentrations of anions in R-42 dithionite test as a function of time



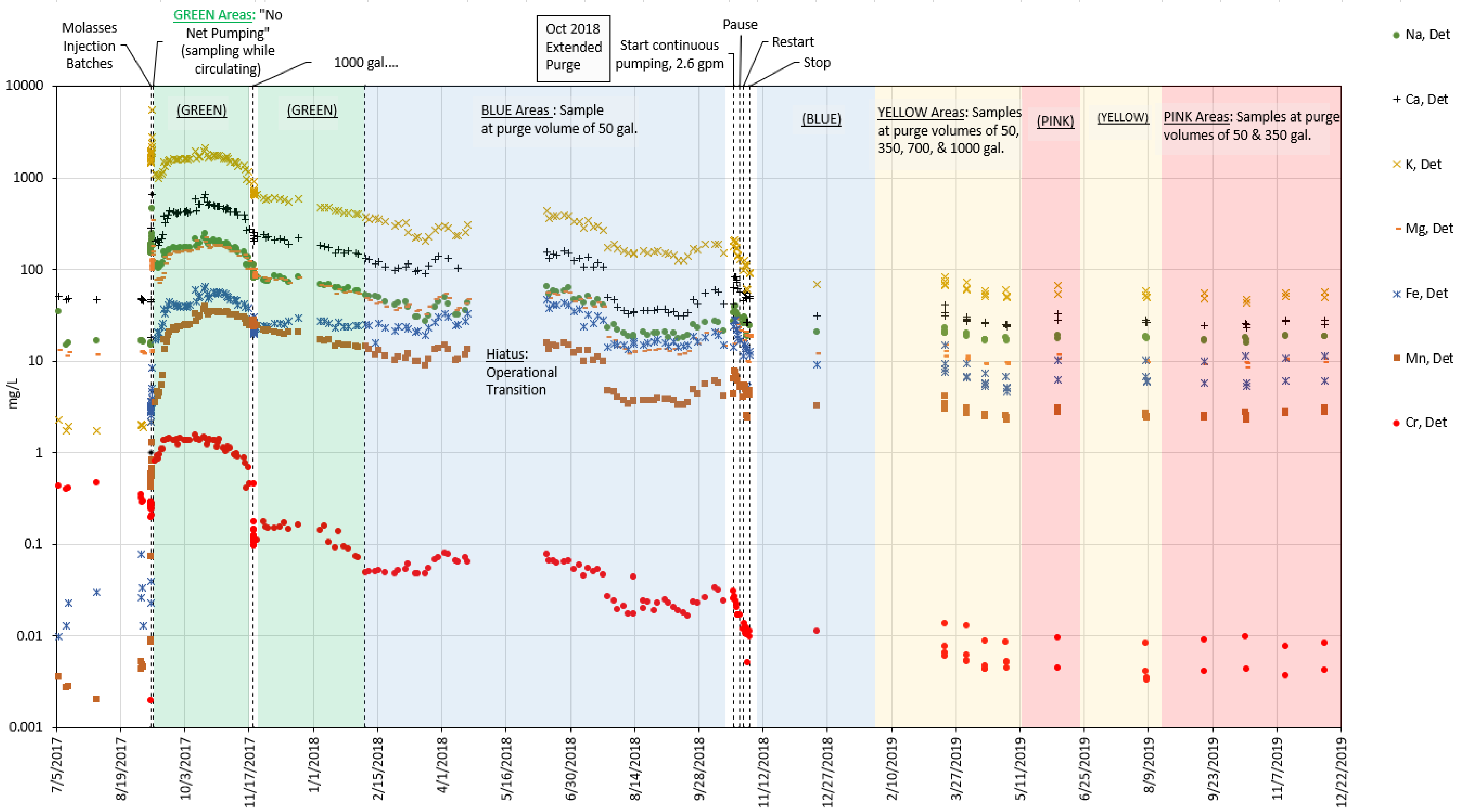
Notes: The pre-test concentrations were approximately as follows: NO2 <0.2, NO3 = 20 (25). Pre-amendment values are shown in mg/L. Also, if different, values for 2014/2015 period are shown in parentheses. Det = Detected, ND = Not detected.

Figure 2.1-6 Concentrations of nitrate and nitrite in R-42 dithionite test as a function of time



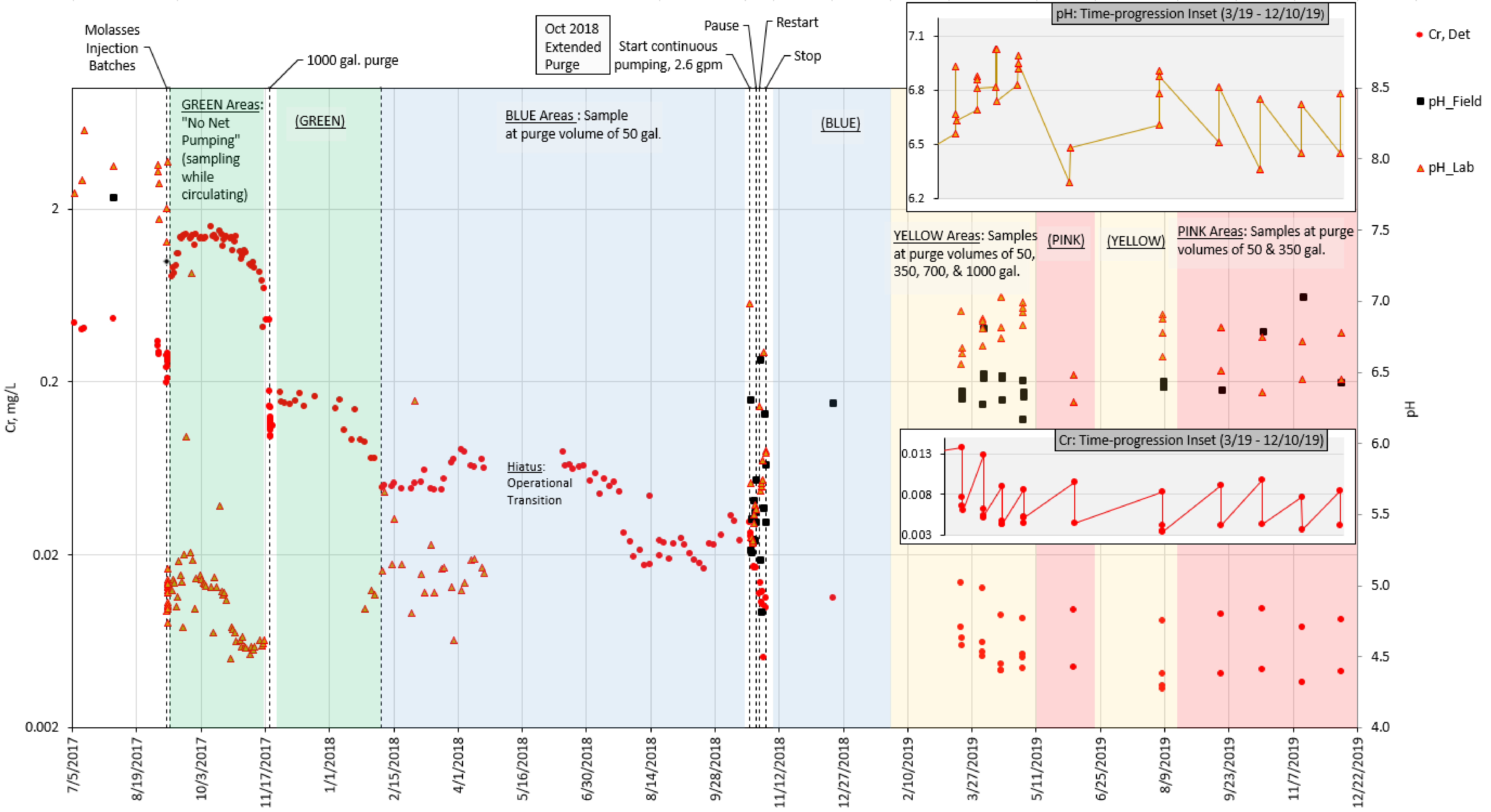
Notes: The pre-test concentrations were approximately as follows: Br ~0.2. Pre-amendment values are shown in mg/L. Also, if different, values for 2014/2015 period are shown in parentheses. Det = Detected.

Figure 2.1-7 Concentration of bromide in R-42 dithionite test as a function of time



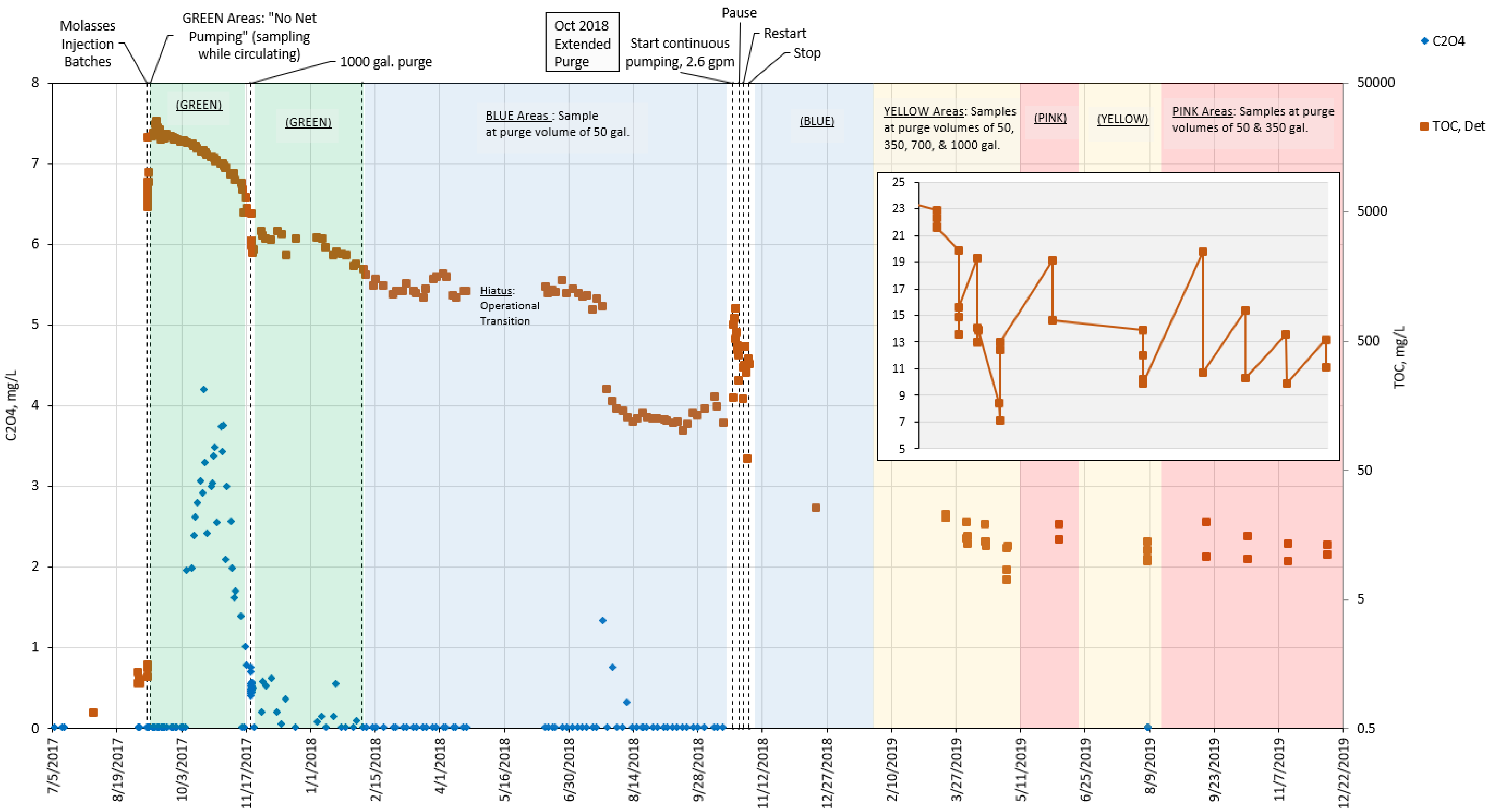
Notes: The pre-test concentrations were approximately as follows: Na = 16; Ca = 47, K = 2, Mg = 12, Fe = 0.01–0.025, Mn = 0.001–0.005, Cr = 0.5. All results are from filtered samples. Pre-amendment values are shown in mg/L. Also, if different, values for 2014/2015 period are shown in parentheses. Det = Detected.

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



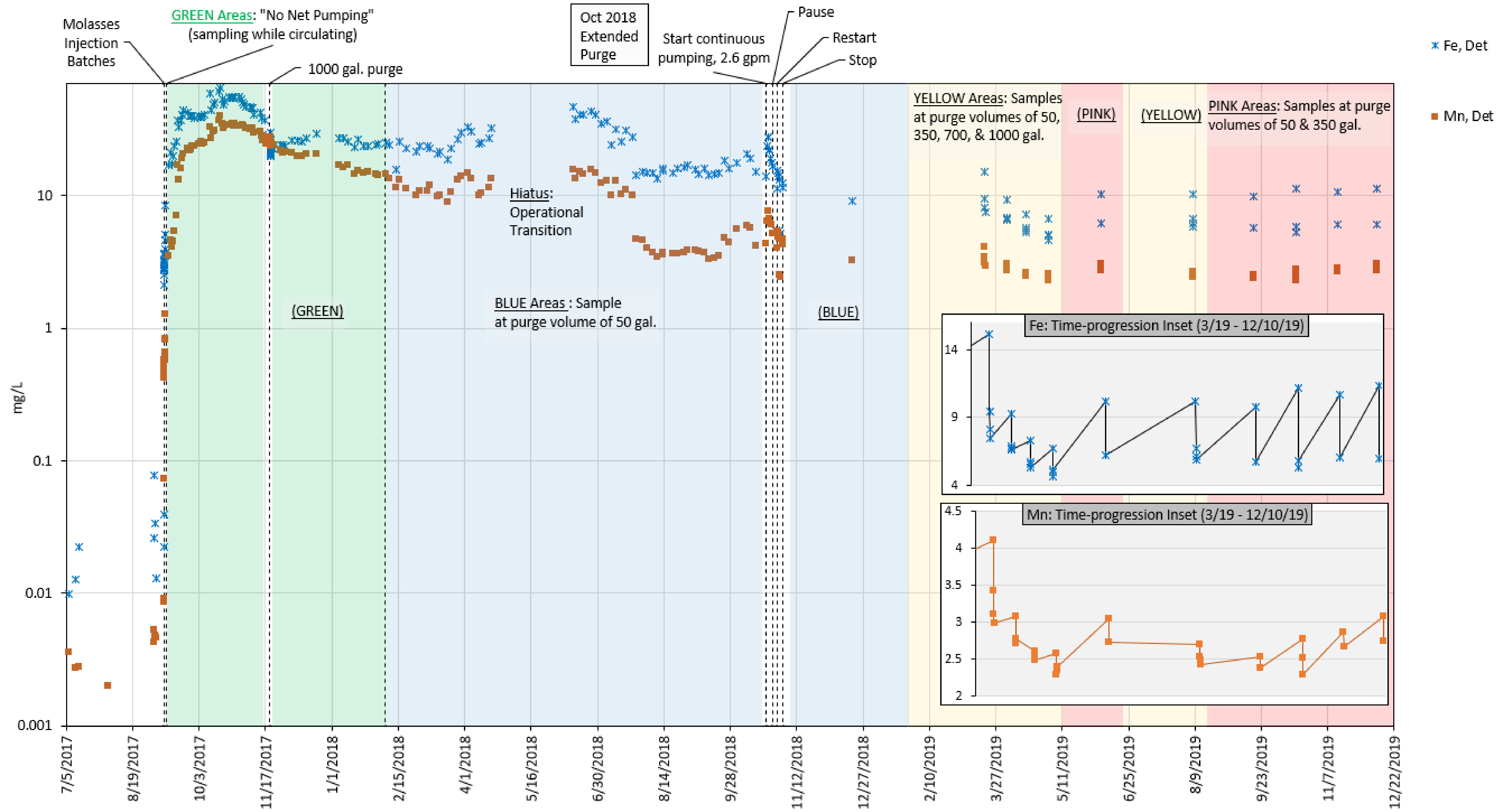
Notes: The pre-test concentrations were approximately as follows: Cr = 0.5 mg/L, pH = 7.8. Pre-amendment values are shown in mg/L. Also, if different, values for 2014/2015 period are shown in parentheses. Det = Detected.

Figure 2.2-2 Concentrations of chromium and pH in R-28 molasses test as a function of time



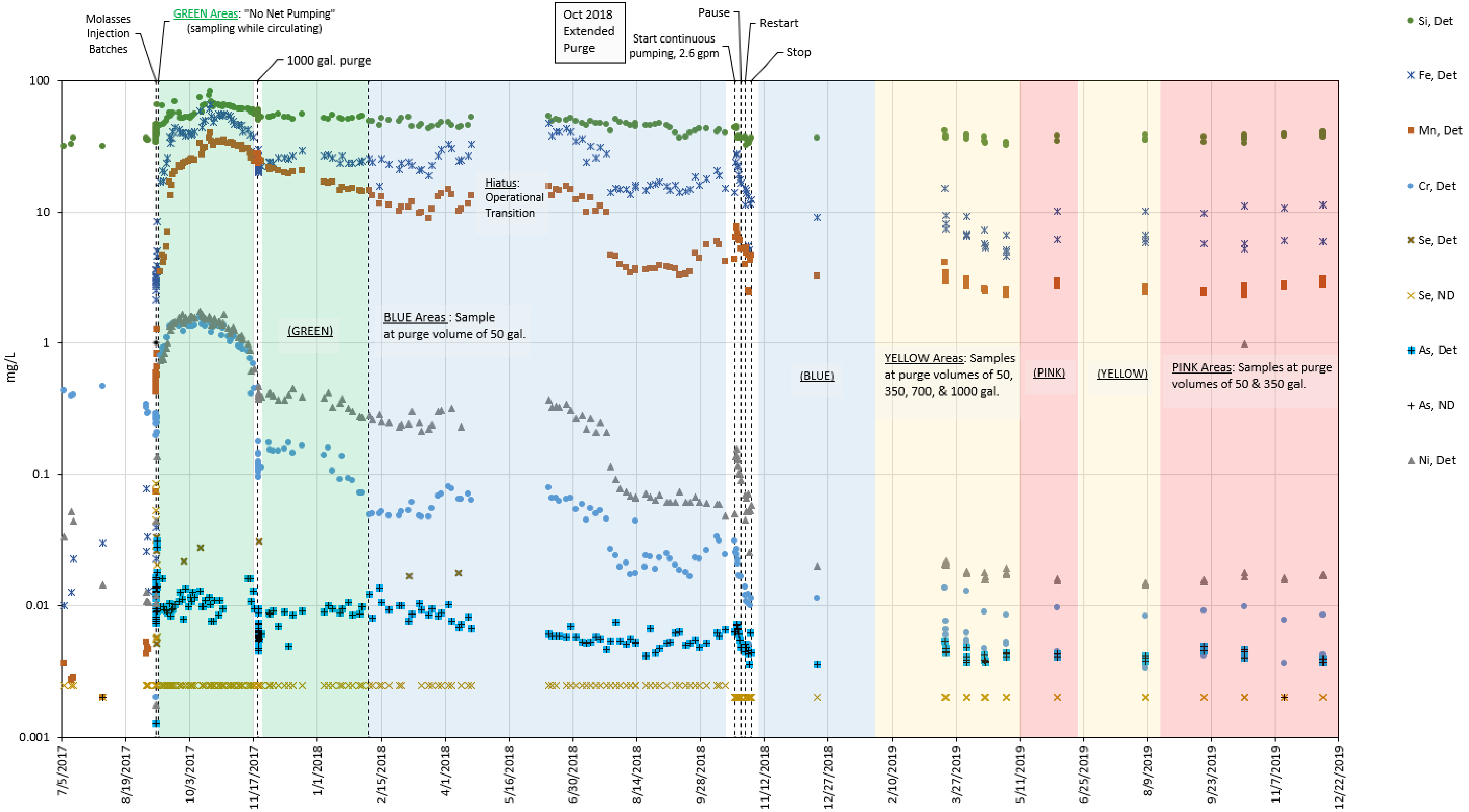
Notes: The pre-test concentrations were approximately as follows: TOC = 1, C2O4 <0.01. Pre-amendment values are shown in mg/L. Also, if different, values for 2014/2015 period are shown in parentheses. Det = Detected.

Figure 2.2-3 Concentrations of TOC and oxalate in R-28 molasses test as a function of time



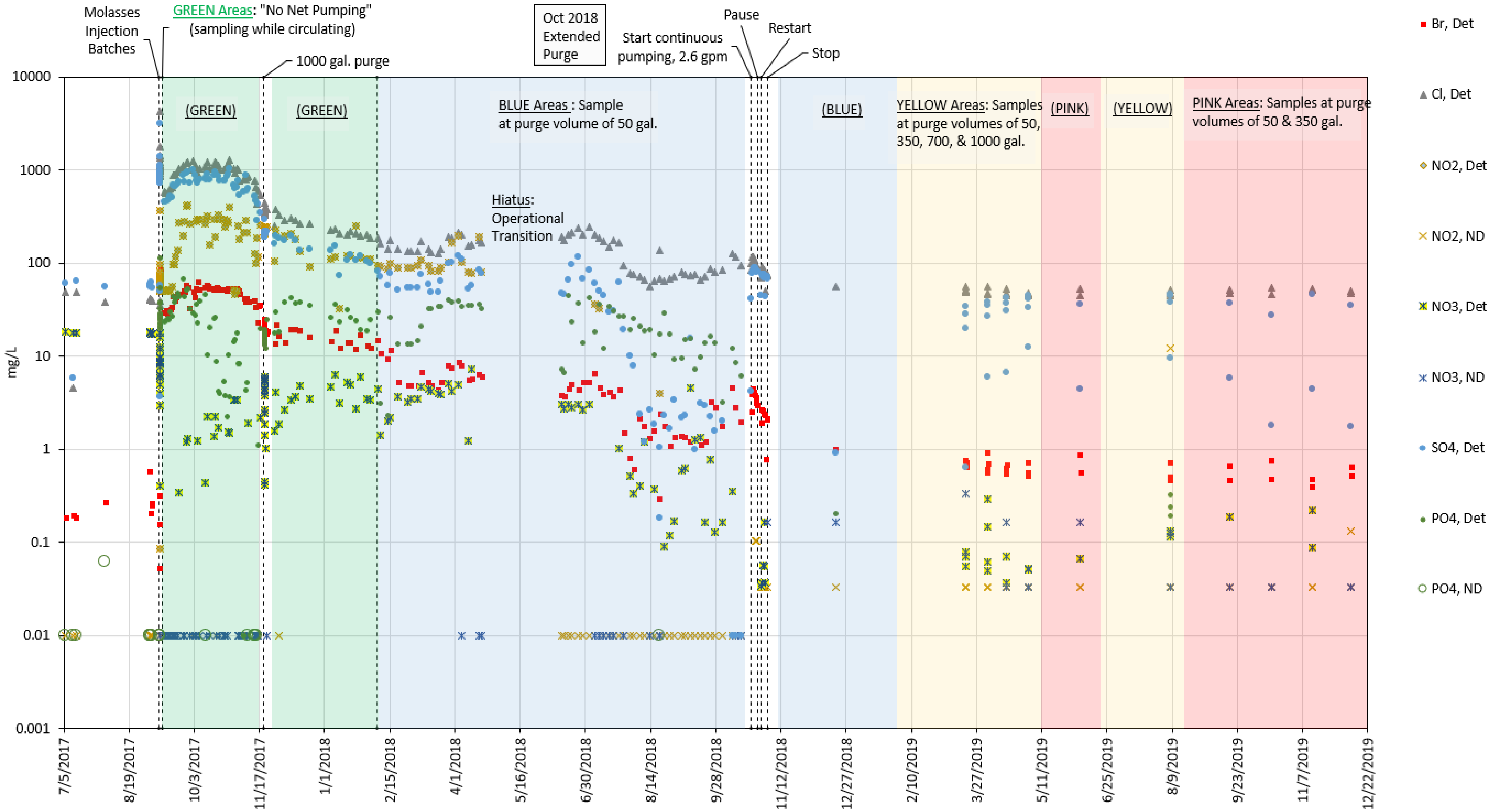
Notes: The pre-test concentrations were approximately as follows: Fe = 0.01–0.025, Mn = 0.001–0.005. All results are from filtered samples. Pre-amendment values are shown in mg/L. Also, if different, values for 2014/2015 period are shown in parentheses. Det = Detected.

Figure 2.2-4 Concentrations of iron and manganese in R-28 molasses test as a function of time



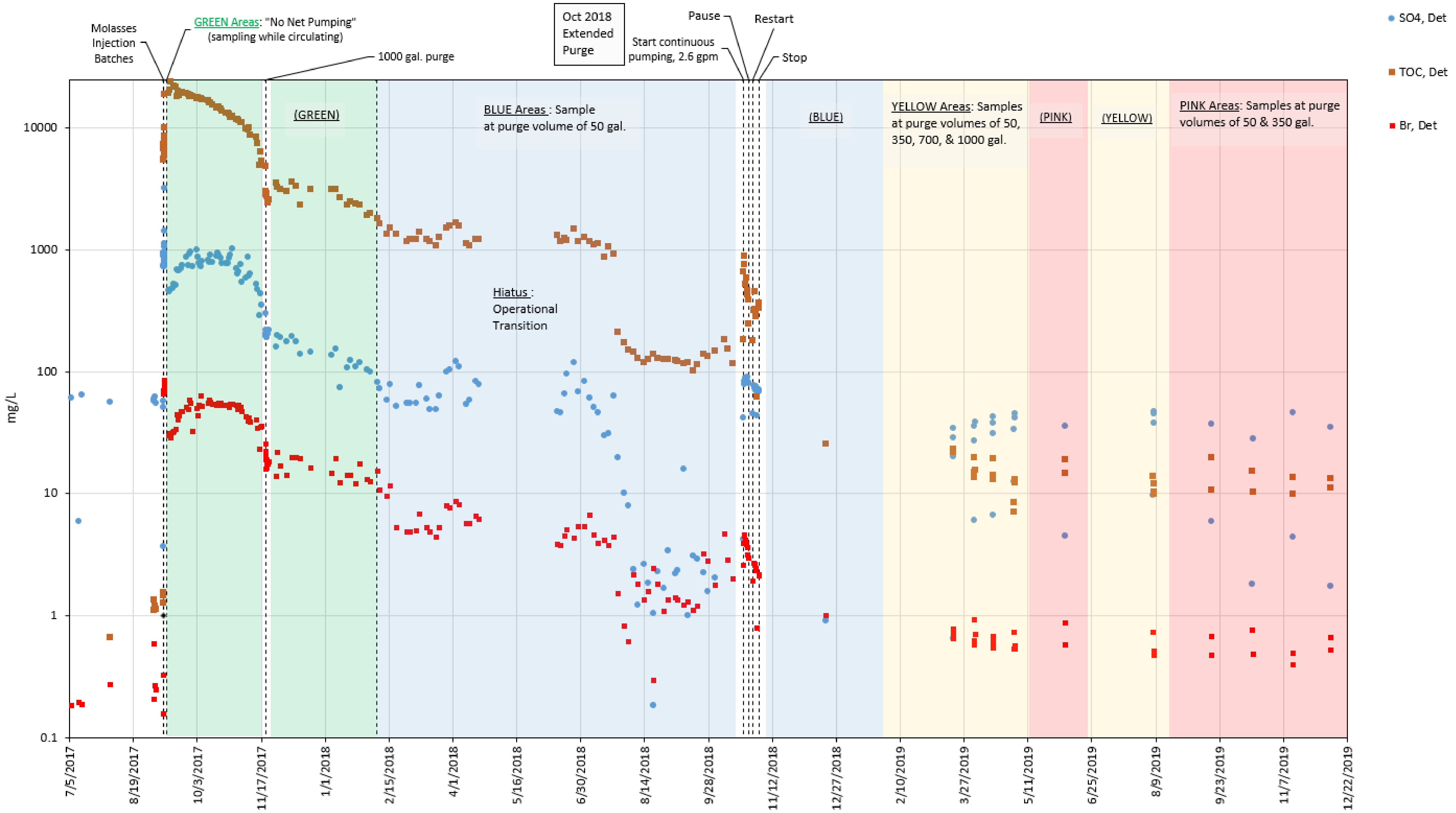
Notes: The pre-test concentrations were approximately as follows: Si = 35, Fe = 0.01–0.025, Mn = 0.001–0.005, Cr = 0.5, Se = ND = 0.01, As = 0.0005, Ni = 0.01–0.04. Pre-amendment values are shown in mg/L. Also, if different, values for 2014/2015 period are shown in parentheses. Det = Detected, ND = Not detected.

Figure 2.2-5 Concentrations of selected constituents during R-28 molasses test as a function of time



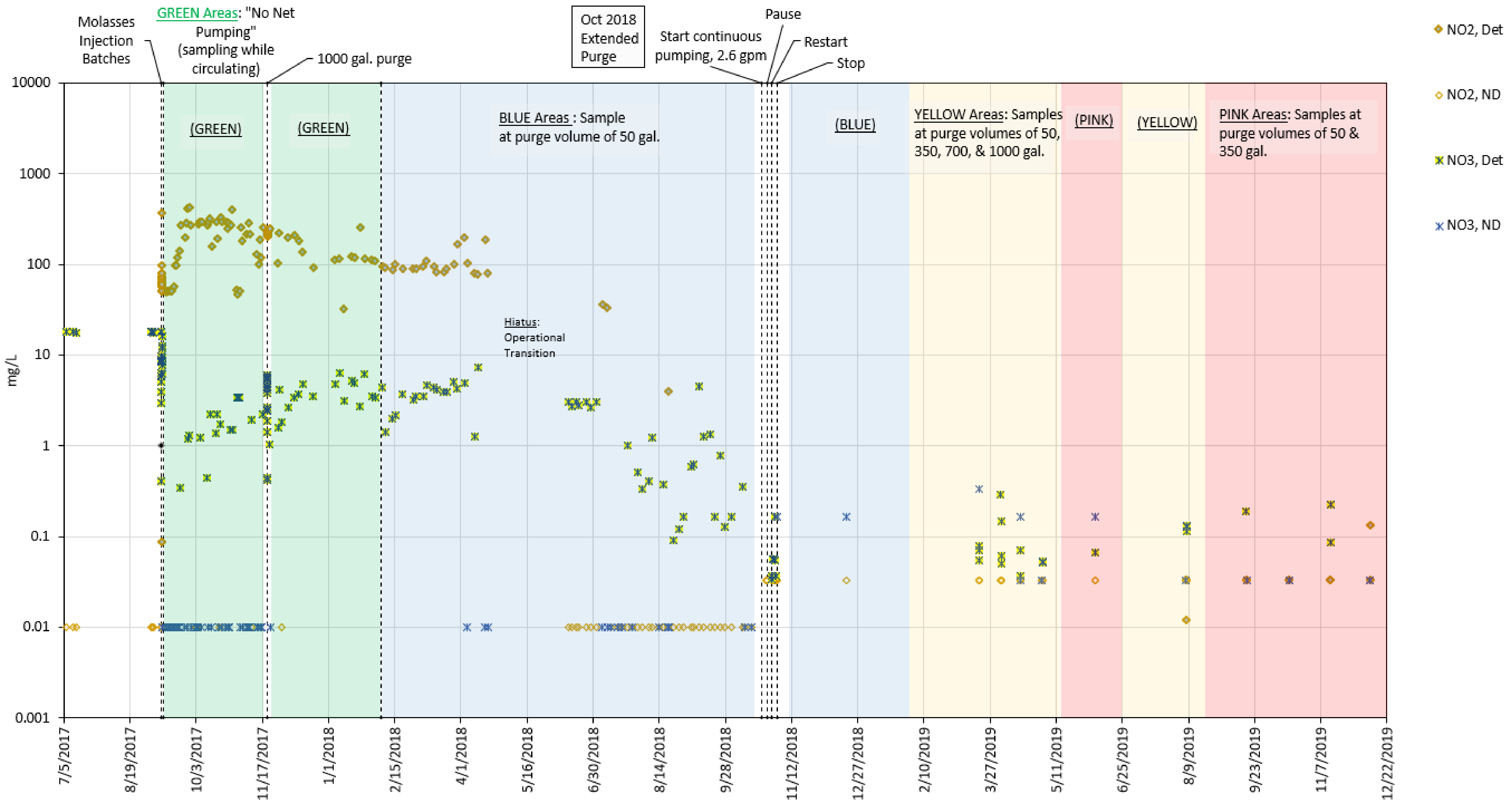
Notes: The pre-test concentrations were approximately as follows: Br = 0.2, Cl = 45, NO2 <0.01, NO3 = 19, SO4 = 60, PO4 <0.01. Pre-amendment values are shown in mg/L. Also, if different, values for 2014/2015 period are shown in parentheses. Det = Detected, ND = Not detected.

Figure 2.2-6 Concentrations of anions in R-28 molasses test as a function of time



Notes: The pre-test concentrations were approximately as follows: Br = 0.2, SO4 = 60, TOC = 1. Pre-amendment values are shown in mg/L. Also, if different, values for 2014/2015 period are shown in parentheses. Det = Detected.

Figure 2.2-7 Concentrations of bromide, sulfate, and TOC in R-28 molasses test as a function of time



Notes: The pre-test concentrations were approximately as follows: NO2 <0.01, NO3 = 19. Pre-amendment values are shown in mg/L. Also, if different, values for 2014/2015 period are shown in parentheses. Det = Detected, ND = Not detected.

Figure 2.2-8 Concentrations of nitrate and nitrite in R-28 molasses test as a function of time

Table 2.3-1
Estimated Amounts of Cr(VI) Reduced in the Pilot Amendment Tests at R-42 and R-28

Date	R-42			R-28		
	Pumping (g)	**Natural Flow (g)**	**Total (g)**	**Pumping (g)**	**Natural Flow (g)**	**Total (g)**
March 2019	291	57	348	57	107	164
April–December 2019	16	32	48	13	67	80
December 2019	307	89	396	70	174	244

Note: Values are rounded to the nearest gram.

Attachment 1

Data Associated with Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon, October 2019 to March 2020
(on CD included with this document)