EMID-701518
Rec'd 7/9/21

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July 9, 2021

Arturo Duran
Designated Agency Manager
Environmental Management
U.S. Department of Energy
Los Alamos Field Office
1200 Trinity Drive, Suite 400
Los Alamos, New Mexico 87544

Re: Notice of Disapproval
Semiannual Progress Report on Chromium Plume Control Interim Measure Performance
January through June 2020
Los Alamos National Laboratory
EPA ID#NM0890010515
HWB-LANL-20-080

Dear Arturo Duran,

The New Mexico Environment Department (NMED) received the United States Department of Energy's (DOE) *Semiannual Progress Report on Chromium Plume Control Interim Measure Performance, January through June 2020* (Report) dated September 2020 and referenced by EM2020-0392 on September 29, 2020, in fulfilment of Milestone #12 of Fiscal Year 2020. The Report constitutes one submittal in a series of semiannual reports that are subject to reporting and interim measures (IM) operational requirements. These requirements are provided in regulatory documents including the applicable IM work plans, NMED approvals, and Section XXIII of the 2016 Compliance Order on Consent (CO). NMED reviewed the Report and issued comments on December 31, 2020 (Comments) that required a revision of the Report be submitted by February 26, 2021, to adequately address NMED concerns. DOE provided responses to the Comments on February 26, 2021 (Responses) without the required revision. NMED's review of the Responses found them to be technically deficient, not responsive of NMED's concerns and disregarding NMED's direction to submit a revised report. DOE also submitted the Responses with the subsequent semiannual report for 2020, which does not comply with the document review protocol established by the CO.

The CO requires DOE to involve NMED in the chromium technical team and pre-submittal meetings to discuss the report content before each submittal and for NMED to provide input to direct the IM operations. In 2020, no such meetings were held with NMED prior to submitting the Report. Over time, DOE's lack of engagement with NMED has resulted in substantial disparity between the two parties on how best to manage the IM, which has resulted in the original IM objectives not being met and a situation where the subsequent reports are propagating unresolved issues from previous submittals. As a result, this Notice of Disapproval (NOD) is hereby issued in accordance with the CO because the Comments remain unresolved, and DOE's Responses are inadequate.

The enclosure includes NMED's follow-up comments to the original Comments that remain unresolved due to DOE's inadequate Responses. The original Comments with DOE's Responses are included as Attachment 1 of the enclosure. Additional attachments that illustrate NMED's positions are also included in the enclosure.

DOE must satisfactorily resolve all the December 31, 2020, informal comments and the disapproval comments provided herein before any subsequent semiannual reports on the IM are submitted, and must not add to, delete from, or introduce other modifications to the revision that do not pertain to these comments. If DOE notes other issues in the Report that may need modification, DOE must contact NMED to discuss the matter before making any modifications to the revision. In accordance with the original Comments, DOE must submit a revision of the Report within 60 days of the date of this letter.

Should you have any questions regarding this correspondence, please contact Christopher Krambis (505) 231-5423.

Sincerely,

Ricardo Maestas Digitally signed by Ricardo Maestas
Date: 2021.07.09 08:41:28 -06'00'

Ricardo Maestas
Acting Chief
Hazardous Waste Bureau

Cc with Enclosure:

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File: LANL 2021 and Reading, Notice of Disapproval for the Semiannual Progress Report on Chromium Plume Control Interim Measure Performance, January through June 2020.
HWB-LANL-20-080

ENCLOSURE
NMED DISAPPROVAL COMMENTS ON THE SEMIANNUAL PROGRESS REPORT ON CHROMIUM PLUME CONTROL INTERIM MEASURE PERFORMANCE, JANUARY THROUGH JUNE 2020, SEPTEMBER 2021
LOS ALAMOS NATIONAL LABORATORY, EPA ID #NM0890010515
LANL-20-080

General Comment No. 1

One of the original objectives of the chromium plume control interim measures (IM) is to capture and remove the hexavalent chromium mass from the regional aquifer[1]. Subsequent IM work plans stressed achieving and maintaining the 50-ppb downgradient chromium plume edge within the laboratory boundary over a period of approximately three years[2]. Since 2016, DOE's IM has removed approximately 300 pounds of chromium from the regional aquifer. As of April 2021, this three-year period elapsed and adjustments to the system performance are now necessary to refocus the IM to its original goal of mass removal via groundwater extraction to build toward the final remedy.

In their Response, DOE makes the case that injection does little to form and maintain hydraulic control along the laboratory's southern boundary because no discernable mound developed over the three-year period, and that cones of depression may develop around extraction wells. This apparent uncertainty indicates a lack of insight regarding the IM performance. To evaluate the IM performance, NMED mapped synoptic water level data from the January through June 2020 monitoring period by triangulation of the three-point problem across all monitoring wells – a standard contouring method in geology and hydrogeology. (NMED's maps and the three-point problem triangulation technique can be shared with DOE in technical team meetings.) The results show the ineffectiveness of injection to reverse the hydraulic gradient and the effectiveness of the IM extraction operation to form an effective cone of depression. The ability to detect this has been previously hampered by DOE's mapping technique of the regional aquifer water table surface at the chromium site. (See NMED's original and follow-up specific comment 4 in Attachment 1 and below, respectively).

DOE cites the tracer test results from CrIN-4 to be proof that injection aided by extraction is the cause of the reversal of the natural hydraulic gradient. The tracer detection at CrEX-1 is evidence that extraction, not injection, is the more effective remediation mechanism because it is physically impossible to reverse the natural hydraulic gradient via injection without a discernable mound. It is more plausible that an injection-dominated operation would have simply diluted the tracer mass to below detection in all directions from the injection source, specifically downgradient away from CrEX-1 and R-50. This would result in a non-detectable concentration at CrEX-1. Considering that wells are more efficient in extraction than injection and that the injection operation resulted in no discernable mounding, NMED concludes that it is the extraction operation that is the more plausible cause of the reversal of the hydraulic gradient and the tracer detection at R-50 and CrEX-1. Consequently, there is a need to adjust the plume control IM to focus on chromium mass removal as stated in the 2013 work plan[1] and related documents[3,4,5].

DOE must hold technical team meetings with NMED to discuss and implement the needed changes to the IM system to achieve all objectives formulated since 2013. As part of the readjustment to the IM system, NMED

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[1] LANL, April 30, 2013, IM Work Plan for the Evaluation of Chromium Mass Removal. 35819
[2] LANL, April 2018, Chromium Plume Control IM Performance Monitoring Work Plan (LA-UR-18-23082). 38423.
[3] NMED, January 25, 2013, Response letter to the Proposal to Submit IM Work Plan for Chromium Contamination in Groundwater (HWB-LANL-12-022). 35714.
[4] LANL, September 27, 2013, Response to the Approval with Modification for the IM Work Plan for the Evaluation of Chromium Mass Removal-Status Report for Pumping Test at Well R-42. (LA-UR-13-27 463). 36020.
[5] LANL, March 31, 2014, Summary Report for the 2013 Chromium Groundwater Aquifer Tests at R-42, R-28, and SCI-2 (LA-UR-14-21642). 36274.

requires DOE to conduct the required capture zone and flooding zone analyses and numerical groundwater modeling[6]. This work must be conducted with NMED's input. Technical details shall be discussed in a pre-submittal meeting prior to the submittal of the next semi-annual IM progress report.

General Comment No. 2

DOE's response does not address this comment and defers a meaningful resolution to an uncommitted future meeting. However, NMED's comment focused on content missing from the Report, which needs resolution now, not in future. NMED's approval of the document cited by DOE was contingent upon DOE involving NMED in the pre-submittal meetings to guide the direction of the IM, on whether to incorporate modeling results in each semi-annual report, and whether monitoring wells are responding favorably.[6] DOE has not held pre-submittal meetings with NMED concerning the content of the Report. DOE also has not addressed the fact that R-45 S2 is not responding favorably to the injection operation, which NMED identified in the Comments in Attachment 1.

The initial chromium concentration trends at R-45 S2 suddenly surged once CrIN-3 injection began on May 23, 2018, and then again immediately following CrIN-1 and CrIN-2 injection on November 13, 2019, to a point where chromium now exceeds the 50 ug/L NMED groundwater standard (Attachment 2). The initial trend indicates this should not have occurred until 2035. This assertion is supported by the opposite response in chromium concentration at R-45 S1. DOE's exclusion of NMED in the IM planning and reporting has resulted in the deterioration of IM monitoring quality, effectiveness, and purpose since NMED approved the work plan in December 2019[7]. Of specific concern to NMED is DOE's inability to monitor and capture the chromium it has pushed down to R-45 S2 because there are no IM infrastructure wells completed at that depth. To rectify this, DOE must implement NMED's modifications to the continued operation and reporting of the IM including submitting numerical modeling scenario runs to evaluate extraction capture zones and injection flood zones (see General Comment No. 1 above). Cessation of all injection operations should take place over a semi-annual monitoring period at a minimum to evaluate whether the trends recorded at R-45 reverse.

Specific Comment No. 1a

DOE's response does not adequately address NMED's comment on this issue because no facts are provided to support their opinions. Contrary to NMED's observations, DOE does not consider PM-3 pumping and the year-long continual injection at CrIN-3, CrIN-4, and CrIN-5 that commenced on May 23, 2018, as possible causes of the corresponding sudden decrease and increase in chromium concentration trends detected at R-45 S1 and R-45 S2, respectively. There is evidence that supports there being a relationship between the documented changes in chromium concentration at R-45 and the commencement of CrIN-3, CrIN-4, and CrIN-5 injections (Attachment 2). CrIN-3 and CrIN-4 are about 1,100 and 1,500 feet southwest of R-45, respectively, and chromium that is not detected by the existing monitoring well network is likely present at depth between CrIN-3/CrIN-4 and R-45 because vertical delineation in this area has not been demonstrated by DOE. While tracers from these injection wells have not been detected at R-45, it is not necessary for the injected water to reach the monitoring well to cause the observed change in trends because the injection will displace groundwater between the two points toward the distant monitoring well and it is highly likely that the tracer would have been diluted to the point of non-detection before it traveled that distance. Consequently, NMED does not

[6] NMED, October 3, 2019, Approval Letter to the Semiannual Progress Report on Chromium Plume Control Interim Measure Performance. 39134. *"Applicability and incorporation of numerical modeling for semiannual reporting might be appropriate to guide IM operational strategies if performance monitoring wells are not responding favorably. The use of modeling for the chromium project should be further discussed with NMED in presubmission meetings for future semiannual progress reports."*

[7] NMED, January 7, 2019, Approval Chromium Plume Control Interim Measure Performance Monitoring Work Plan. 38745.

concur with the DOE statement: *"The increased rate of change in chromium concentration in screen 2, starting in the 2018 timeframe, began before any continuous IM operational activities in the area..."*.

NMED also does not concur with the statements DOE provided to explain the responses shown in Attachment 2. The site data in the form of measured water levels, vertical gradients, and an absence of overlying perched groundwater, indicate infiltration is not present in this area as *"recent post-Cr infiltration"* toward R-45 S2. As a result, NMED does not agree that the decreasing chromium at R-45 S1 is due to *"young water with very low chromium concentrations infiltrating in that area"*, but instead to the IM injection operations. DOE must perform capture zone and flood zone analyses and conduct groundwater modeling to provide insight to the R-45 chromium concentration trends and NMED will consider whether to allow the injection strategy at CrIN-1, CrIN-2, and CrIN-3 to continue. Technical details must be discussed in a technical team meeting prior to the submittal of the next semi-annual IM progress report.

Specific Comment No. 1b

NMED does not find DOE's response to this comment acceptable because DOE deflects the request to reference past submittals, a future publication and meetings and does not consider the fact that the work plan requires aquifer properties and migration rates from tracer tests be provided in the IM performance reports. Each submittal is an update on the performance of the chromium plume IM and that the tracer detections DOE discussed in the Report are recent and ongoing. Additionally, the required aquifer properties are not presented in the previous report, when two tracers were documented to have been first detected. DOE acknowledged in its response that tracer responses provided information on *"...how fast injected water has migrated through the regional aquifer..."* and *"...have been used to estimate effective porosity in the regional aquifer..."*. The information is required by the work plan for inclusion in the semiannual reports[2] including the Report.

NMED does not concur with DOE's statement that tracer responses do not provide information that can be used to directly quantify aquifer properties or to calculate groundwater flow velocity. DOE's reference to natural flow is moot because the purpose of the Report is to evaluate the performance of the plume control IM not natural flow patterns. As such, DOE must provide the aquifer parameters for each tracer detection in the revision as required by the work plan. NMED also does not concur with DOE that aquifer parameters like hydraulic conductivity are best inferred from aquifer tests. Hydraulic conductivity is not directly derived from aquifer tests but is indirectly calculated from transmissivity that is directly derived from aquifer tests. Additionally, DOE typically performs single-well pumping tests, not well interference aquifer tests that test the formation hydraulics between wells. Single well pumping tests do not provide meaningful storativity values as DOE claimed in the Response, and hydraulic conductivity is an estimate for conditions around the well only. In this case, the cited tracer test results would provide better aquifer information than the single-well pumping tests. Consequently, DOE must calculate hydraulic conductivity from each tracer test for inclusion in the revision and provide a comparison to all the proximal pumping tests as requested in the original Comments (Attachment 1).

DOE contradicts itself in the final paragraph of its response *"The paper also summarizes effective/flowing porosity estimates and flow distribution estimates (i.e., cumulative fractions of flow occurring in cumulative fractions of total porosity) that have been derived from the tracer and geochemical signature responses to date. DOE must provide the manuscript of that paper and discuss the findings in a future technical team meeting."* The inclusion of this information in the report revision is required[2]. DOE must adequately address NMED's request to characterize aquifer properties (e.g., effective porosity, hydraulic conductivity) and provide the travel time, groundwater flow velocity and radius of influence between injection wells and performance monitoring wells for each tracer detection. These data will be used to refine the chromium groundwater model and the capture zone and flood zone analyses to evaluate the actual effects DOE's IM injection operations are having on the groundwater hydraulics of the regional aquifer (see General Comments Nos. 1 and 2 above).

Specific Comment No. 2a

NMED does not accept DOE's response to this comment because the comment does not pertain to the upcoming semiannual report, but to the semiannual report in review. NMED requires a revision to the Report with the narrative that DOE claimed in its response will address NMED's comment concerning verification that "*...injection water had been pushed sufficiently upgradient of each injection well during IM operations conducted before the EMCA pause. Furthermore, by the end of the pause, upgradient groundwater with higher concentrations of chromium had not migrated back into portions of the plume where the injection wells are located.*" The numerical groundwater model is to be updated in accordance with the October 3, 2019, approval letter[6] with the recent tracer detection results to provide a more suitable tool to assess DOE's claim. As stated in the original comment, if DOE cannot support this statement, it must be removed from the Report in the revision.

Specific Comment No. 2b

NMED does not accept DOE's response to this comment because the "conceptualization" of the fate and transport of chromium from injection to extraction wells is based on conjecture whereas the required updated modeling conducted in accordance with the October 3, 2019, approval letter[6] would provide a more tenable response. DOE's conceptualization provides insights to complexities, such as the effects dispersion and layering, have on an advancing front that a model would be best suited to explain. Additionally, DOE again defers the response to the upcoming semiannual report even though NMED's comment pertains to the semiannual report in review.

DOE's conceptualization that it is reasonable to expect the chromium mass from R-50 S1 and CrIN-4 will be captured by CrEX-1 is unsupported because the tracer in CrIN-4 was first detected in CrEX-1 in late 2018 as shown by Figure 3.2-29 of the Report, yet the chromium mass recovered did not correspondingly increase but decreased over the same timeframe as shown in Figure 3.2-20 of the Report. It is more reasonable that the two-dimensional movement of the tracer and chromium from CrIN-4 to CrEX-1 would arrive at similar times in similar mass (flux) with respect to the initial mass. Additionally, if dilution were a factor in explaining the lack of chromium response at CrEX-1, the tracer would also have been equally diluted. However, the arrival of the tracer at CrEX-1 exhibited a classic breakthrough curve, not a decreasing trend as with the chromium. In the revision, DOE must provide a quantitative evaluation of the mass injected to the mass recovered for both the original tracer and chromium at CrIN-4 to CrEX-1 using the updated numerical groundwater model or remove the "conceptualization" from the revised Report.

It is plausible that injection is interfering with ability to accurately measure recovered chromium via dilution. Table 2.1-3 of the Report indicates that DOE bases the chromium mass recovery on averages from field screening using HACH colorimetric field test method. This method only has a resolution of ±10 ug/L and is not suitable for an accurate mass recovery estimate. DOE should be collecting and submitting samples for laboratory analysis to determine the chromium mass removal. DOE must use laboratory analytical data and more frequent measurements to make the recovery estimates more accurate through integration over time and not averages.

NMED does not concur with DOE's statement *"that the decreasing Cr concentration trends in the extraction wells also reflect a removal of Cr at a faster rate than it is being replenished by upgradient sources"*. The Report indicates only 296.6 pounds of chromium mass have been removed from 169,991,100 gallons of groundwater extracted since the fourth quarter of 2016. The plots in Attachment 3 positively show that the chromium mass recovery rate is directly proportional to the volume extracted, that the recovery rate has not increased but is quite linear, and that the source has had nothing to do with the reported recovery rates. It is more likely that over time, the extraction wells are pulling clean water from storage outside the plume and from the IM injection operations as the radius of influence increases. This would dilute the chromium concentration at the point of recovery. A revised model run should have been used to verify this statement before its inclusion in the Report. DOE must include such a model run to demonstrate the validity of their statement that chromium mass recovery is occurring at a faster rate than the upgradient source can provide or remove the statement from the revision. It should be noted that chromium concentration increases with depth at CrEX-4 and R-70 and the recovery wells do not fully penetrate the chromium plume. Additionally, with the effective removal of the two monitoring wells that formerly monitored the highest chromium concentrations presumably near the source(s) from the groundwater monitoring plan, the source areas are no longer being monitored.

Specific Comment No. 3

DOE incorrectly states in their response that no specific graphical presentation format was discussed with NMED. In fact, NMED provided DOE explicit written directions in what was required in the approval letter[8] and again verbally during the subsequent May 21, 2020, meeting. Proper hydrographs prepared as NMED originally directed and as discussed over the phone on February 9, 2021, and in a follow-up email on February 25, 2021, must be included in the revision, not only in the subsequent reports. DOE must comply with these requirements and include the proper hydrographs in the revision.

Specific Comment No. 4a

The three-point problem is the standard contouring method in geology and hydrogeology. In the response, DOE did not address the issue of the 5830-foot closed contour line between CrEX-4 and CrEX-1 in Figure 3.3-1 of the Report as requested in the Comments (Attachment 1). Data do not support this interpretation because all adjacent wells have water table elevations higher than 5830 feet. Conversely, contour lines must be present when data supports such a need such as DOE's omission of a 5830-foot contour line between R-13 and R-44 S1. This is another mapping error that needs to be corrected in the revision. Contour lines generated by automated geostatistical software must have values that lie within the upper and lower data limits to constrain the interpolation otherwise errant results can occur because the software method's inability to deal with data gaps and anomalies.

The methodology used by DOE to construct the water table contour map in the Report is not appropriate as indicated by the facts provided in the preceding paragraph and the contrast in results obtained by NMED using the three-point problem. The three-point problem satisfies the method requirement for mapping the water table surface of the regional aquifer[9] whereas kriging does not necessarily align with industry standards, nor does it provide any more consistency over time than other methods of interpolation. While kriging honors the data at the measurement locations, it assumes a normal distribution of the data and no trend to the data, and

[8] NMED, May 6, 2020, Approval with Modification Semiannual Progress Report on Chromium Plume Control Interim Measure Performance, July Through December 2019.

[9] NMED, August 31, 2016, Ground Water Discharge Permit, Los Alamos National Laboratory Underground Injection Control Wells Discharge Permit-1835. 37680.

an autocorrelation of the data. Consequently, kriging is prone to misrepresent the groundwater flow system if not properly constrained to the data limits and if the assumptions are not satisfied. Kriging is also highly prone to interpolation artifacts that cause excessive smoothing of the surface, abrupt changes in the interpolated surface, and overemphasis of isolated observations. The occurrence of the 5830-foot contour line in Figure 3.3-1 of the Report is an example of this problem. Because kriging assumes no trend by default, it is not programmed to contour groundwater elevations, which obviously have a trend i.e., the groundwater flow direction. Hence, kriging and other computer-generated geostatistical interpolation methods must be used with caution and only by a highly experienced hydrogeologist. If DOE desires to use kriging to model the water table surface, DOE must provide the following in the revision:

- Gridding resolution (delta x and delta y) to interpolate and to contour the data
- Spatial autocorrelation
- Variogram and its nugget effect, range, and sill
- Drift
- Interpolation error

In the revision, DOE must demonstrate how the above kriging criteria is suitable to model the water table surface configuration for each map presented in the Report. The maps provided in the Report do not represent accurately the IM impacts on the regional aquifer water table. As a result, an accurate assessment of IM effectiveness is not possible.

In addition, use of monthly averages instead of actual synoptic data is not consistent with the industry standard[10], does not comply with permit requirements[9], and does not provide better understanding of the long-term changes in the water table caused by IM activities because averages incorporate water table fluctuations due to other phenomena such as barometric influences and pumping that skew contouring results. Use of synoptic data from continuously recording pressure transducers eliminate such interferences specifically when strategic timeframes such as early morning weekends and holidays are selected. NMED does not concur with DOE's claim that the low hydraulic gradient requires the use of averages. This statement did not consider NMED's comment that a series of tenable water table maps using manual triangulation i.e., the three-point problem and synoptic water table elevation data were prepared by NMED (see General Comment No. 2), which demonstrates that use of monthly averages to map the flat water table are not necessary.

The mapping requirements include only 14 wells[9]. This excludes R-28, R-48, R-70, R-35b and R-15. Data from these wells and SIMR-2, one of the 14 wells required by the DP but is typically omitted by DOE from the water table maps, are as instrumental in understanding long-term changes to the water table from IM activities. These data must be incorporated into the mapping for the revision and all future submissions.

Two quarterly water table contour maps are required in each semiannual report as required by the approved work plan: *"The maps presented in the semiannual reports will be the same as those presented in quarterly reports provided under discharge permit (DP)-1835"*[2]. DOE incorrectly stated in their response that *"The language in the Performance Monitoring Work Plan is intended to state that the single water-table map that will be included in each semiannual performance monitoring report will be the map from the most recent DP-1835 quarterly report."* The work plan is clear that multiple maps that correspond to the quarterly maps are to be

[10] ASTM-D6000-15 Standard Guide for Presentation of Water-Level Information from Groundwater Sites.

presented in each semiannual report. DOE must include, at a minimum, the two most recent quarterly water table maps of the regional aquifer in the revision.

Specific Comment No. 4b

NMED does not concur with DOE's statement that *"subtle depressions in the water table can also be caused by local areas of present-day recharge from the vadose zone resulting in the appearance of water-table "mounding" and an adjacent depression"*. NMED contoured the same data for the May 1, 2018, baseline water table map, which is synoptic, but using the three-point problem method and did not come up with the depression. DOE's position that a subtle, but measurable, depression occurs in the water table around a mound is unlikely. Other factors that also do not support DOE's conceptualization of local areas of recharge from the vadose as the source for mounding in the regional aquifer water table include:

- No drilling records corroborate the presence of a perched aquifer or other vadose zone water is present in the area to provide this recharge,
- No presence of significant vertical downward hydraulic gradients in the regional aquifer that would result from recharge and the resulting mounding hypothesized by DOE to occur along the water table, and
- No mounding is observed from sustained engineered IM injection operations along the regional aquifer water table, or at least not at detectable magnitudes by the existing monitoring well network.

It is not plausible that natural recharge in a desert environment such as Los Alamos that must infiltrate through more than 900 feet of vadose zone could provide more flux to the water table than the injection operations of the IM. It is more plausible that there is an irregularity in DOE's wellhead reference survey data and/or that DOE mis-contoured the water table because of its incorrect use of monthly water level averages, errant and anomalous data, and by employing an automated geostatistical contouring method. DOE must select a more representative timeframe for the baseline water table map and recontour the map for inclusion into the revision using the three-point problem. The mapping must be undertaken with NMED involvement and approval before the figure will be accepted for inclusion in the revision.

Specific Comment No. 5

NMED does not accept DOE's response to this comment because DOE appears to avoid the need to revise the Report by deferring that *"going forward"* future reports will address this issue. DOE must revise the Report, regardless of future submittals to address NMED's concern. This requirement is especially significant considering that the monitoring period covered by the Report is inclusive of the effects the COVID shutdown may have had on the vertical gradients at the chromium plume that would be of interest to any serious hydrogeological analysis. Steps to resolution for this comment were discussed during the February 9, 2021, telephone correspondence between NMED and N3B. DOE must use the agreed upon approach in the revision of the Report as well as in all forthcoming semiannual reports.

Specific Comment No. 6

NMED's comment did not pertain to CrEX-5, CrIN-1, and CrIN-2 operations, but those along the laboratory's southern boundary at R-50. Based on the various work plans[1,2], DOE must maintain the operations at CrEX-1 as an extraction well and CrIN-5 and possibly CrIN-4 (if it can be shown it is not a cause of the increasing chromium at R-45 S2 through modeling) as injection wells to continue the hydraulic control along the laboratory's boundary until a final remedy is implemented.

Specific Comment No. 7

NMED requires a system-wide evaluation using capture zone and flood zone analyses and updated model simulations to provide insight to the IM performance. At a minimum, NMED believes the IM injection operations at CrIN-1, CrIN-2 and CrIN-3 are the cause of the unfavorable response at R-45 S2 (see Specific Comment No. 1a).

ATTACHMENT 1

ORIGINAL NMED COMMENTS WITH DOE RESPONSES

U.S. Department of Energy Response to the New Mexico Environment Department Hazardous Waste Bureau Draft Comments, on the Semiannual Progress Report on Chromium Plume Control Interim Measure Performance, January through June 2020, Dated December 31, 2020

INTRODUCTION

To facilitate review of this response, the New Mexico Environment Department's (NMED's) comments are included verbatim. The U.S. Department of Energy (DOE) Environmental Management Los Alamos Field Office responses follow each NMED comment.

GENERAL COMMENTS

NMED Comment

1. *The April 2018 Chromium Plume Control Interim Measure Performance Monitoring Work Plan (Work Plan) states that a secondary objective of the Interim Measures (IM) "is to hydraulically control plume migration in the eastern downgradient portion of the plume" and that the "objective of the performance monitoring and associated reporting is to collect, evaluate, and report on the performance of the IM ... to guide adjustments in the distribution and rates of extraction and injection". Unlike the IM extraction operation conducted at CrEX-1 and CrEX-2 that has demonstrated the rapid development of a sustained cone of depression that may serve to control plume migration, activating CrIN-4 and CrIN-5 since 2017 has not resulted in similar evidence for the potential for hydraulic control via injection, specifically by creating a hydraulic mound along the Los Alamos National Laboratory (LANL) – San Ildefonso Pueblo (SIP) boundary. The fact that the IM is not fulfilling all objectives of the Work Plan, the Department of Energy (DOE) must adjust the distribution and rates of extraction and injection in the IM system to achieve the secondary objective of the Work Plan.*

DOE Response

1. The interim measure (IM) objective is being met through the combination of groundwater extraction and injection of treated water. The combination of extraction and injection does not rely on development of a groundwater mound at the injection wells to achieve hydraulic control. Singular or integrated cones of depression that may develop around extraction wells are beneficial and likely result in capture of upgradient chromium flux as well as modification of the flow field downgradient of the well. Injection into the aquifer via the injection wells drives groundwater flux in a generally radial manner and modifies the groundwater flow direction with or without discernable mounding. In areas with high hydraulic conductivity like within the chromium plume, a large discernable mound may not form, but even a mound of modest height that may not be detected with the existing monitoring network can be effective in reversing the gradient, especially when aided by nearby extraction. The presence in R-50 S1 and CrEX-1 of the tracer Sodium-1,5 naphthalenedisulfonate deployed into CrIN-4 is a direct indication of that process, and definitively demonstrates the reversal of the gradient in that area.

   Whereas the system allows for some flexibility to adjust the distribution and rates of extraction and injection, the performance to date along the southern portion of the plume, along the boundary between Los Alamos National Laboratory (LANL or the Laboratory) and the Pueblo de San Ildefonso, indicates that there is no need to make any adjustments at this time. IM performance along the eastern portion of the plume will continue to be monitored and operational adjustments will be made if necessary.

NMED Comment

2. Following review of the first IM progress report submitted in 2018, on March 28, 2019 NMED sent the letter titled, "Approval, Annual Progress Report on Chromium Plume Control Interim Measure Performance" (2019 Letter). General Comments Nos. 1 and 3 attached to the 2019 Letter directed DOE to perform capture zone and flooding zone analyses for the IM operations and present the results in map format in future IM performance reports. The Semiannual Progress Report on Chromium Plume Control Interim Measure Performance, January through June 2020 (Report) did not include this information. Submit a revised report that includes the capture zone and flood zone analyses as directed by the 2019 Letter.

DOE Response

2. DOE's responses pertaining to capture zone and flood zone analyses are captured in a letter from NMED to DOE dated October 3, 2019 and titled Semiannual Progress Report on Chromium Plume Control Interim Measure Performance. The responses noted that "IM data is being incorporated into ongoing work for the chromium project and provides very valuable input for assessing plume-scale hydrology related to pumping and injection, especially as it informs evaluation of remedial design. Applicability and incorporation of numerical modeling for semiannual reporting might be appropriate to guide IM operational strategies if performance monitoring wells are not responding favorably." DOE's response to NMED's comments was accepted in NMED's October 3, 2019, approval letter.

   DOE continues to incorporate numerous data streams into the numerical modeling being conducted for the chromium plume. Those data streams include cross-hole pressure responses from intentional or opportunistic aquifer tests, intentional and opportunistic injection-well tracer data, water-level information and mapping of the evolution of the water table in response to IM operations, and geochemical data from performance monitoring wells. These data and the model will be instrumental in development of the next-phase remediation strategy for the plume. The need and timing for incorporation of capture-zone analyses in future semiannual performance monitoring reports will be discussed with NMED in future technical team meetings.

SPECIFIC COMMENTS

NMED Comment

1. ***3.2.1 Water-Quality and Tracer Results, Page 4.***

   a. ***DOE Statement:*** *"IM operations along the eastern portion of the plume have only occurred for the brief period of November 2019 through late March 2020, as described above. However, during this short operational period, concentrations of chromium in R-45 S1 dropped at a greater rate than prior decreases following an initial increase in the chromium concentration. The more rapid decrease in concentrations that occurred following start of eastern area operations also corresponds to arrival of injection water as indicated by increasing concentrations of chloride and sulfate in R-45 S1. R-45 S2 did not show similar responses for the same period."*

      NMED Comment: *The Report does not include a discussion of the notable steady increase in the chromium concentration at R-45 S2 from background (<10 ug/L) to 20.1 ug/L between 2009 and 2016 as shown in Figure 3.2-7. From late 2018, this trend exhibits a sudden increase to the current 49.9 ug/L chromium concentration that may coincide with IM injection operations. Revise the Report to provide a detailed narrative that discusses source, transport, and fate of these documented trends. The revised report must provide a tenable explanation of the source and cause of the sudden accelerated increase since late-2018. Include in the explanation the possibility that the late 2018 increase is due to the IM injection operations implemented in 2017 (see Specific Comment No. 6) and/or the possibility that pumping from PM-3 is drawing the chromium mass downward from screen 1 to screen 2. On November 19, 2020, the chromium concentration at R-45 S2 was at 49.9 ug/L. It appears that based on this trend, the chromium concentration at R-45 S2 will soon exceed the enforceable standard of 50 ug/L.*

   b. ***DOE Statement:*** *"One of the two tracers deployed in the injection wells in 2017 is now being detected in R-50 S1 and in CrEX-1. Sodium-1,5 naphthalenedisulfonate (Na-1,5 NDS), injected into CrIN-4 in May 2017, increased in concentration in R-50 S1 and CrEX-1 and hit a maximum value in mid-2018 followed by a decline in late 2018. It has remained relatively stable with a possible slow decline since early 2019 (Figures 3.2-25 and 3.2-29). This indicates the IM operations have established a hydrologic connection between CrIN-4 and the R-50/CrEX-1 area. ... Sodium-1,3,6 naphthalenetrisulfonate (Na-1,3,6 NTS), injected into CrIN-3 in September 2018, was detected a few months later in R-44 S1 and has continued to be detected into 2020 (Figure 3.2-27)."*

      NMED Comment: *The Work Plan states that "the purpose of the tracer tests is to characterize aquifer properties and provide the rate of migration of treated (and traced) water between injection wells and performance monitoring wells". The Work Plan also states that the tracer test results would be provided in the semi-annual IM performance reports. The Report documents several tracer detections but does not discuss the results in detail. For each detected tracer including the "opportunistic" chloride and sulfate tracers, provide a narrative in the revised report that characterizes the aquifer properties, the groundwater pathways, radii of influence and the rate of migration between injection and monitoring points. At a minimum, the aquifer properties must be characterized by using the tracer travel times to quantify the average linear groundwater flow velocity, hydraulic conductivity, hydraulic gradient and the effective porosity of each pathway.*

In the narrative, provide a comparison of the tracer-derived aquifer parameters to those determined by the single well pumping tests conducted at these wells.

DOE Response

1.a DOE has been tracking and documenting the increases in chromium concentration at R-45 screen 2 for several years, starting before any IM operational activities began along the eastern portion of the plume. The increased rate of change in chromium concentration in screen 2, starting in the 2018 timeframe, began before any continuous IM operational activities in the area, specifically extraction from CrEX-5 and injection in CrIN-1 and CrIN-2. Possible explanations for the increase could be variability in chromium concentrations in the plume at any given location over time, or localized downward gradients caused by local infiltration of young post-chromium-release effluent at locations that may be different from the locations where Cr originally infiltrated (because of higher post-Cr surface discharge rates) are at least partially responsible for the observed trend in R-45 screen 2. That is, the more recent post-Cr infiltration may be pushing some Cr deeper and laterally away from the infiltration points toward R-45 screen 2. Decreasing concentrations of chromium in R-11 and R-45 screen 1 in recent years support the likelihood of young water with very low chromium concentrations infiltrating in that area. This scenario also likely explains the low chromium concentration observed in R-70 screen 1 while chloride (a key indicator of younger, post-chromium releases) remains proportionally elevated.

Additional discussion regarding possible explanations for the observed increases of chromium in R-45 screen 2 will be included in the next semiannual report. Monitoring of R-45 screen 2 (and all the other performance monitoring wells) will continue as continuous operations of the IM take place along the eastern portion of the plume. Additionally, the tracers that will be deployed into CrIN-1 and CrIN-2 (along with the opportunistic tracers from the ion exchange system) will provide useful information regarding the hydraulics associated with IM operations in that area.

1.b. Information regarding tracer detections has been provided in prior semiannual progress reports. The tracer responses at monitoring wells resulting from tracer injections into CrIN wells, as well as geochemical signatures of treated injection water arriving at monitoring wells, have provided valuable insights into where and how fast injected water has migrated through the regional aquifer along the periphery of the chromium plume. Besides providing this type of information, the tracer and geochemical signature responses have been used to estimate effective porosity in the regional aquifer in the affected areas and to provide information on the spatial distribution of injection water.

The tracer and geochemical signature responses do not provide information that can be used to directly quantify aquifer properties such as hydraulic conductivity, hydraulic gradient, or natural gradient flow velocity/direction. These properties are best inferred from other types of information, such as analyses of single-well and cross-well pumping test data for hydraulic conductivity, distributed water-level data (under non-pumping/injection conditions) for hydraulic gradient, and model calibrations plus borehole dilution tracer test data for natural gradient flow velocity and direction. It follows that the tracer and geochemical signature responses do not provide parameter estimates that can be compared directly with parameters determined from single-well pumping tests, which are limited to estimates of local aquifer transmissivity and storativity.

The tracer and geochemical data collected to date, have indicated the following:

A significant amount of water injected into CrIN-4 has distributed in the direction of CrEX-1, with about 10% of the 1,5-NDS tracer injected into CrIN-4 in May 2017 having been recovered at

CrEX-1 to date. Furthermore, this tracer also has a well-defined breakthrough curve at R-50 screen 1. Injected water is assumed to be spreading out from CrIN-4 in all directions, but the tracer arrivals at CrEX-1 and R-50 screen 1 are significant in that they demonstrate that injected water has moved significant distances against the natural gradient in this area of the plume when aided by pumping at CrEX-1.

The geochemical signatures at R-50 screen 1 suggest that the water in R-50 screen 1 is now predominantly water injected into CrIN-4. The sulfonate tracer deployed in CrIN-5 has not appeared in R-50 screen 1, CrEX-1, nor in any other monitoring location. Also, the lack of a tracer or geochemical signature in R-50 screen 2 shows that the injection water flow has been predominantly in the upper part of the aquifer where the CrIN-4, CrEX-1 and R-50 screen 1 well screens are located.

A significant amount of water injected into CrIN-3 has migrated in the direction of R-44 screen 1 (confirmed by detection of the unique tracer deployed in CrIN-3), with a faster arrival time than from CrIN-4 to R-50 screen 1, which is not surprising given that the inferred natural gradient should be aiding flow from CrIN-3 to R-44 screen 1 while it is opposing flow from CrIN-4 to R-50 screen 1. As at R-50, the lower screen at R-44 has not seen tracer or geochemical signature arrivals, indicating that injection water has been predominantly in the upper part of the aquifer where the CrIN-3 and R-44 screen 1 screens are located. The characteristic of groundwater in R-44 screen 1 is now predominantly injected water from CrIN-3 with very low chromium concentrations.

R-45 screen 1 has seen a significant arrival of geochemical signatures associated with injection, with an arrival even more rapid than observed between CrIN-3 and R-44 screen 1. It is not yet known whether the treated water is arriving from CrIN-1, CrIN-2, or a combination of these wells, as unique tracers have not yet been deployed in CrIN-1 or CrIN-2. As at R-44 and R-50, the lower screen at R-45 has not seen geochemical signatures of injected water to date.

Additional discussion is presented by Reimus et al. in the pending Proceedings of the 2021 Waste Management Symposium. The paper also summarizes effective/flowing porosity estimates and flow distribution estimates (i.e., cumulative fractions of flow occurring in cumulative fractions of total porosity) that have been derived from the tracer and geochemical signature responses to date. DOE will provide the manuscript of that paper and offers to discuss the findings in a future technical team meeting.

NMED Comment

2. Section 3.2.1 Water-Quality and Tracer Results, Page 6

a. ***DOE Statement:*** *"This summary provides the results from samples collected on June 30 and July 1, 2020, from the five IM injection wells (i.e., CrIN-1, -2, -3, -4, -5) prior to restart in July 2020. The samples were collected approximately 98 days after the IM system was shut down on March 25, 2020. Each of the injection-well samples was collected after approximately 1000 gal. of water (greater than three casing volumes) was purged from each well. Chromium concentrations in these samples were all reported as nondetected at a detection limit of 3 μg/L (Appendix A). These concentrations are consistent with those of chromium in the ion exchange treatment system effluent. The results indicate that injection water had been pushed sufficiently upgradient of each injection well during IM operations conducted before the EMCA pause. Furthermore, by the end of the pause, upgradient groundwater with higher concentrations of chromium had not migrated back into portions of the plume where the injection wells are located."*

NMED Comment: *Provide an explanation in the revised report for how IM injectate was pushed sufficiently upgradient of each injection well (especially CrIN-1 and Crln-2) during the short four-month IM operational period as noted on page 4 but upgradient groundwater did not migrate back with the natural hydraulic gradient after the 98 day pause. In the explanation, provide:*

- *Quantitative evidence that the IM injection created enough of a reversal in the natural hydraulic gradient to push the injectate "sufficiently upgradient".*
- *Hydraulic groundwater flow and transport calculations that support the assertion that IM injection operations pushed the injectate upgradient.*
- *An explanation how and why it took years for the tracers injected into CrIN-4 to be detected at R-50, which is also influenced by CrEX-1 and -2 pumping (R-44 is downgradient of CrIN-3), but injection of treated water was "pushed sufficiently upgradient of each injection well" including CrIN-1 and CrIN-2 within four months.*
- *The fate of the chromium mass decreased by the IM injection.*
- *The total volume of injectate per well during IM operations compared with the 1,000 gallons removed before sampling after the shutdown to assess the representativeness of the June 30 and July 1 samples of upgradient conditions.*
- *Water level and groundwater quality trends in the upgradient wells.*

If, after this reanalysis, the statement cannot be supported quantitatively, remove the statement (last two sentences of paragraph) from the Report.

b. DOE Statement: *"The results indicate that injection water had been pushed sufficiently upgradient of each injection well during IM operations conducted before the EMCA pause. Furthermore, by the end of the pause, upgradient groundwater with higher concentrations of chromium had not migrated back into portions of the plume where the injection wells are located."*

NMED Comment: *Explain in the revised report whether the decrease in chromium concentrations in R-44 S1 and R-50 S1 shown in Figures 3.2-4 and 3.2-8, respectively, and as discussed on page 4 of Section 3.2.1, is the result of the chromium mass being 1) moved from the area of injection, 2) being recovered by the concurrent CrEX pumping operations, and/or 3) the result of dilution. In the first case, clarify in the revised report why DOE stated that the chromium did not migrate back to the injection wells if the mass wasn't initially pushed away from the points of injection. In the second case, explain in the revised report why mass recovery is not reflected in the time series plots shown in Figures 3.2-20 through 3.2-23. In the third case, discuss in the revised report whether the decreasing chromium concentration is due to dilution. In each discussion, the results of the September 2018 CrIN-3 Na-1,3,6 NTS and May 2017 CrIN-4 Na-1,5 NDS tracer tests needs to be considered so there are no contradictions with tracer findings.*

DOE Response

2.a. Additional discussion to address NMED's comment will be included in the next semiannual performance monitoring report due to NMED by March 31, 2021. The gist of DOE's statement regarding speculation that injection water was pushed sufficiently upgradient is simply based on the fact that no increases in chromium concentrations were observed in any of the injection wells, including CrIN-1 and CrIN-2 following the 98-day shutdown. A reasonable explanation for this observation is that treated water with low chromium concentrations was distributed sufficiently upgradient of the injection wells such that higher concentrations of chromium in groundwater upgradient of each injection well did not drift back into any of the injection wells during the shutdown period. Some relatively simple calculations can be conducted in which it is assumed that flow into the injection wells is radial over the thickness of the screened intervals (using a flow porosity less than total porosity to account for preferential flow in more conductive layers), with a superimposed natural gradient flow that serves to limit the upgradient distance that injected water can travel before a stagnation point is encountered. These calculations are dependent on the assumed flow porosity and the natural gradient flow in the aquifer at the specific locations. During the 135 days of nearly continuous injection into CrIN-1 and CrIN-2 (from Nov. 12, 2019 to March 25, 2020) the average injection rate into both wells was approximately 50 gpm, and the total volume injected into both wells was about 9.8M gallons (37,200 m^3) each. If there were no natural flow, this injection volume would have been enough to displace the aquifer water within an approximately 72 meter radius around the wells over the 50 ft thickness of the screened intervals, assuming a flow porosity of 0.15 (i.e., assuming that 60% of the total porosity of 0.25 transmits significant flow). If a natural flow velocity of 0.27 m/day (consistent with the results of the borehole dilution tracer test in R-50 screen 1 in 2015 after assuming a flow porosity of 0.15) is superimposed on the radial injection flow, a stagnation point is predicted at about 70 m upgradient of the injection well, and during the 135 days of injection, the leading edge of the injection water would have moved approximately 32 m upgradient. In the subsequent 98 days of IM shutdown, the natural flow would move this leading edge about 26 m back downgradient (i.e., 98 x 0.27) toward the injection wells, leaving the untreated aquifer water about 6 m short of the injection wells at the time they were sampled. Obviously, there are many uncertainties and unknowns associated with these simple calculations, but they serve to show that it is reasonable to expect that a sufficient amount of treated water was injected into CrIN-1 and CrIN-2 to preclude aquifer water from drifting back into the wells during the 98-day shutdown period prior to sampling.

Regarding the time frame for observation of tracers and treated water at R-50 screen 1 relative to time frames associated with pushing water upgradient at CrIN-1 and CrIN-2, it is informative to consider that Cl concentrations in R-50 screen 1 reached half the difference between their initial value and the average value in treated water after about 100,000 m^3 of water was injected into CrIN-4 (this is a better metric than time given that the IM was not operated continuously during the time of the R-50 screen 1 observations). The distance between CrIN-4 and R-50 screen 1 is about 135 m. Given that 100,000 m^3 of injection resulted in a strong response 135 m upgradient, it is not at all unreasonable to expect that an injection of ~37,000 m^3 into CrIN-1 and CrIN-2 could result in pushing water 32 m upgradient from CrIN-1 and CrIN-2 (see previous paragraph). In fact, if radial distance is assumed to depend on square root of volume injected (as per radial flow), the corresponding distance moved upgradient from CrIN-1 and CrIN-2 would be over 80 m if the aquifer properties at CrIN-1 and CrIN-2 were similar to those between CrIN-4 and R-50. We recognize that water movement from CrIN-4 toward R-50 was likely aided by pumping of CrEX-1, but the fact that there were significant interruptions to the IM during the time of the R-50 response would have resulted in flow direction reversals during this time period as well (in contrast, the CrIN-1 and CrIN-2 injections pushing water upgradient were nearly uninterrupted). Also, the relatively quick rebound in chromium concentrations observed in R-50 screen 1 provides some indication that the current extent of the injection signal is near the R-50 area, meaning that there is likely a stagnation point not far upgradient of R-50 screen 1.

2.b. In the next semiannual progress report, due to NMED by March 31, 2021, DOE will provide additional discussion on the conceptual model for decreases in chromium concentrations in R-44 screen 1 and R-50 screen 1 and for the lack of observed rebound. The discussion will incorporate all applicable data, including the tracer data, to present a conceptual model including viable alternatives.

Our conceptualization of the processes resulting in Cr concentration decreases in R-50 screen 1 and R-44 screen 1 are as follows. The very early subtle declines in Cr concentrations (as well as early changes in concentrations of other constituents) may be the result of the pushing or pulling of waters of naturally varying concentrations near the monitoring wells, which would be expected to occur long before injection water itself arrives at a monitoring well. However, once significant trends are established, they appear to be reflecting a mixing of aquifer water with injection water in the monitoring wells. The trends are increasingly away from aquifer water chemistry and towards injection water chemistry (including both decreases in Cr concentrations and increases in chloride and sulfate concentrations). Such mixing is consistent with dispersion of an advancing front of treated water that is displacing aquifer water, with the dispersion likely being a manifestation of multiple arrivals of treated water in different hydraulically conductive layers/zones that intersect the monitoring wells at different times because of different hydraulic conductivities. Currently, the water in both R-50 screen 1 and R-44 screen 1 appears to be predominantly treated water (i.e., the original aquifer water is largely displaced from the wells), as the concentrations of chloride and sulfate are close to average concentrations in treated water, and Cr concentrations are much closer to levels in treated water than original aquifer levels.

As for the fate of Cr mass in the vicinity of R-50 screen 1 and R-44 screen 1, it is reasonable to expect that much of the mass originally present in the vicinity of R-50 screen 1 has been pushed/pulled upgradient and will largely be captured by CrEX-1. In the case of R-44 screen 1, the Cr mass originally present near this well likely mixed with both injected water and downgradient water and has drifted downgradient, resulting in gradually decreasing Cr concentrations (although temporary increases could occur in some locations, particularly at the leading edge of the Cr front). This is the expectation for any Cr mass that is ultimately not captured by extraction wells; i.e., it will drift downgradient where it will be dispersed into ever-larger volumes of water and thus decrease in average concentration over time. Importantly, one of the goals of the IM is to cut off this downgradient Cr from its source, so there will no longer be a means of sustaining elevated Cr concentrations at downgradient locations, and the concentrations should therefore steadily decrease over space and time.

Regarding the question about why Cr mass recovery is not reflected in the concentration trends in the extraction wells (Figs. 3.2-20 to 3.2-23), we are assuming the concern here is that Cr concentrations are not increasing to reflect a recovery of downgradient Cr that is being pushed upgradient by the injection wells. We do not expect that this would occur because Cr concentrations downgradient of the extraction wells are typically lower than upgradient of the extraction wells. Thus, the recovery of downgradient Cr mass would be expected to coincide with decreases in Cr concentrations in extraction wells as the downgradient water is mixed with upgradient water of higher Cr concentrations, which is what is being observed in some of the extraction wells. This effect will be amplified if some of the treated water injected into injection wells is captured by extraction wells, as is occurring at CrEX-1 (from CrIN-4). However, we believe that the decreasing Cr concentration trends in the extraction wells also reflect a removal of Cr at a faster rate than it is being replenished by upgradient sources, and this is probably the dominant reason why decreasing concentration trends are being observed, particularly in extraction wells that are located quite far upgradient from injection wells (e.g., CrEX-2).

NMED Comment

3. ***Section 3.2.2 Water-Level Data, page 6***

DOE Statement: *"Figures 3.2-31 and 3.2-32 show water-level data for R-35a, R-35b, R-36, R-70 S1, and R-70 S2, along with PM-3 pumping rates. The water-level data in the plots are shown as a change from an average water level in feet above mean sea level for the time period shown in the figures. This allows the wells with different absolute water elevation to be shown on the same plot. Water-level data for R-35a is plotted separately in Figure 3.2-32 because the displacements in R-35a are significantly greater than the other wells/screens. All water-level data shown in these plots were processed to remove erroneous data points and to apply a barometric pressure correction."*

NMED Comment: *These water-level data plots (hydrographs) were requested by NMED for inclusion in the Report in the May 6, 2020 letter Approval with Modification Semiannual Progress Report on Chromium Plume Control Interim Measure Performance, July Through December 2019 (2020 Letter) and during a May 21, 2020 meeting with DOE. NMED made this request to evaluate whether PM-3 pumping effects can be detected in adjacent regional aquifer monitoring wells. DOE provided the change from an average water level in the Report, which is not what NMED requested. In addition to not satisfying NMED's May 2020 request, Figures 3.2-31 and -32 show plots that are unintelligible. In the revised report, provide a series of five (5) new updated hydrographs, one for each well, using only the unprocessed water levels measured in each well (i.e. do not provide any alternations to the data such as the change from an average) at a vertical scale of 5 feet (for R-35a use a vertical scale not to exceed 20 feet). In each of these five hydrographs, provide:*

- *the unprocessed well water-level elevations,*
- *barometric change (not direct barometer readings),*
- *barometrically compensated water-level elevations, and*
- *PM-3, CrEX-5 and CrIN-1 pumping.*

Also, provide a table of the barometric data and the Los Alamos County pumping information used in each hydrograph and explain how the barometric compensation was performed on the well water levels presented in the new hydrographs[1]. All data requested must be updated for the entire semi-annual period (January 1, 2020 through June 30, 2020). These five hydrographs must also be included in all successive reports.

1 Note: NMED successfully performed barometric compensation on 2020 R-70 water level data using the method outlined by Gonthier, 2007 (http://pubs.usgs.gov/sir/2007/5111/) and was able to discern the previously hidden effects from CrEX-5 pumping on both screens. NMED recommends DOE to use this method for barometric compensation of water levels measured in wells as discussed during the September 8, 2020 chromium technical team meeting.

DOE Response

3. No specific graphical presentation format was discussed with NMED before submittal of the semiannual report. DOE will, however, provide updated plots in the semiannual performance monitoring report due to NMED by March 31, 2021. The plots will include the full period of record through December 31, 2020, and will be in the format that NMED has described in Specific Comment No. 3. Pursuant to a call held with NMED on February 9, 2021, DOE agrees that the information on barometric change (second bullet in the list above) will be provided as change relative to an initial

value for each well for the period of data reported in a given semiannual performance monitoring report.

NMED Comment

4. ***Section 3.3 Water-Table Map, page 7***

   a. ***DOE Statement:*** *"For this semiannual report, a water-table map (Figure 3.3-1) depicts average water levels for May 2020. For comparison, Figure 3.3-2 shows the water table on May 1, 2018, as a baseline condition with little to no influence from IM operational pumping or injection.*

      NMED Comment: *In the revised report, explain why a cone of depression is shown in Figure 3.3-1 Water table showing average water levels for May 2020 when the IM extraction wells had been inoperative since March 25, 2020. Additionally, explain the basis for depicting the closed concentric contours in Figure 3.3-1 when there are no data to support the depicted depression in the water table. In the revised report, redraft Figure 3.3-1 using a standard method of interpolation of a snapshot of the data (synoptic), which is the industry standard in preparing water table maps.*

      Preparing water table maps is one of the most fundamental elements of groundwater studies. Using manual triangulation and synoptic data downloaded from Intellus, NMED successfully mapped the water table for May 17, 2020 at 1:00 AM and June 14, 2020 at 3:00 AM and no discernable cone of depression was evident during the shutdown. These maps demonstrate Figure 3.3-1 misrepresents the regional water table surface. NMED did the same for the January 1, 2020 11:00 AM and March 22, 2020 at 3:00 AM data before the IM operation shutdown and a pronounced cone of depression was evident around CrEX-2 that extended to CrEX-1 and CrEX-4. With these maps, NMED has demonstrated that standard interpolation methods are adequate for accurate representation of the regional aquifer water table. Based on its own evaluation of the select synoptic data, NMED has concluded that DOE's contouring method produces unacceptably biased results.

      The Work Plan requires quarterly water-tables be provided in each report. The maps were not provided for both quarters in the Report. In the revised report, plot the water tables for the first and second quarters as required by the Work Plan using only synoptic data (not monthly average) and a common interpolation method (e.g., Kriging, triangulation. . .). These maps should include data from all installations including the CrIN and CrEX wells as directed by General Comment No. 1 in the 2019 Letter. Based on the revised water table maps, provide a reanalysis of the water table and IM effectiveness in the Section 3.3 narrative of the revised report.

   b. ***DOE Statement:*** *"A snapshot of the water table on May 1, 2018, at 3:00 p.m. was selected for the baseline condition because water levels had recovered from prior IM testing, which ceased on April 23, 2018. Although a faint depression between CrEX-1, CrEX-3, and CrEX-4 is apparent in the baseline water-table map (Figure 3.3-2) at 1-ft contour resolution, this feature does not appear to be related to IM operation and is caused by water-level variability on the scale of inches. When evaluated at 1-ft resolution, a similar water table surface feature is evident on a contour map for May 1, 2016, before most IM activities were initiated (except for CrEX-1 testing, which ceased on November 18, 2015). The causes of a natural faint depression in a relatively flat region of the water table are likely related to spatial variability in hydraulic properties of the aquifer or spatial and temporal variability in aquifer recharge at hydraulic windows in the surrounding areas."*

NMED Comment: *NMED is concerned about the potential for the "natural faint depression" to influence contaminant transport, especially in the vertically downward direction such as what is likely occurring at R-70 and R-45. NMED reviewed the baseline water table map depicted by Figure 3.3-2 using manual triangulation to remove bias. NMED could not duplicate the depression shown in Figure 3.3-2 despite the water level at CrPZ-2b being slightly depressed compared to surrounding wells. In the revised report:*

- *Explain how a depression in the water table can be caused by anything other than pumping.*
- *Include a series of isopach maps that show where lower permeable units are discontinuous in the area of the water-table depression to support the assertion of hydraulic windows as the cause of the depression.*
- *Recontour Figure 3.3-2 using only the actual synoptic data (i.e. R-11 was estimated) and by employing only a common or standard contour interpolation method. Use of synoptic data and standard contour interpolation methods are required in the construction of water table maps for the revised report and for all subsequent report submittals (See Specific Comment No. 4a).*

DOE Response

4.a. Water-table mapping for the chromium project is presented in each semiannual performance monitoring report and for quarterly discharge permit reports (DP-1835) provided to the NMED Groundwater Bureau. The purpose of the maps for both reporting requirements is to examine long-term structural changes in the water table caused by IM activities.

The methodology used by DOE is robust and appropriate for the site. The method uses Kriging and thus is aligned with industry standard. Also, importantly, the method provides for a degree of automation that allows for consistency in the analysis over time. The use of monthly averages instead of synoptic data is appropriate for the objective, and also ensures that any given water-table depiction is not driven by one or more anomalous values in any given well.

The extremely low gradient in the plume area supports use of periodic monthly averages to represent long-term changes specifically associated with the IM. Various short-duration perturbations such as monthly groundwater monitoring for the Interim Facility-Wide Groundwater Monitoring Plan and daily and longer variations in pumping rates from nearby Los Alamos County water-supply wells could have a local effect at one or more locations, resulting in erroneous water-table depictions if a more synoptic approach were to be used.

The semiannual performance monitoring report due to NMED by March 31, 2021, will include additional discussion of the structure of the water table in the context of IM operations and also include additional discussion of the assumptions and variables that may factor into the depiction of the water-table structure.

As described in DOE's response to NMED's comment on the March 2019 seminannual performance monitoring report, which was subsequently approved by NMED in a letter dated October 3, 2019, inclusion of the extraction well and injection well data should not be used because there is no way to extrapolate in-well transducer data to a water-level elevation in the aquifer around the wells. Although there are methodologies for estimating a simplified configuration of the water table in the aquifer surrounding an injection or extraction well, the inherent uncertainties in such calculations (due to aquifer heterogeneity) would be too large relative to the extremely flat water-table gradient in the project area to effectively contribute to water-table maps.

DOE proposes to continue working with NMED beyond the submittal of the March 31, 2021, semiannual performance monitoring report to optimize the approach for developing water-table maps to meet the overall performance monitoring objective.

DOE acknowledges that the language in the NMED-approved April 2018 Chromium Interim Measure Performance Monitoring Work Plan may have more than one interpretation. The language in the Performance Monitoring Work Plan is intended to state that the single water-table map that will be included in each semiannual performance monitoring report will be the map from the most recent DP-1835 quarterly report. However, DOE proposes that in future semiannual performance monitoring reports, the two most recent water-table maps from the two most recent DP-1835 quarterlies will be included.

4.b. In addition to being potentially caused by pumping, subtle depressions in the water table can also be caused by local areas of present-day recharge from the vadose zone resulting in the appearance of water-table "mounding" and an adjacent depression. For example, although the water table generally dips gently from west to east across the chromium plume area, a suspected recharge window causing slight mounding in the water table to the east of CrPZ-2 could cause the appearance of a lower point to the west. Alternatively, heterogeneity in hydraulic conductivity could influence flow variations, leading to variable pressure near some wells (e.g., CrPZ-2). The water table in the chromium area is relatively flat, which is associated with higher hydraulic conductivity in the area. Therefore, even relatively small localized variations in hydraulic conductivity may be linked to discernable changes in pressure measurements. Both of these possibilities (recharge effects and/or hydraulic conductivity heterogeneity) are hypotheses, and neither can be proven with conclusive data to confirm which may be causing the observed low point at CrPZ-2. Finally, the data from CrPZ-2 could be erroneous. There is currently no physical support for this hypothesis besides the generally lower pressure values recorded at CrPZ-2; however, the piezometer wells have a different construction than the monitoring wells. Further, there is no indication from water-level data from R-70 and R-45 that a strong vertical downward exists between the upper and lower screened intervals.

The hydraulic windows commonly referred to in DOE's reports are intended to describe locations where recharge to the water table is occurring from the vadose zone. Water-level elevations, geochemical data, and the structure of geosurfaces in the vadose zone have been used to approximate locations of hydraulic windows from the vadose zone. See Attachment 3 of the 2018 "Compendium of Technical Reports Conducted Under the Work Plan for Chromium Plume Center Characterization."

The R-11 data point on Figure 3.3-2 was estimated using linear regression based on relationships with other nearby wells. Water-level values from these nearby wells were used in water-table interpolation. However, R-11 was not used in the contouring because such use would have been redundant.

See also response to NMED comment No. 4a.

NMED Comment

5. ***Section 3.3 Water-Table Map, pages 7 and 8***

DOE Statement: *Table 3.3-1 presents water levels and head difference for dual-screen locations within the chromium project area. All dual-screen locations near where extraction and injection are occurring display subtle changes in water levels. These changes are currently so small that it is not possible to discern whether they are caused by IM pumping and injection or by water-supply pumping. These data and evaluation will be included in future reports.*

NMED Comment: *The data provided in Table 3.3-1 are monthly averages not actual water level data. In the revised report and all subsequent reports provide actual water levels in this table and reanalyze using barometric compensation of the data*[1] *to determine whether vertical gradients can be detected in dual screened wells R-50, R-61, R-44, R-45, and piezometers CrPZ-2a and CrPZ-2b. In the revised report, provide hydrographs since the installation date of each dual screen well, an interpretation of the vertical pressure gradients in these wells, and a discussion of the effects of IM operations on these water levels. Changes in vertical head gradients due to IM operation can provide information on capture zone effectiveness, since vertical head gradients can potentially influence the direction of contaminant transport (see Specific Comment No. 1a).*

DOE Response

5. To address the analysis of varying vertical gradients in R-50, R-61, R-44, R-45, and piezometers CrPZ-2a and CrPZ-2b, DOE proposes to change the methodology that was previously agreed upon with NMED. As agreed to in a discussion with NMED on February 9, 2021, going forward, inclusive of the March 31, 2021, semiannual performance monitoring report, future reports will address the analysis using figures that plot the full period of record for water-level data from each paired set of screens noted in NMED's comment and will also include the paired screens in R-70. Annotation or discussion will be used to evaluate variations in the gradient as a function of potential causal mechanisms, including seasonal pumping at Los Alamos County water-supply wells and IM operations. Table 3.3-1 will no longer be included.

NMED Comment

6. ***Section 4.0 Discussion, page 8***

DOE Statement*: It was stated in the "Interim Measures Work Plan for Chromium Plume Control" (LANL 2015, 600458) that it may require up to 1 yr of continuous IM operation to see clear indication of plume response at performance monitoring wells. Based on the trends in chromium and various tracers in performance monitoring wells in the southern portion of the plume, where IM operations have been underway for some time, it appears that they have been effective at establishing the 50 µg/L plume edge upgradient of R-50 (see Figure 1.0-1).*

NMED Comment: *The Work Plan stipulates that "the secondary objective of the IM is to hydraulically control plume migration in the eastern downgradient portion of the plume". Based on the geochemistry and tracer test results, it is apparent to NMED that the reduction of chromium concentration is due to dilution and not due to hydraulic control or due to mass recovery. It is apparent that the IM extraction can be effective at creating a notable cone of depression that can prevent plume migration. However, injection as part of the IM has not produced any detectable mound that can prevent plume migration. NMED recommends that DOE reconsider its approach and* *prepare a plan that outlines the necessary adjustments to the IM system that will achieve hydraulic control along LANL's southern property boundary with SIP (see General Comment No. 1).*

DOE Response

6. DOE notes that only limited operations have occurred in the eastern downgradient portion of the plume (i.e., continuous extraction from CrEX-5, and continuous injection into CrINs-1 and -2). So efforts on the secondary objective cited in the work plan are just getting underway. Additionally, besides the challenges of demonstrating the presence and extent of possible mounding, IM performance to date, manifested by decreasing chromium concentrations in R-50 and breakthrough data from intentional and opportunistic tracers, are insights into the hydraulic dynamics that have been established in the regional aquifer along the southern portion of the plume. DOE contends that there is no technical basis for reconsidering the approach to the IM along the southern boundary at this time. Information on performance along the eastern portion of the plume will be evaluated and reported on in subsequent performance monitoring reports.

NMED Comment

7. ***Section 5.0 Recommendations, page 9***

   DOE Statement: *Based on the positive IM performance observed to date in monitoring wells along the southern portion of the plume, the operational approach of the IM at the southern boundary involving extraction at CrEX-1 and CrEX-2 and injection primarily into CrIN-4 and CRIN-5, and periodically into CrIN-3, should not be fundamentally changed.*

   NMED's Comment: *NMED does not concur. See General Comments No. 1 and Specific Comment No. 6.*

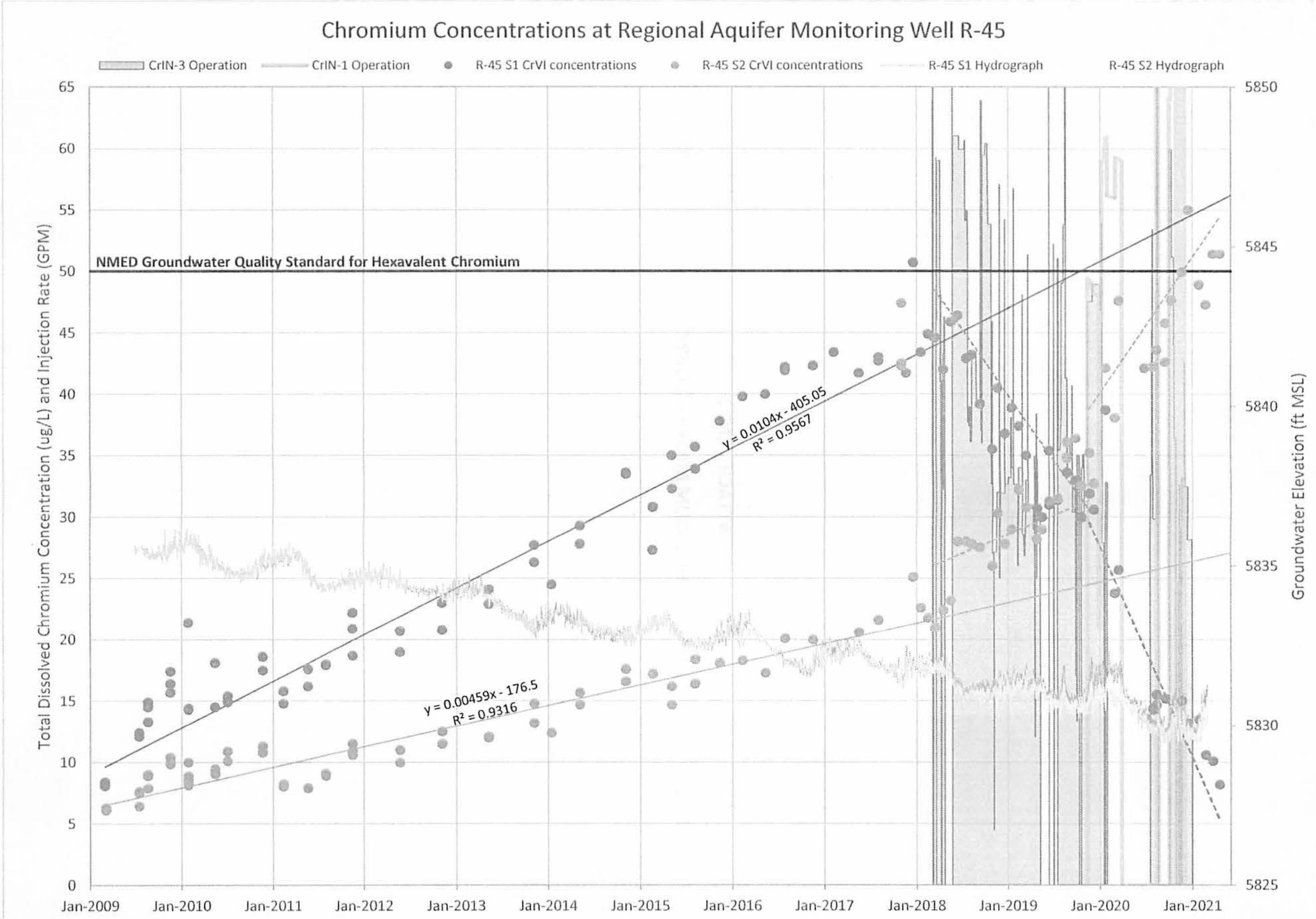
DOE Response

7. See response to NMED Specific Comment No. 6 and General Comment No. 1.

Reimus, P., D. Katzman, M. Ding, and B. Willis, 2021. "Using Tracers and Opportunistic Geochemical Signatures to Inform Modeling of Cr(VI) Migration at LANL – 21081," WM2021 Conference, March 7 – 11, 2021, Phoenix, Arizona, USA.

ATTACHMENT 2

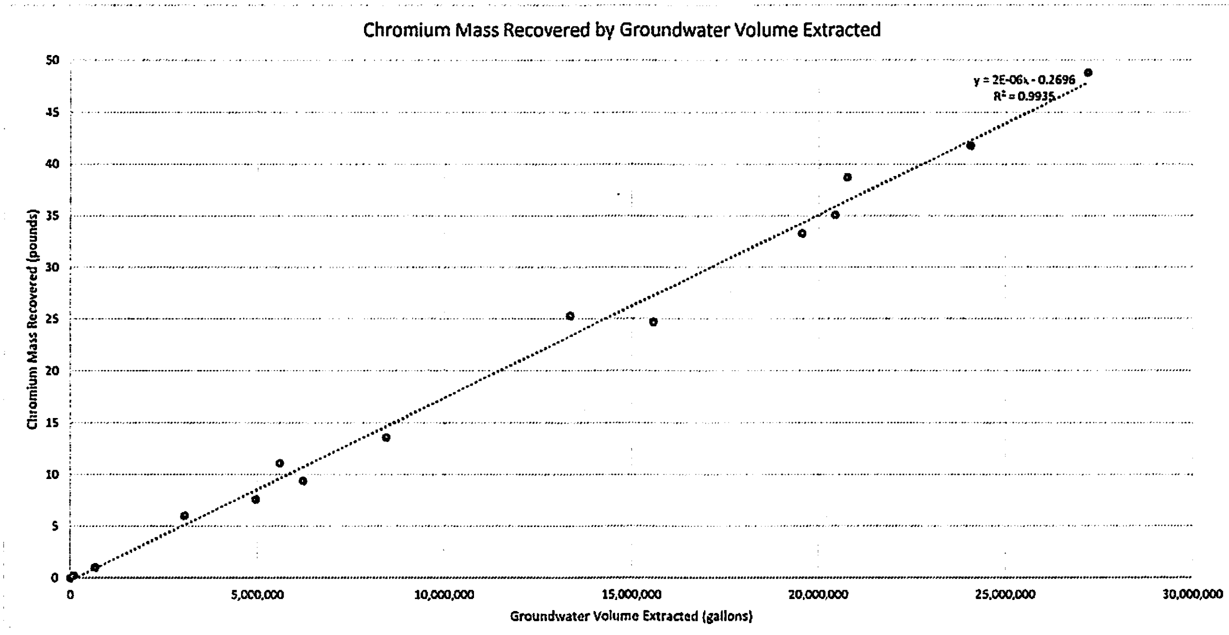
PLOT OF CHROMIUM CONCENTRATIONS AND WATER LEVELS WITH INTERIM MEASURES INJECTION OPERATIONS AT REGIONAL AQUIFER MONITORING WELL R-45



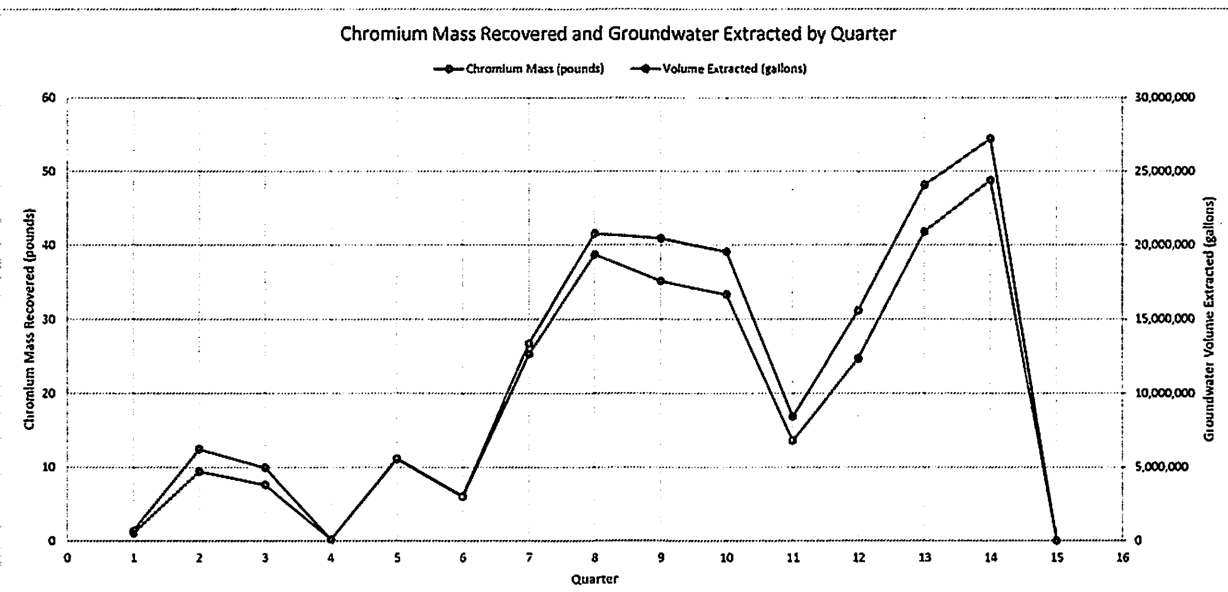
NMED New Mexico Environment Department

ATTACHMENT 3

CHROMIUM MASS RECOVERY



Chromium Mass Recovered by Groundwater Volume Extracted
y = 2E-06x - 0.2696
R² = 0.9935
Chromium Mass Recovered (pounds)
Groundwater Volume Extracted (gallons)
0
5
10
15
20
25
30
35
40
45
50
0
5,000,000
10,000,000
15,000,000
20,000,000
25,000,000
30,000,000



Chromium Mass Recovered and Groundwater Extracted by Quarter
Chromium Mass (pounds)
Volume Extracted (gallons)
Chromium Mass Recovered (pounds)
Groundwater Volume Extracted (gallons)
Quarter
0
10
20
30
40
50
60
0
5,000,000
10,000,000
15,000,000
20,000,000
25,000,000
30,000,000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16