Pacific Gas and Electric Company

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June 30, 2014

Ms. Lauri Kemper
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California Regional Water Quality Control Board, Lahontan Region
2501 Lake Tahoe Boulevard
South Lake Tahoe, California 96150

Subject: Remedial Timeframe Assessment
Pacific Gas and Electric Company, Hinkley Compressor Station,
Hinkley, California

Dear Ms. Kemper:

Pacific Gas and Electric Company (PG&E) is pleased to submit the attached report presenting the results of a Remedial Timeframe Assessment. This report is submitted in response to a requirement included in a letter from the California Regional Water Quality Control Board, Lahontan Region (Water Board) to PG&E dated February 19, 2014. The objective of the timeframe assessment is develop a realistic range of remedial timeframes, and to characterize the certainty of those timeframe estimates. Based on the results of the timeframe analysis, and considering the results of previous phases of remedy implementation presented in this attached report, an adaptive management approach is recommended to drive remediation effectiveness.

We hope this information will be useful to Water Board staff as they develop interim clean goals and requirements. Please feel free to contact Iain Baker at (415) 265-5196, if you have any questions regarding the information presented in this submittal.

Sincerely,

Iain Baker on behalf of
Kevin M. Sullivan

Enclosure: Remedial Timeframe Assessment

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Pacific Gas and Electric Company

Remedial Timeframe Assessment

PG&E Hinkley Compressor Station
Hinkley, California

June 30, 2014

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Remedial Timeframe Assessment

PG&E Hinkley Compressor Station, Hinkley, California

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Acronyms and Abbreviations List

ATUs	Agricultural Treatment Units
BUOW	burrowing owl
Cr(III)	trivalent chromium
Cr(T)	total dissolved chromium
Cr(VI)	hexavalent chromium
DVD	Desert View Dairy
FS	Feasibility Study
ft	feet
GMP	General Monitoring Program
gpm	gallons per minute
HCP	Habitat Conservation Plan
IRZ	In Situ Reactive Zone
µg/L	micrograms per liter
mg/L	milligrams per liter
MGS	Mohave ground squirrel
MT3DMS	Modular Three-Dimensional Multi-Species Transport Model
NOA	Notice of Applicability
NWFI	Northwest Freshwater Injection
PG&E	Pacific Gas and Electric Company
SCRIA	South Central Re-Injection Area
TOC	total organic carbon
Water Board	California Regional Water Quality Control Board, Lahontan Region
WDRs	Waste Discharge Requirements

Executive Summary

The objective of this remedial timeframe assessment report is to develop a realistic range of remedial timeframes for the Pacific Gas and Electric Company (PG&E) Hinkley Compressor Station Remediation Project and to characterize the certainty of timeframe estimates to guide remedial goal development and cleanup requirements. Based on the results of this remedial timeframe assessment, an adaptive management approach is recommended to drive remediation effectiveness. A remediation forecast for routine effectiveness evaluations is provided in this report. In a letter dated February 19, 2014 (February 19 letter), the California Regional Water Quality Control Board, Lahontan Region (Water Board) requested that PG&E provide an updated 2014 groundwater flow and solute transport computer model simulation to help evaluate the effectiveness of existing and planned remediation systems in cleaning up hexavalent chromium (Cr[VI]) in groundwater at the PG&E Hinkley Compressor Station in Hinkley, California (the Site). The letter stated that "Water Board staff will evaluate this information when developing interim cleanup requirements to be proposed in a draft cleanup and abatement order later this year." This report is being submitted in response to the Water Board's request.

Remedial timeframe estimates under various remedial scenarios were first estimated in the Feasibility Study (FS) prepared for the Site and submitted to the Water Board in 2010. These estimates were provided as a means for comparison of results for the various remedial alternatives. To respond to the February 19 letter request, the groundwater flow and solute transport computer model used in the FS was updated based on current concentration data and experience at the Site with remedial implementation to date. This updated model was then used to simulate future concentrations of Cr[VI] in groundwater beneath the Site and cleanup timeframes. Modeling was conducted using remedial scenario Alternative 4C-2 that was used in the FS and an updated scenario that represents currently planned construction and operational conditions. Of equal importance, a more qualitative evaluation of remedial implementation performance is provided to characterize the uncertainty in modeling predictions. It should be noted that the modeling analysis presented in this remedial timeframe assessment is intended to provide a guide for evaluation of remedy performance over time; it does not provide definitive predictions for remedy timeframe and should not be used in cleanup orders with the expectation of certainty.

As a first step to updating the model predicted remedial timeframes, the ability of the groundwater flow and solute transport model to capture the performance of the various remedy elements was evaluated. A comparison of model predicted performance to actual performance for the period from Fourth Quarter 2007 to First Quarter 2014 indicated:

- In the area north of Highway 58, where extraction and agricultural treatment and freshwater injection are used for hydraulic containment:
  - There was very good agreement between the simulated and contoured distribution of Cr(VI)-affected groundwater, especially when comparing the extent of concentrations greater than 10 micrograms per liter (µg/L).
- In the area south of Highway 58 where In Situ Reactive Zone (IRZ) treatment has been implemented:
  - There was very good agreement between the model results and the observed propagation of the clean water front downgradient from the IRZ injection locations.
  - The model overpredicted treatment lateral from injection points. Variation of one of the solute transport parameters, the total organic carbon (TOC) threshold concentration at which Cr(VI) reduction is triggered, improved the model predictions of lateral treatment, but underpredicted downgradient treatment from IRZ injection points.
  - The model cannot account for the very fine-scale heterogeneities that occur within the complex hydrogeologic environment in the aquifer.

The second step in updating the model predicted remedial timeframes involved running the model using an updated remedial design layout and implementation plan/schedule using the TOC threshold value assumed in the FS (Scenario 2) and an increased TOC threshold value (Scenario 3). The results for these modeling runs were compared to results for the updated FS Alternative 4C-2 design layout and implementation schedule (Scenario 1).

The model estimated treatment times for the Cr(VI) contiguous plume core south of Thompson Road from Scenarios 2 and 3 were:

- The model predicted time to reduce the total mass by 80 percent ranges from 8 to 13 years.
- The model predicted time to reduce Cr(VI) concentrations to less than 50 µg/L across 99 percent of the initial 50 µg/L footprint range from 6 to 13 years in given layers across the majority of the aquifer represented by model layers 1 and 3, with

less permeable portions of the aquifer predicted between 15 and 23 years represented by model layer 2.

- The model predicted time to reduce Cr(VI) concentrations to less than 10 µg/L across 99 percent of the initial 10 µg/L footprint range from 11 to 27 years in given layers across the majority of the aquifer represented by model layers 1 and 3, with less permeable portions of the aquifer predicted between 37 and 50 years represented by model layer 2.

While the model is a useful tool in evaluating the relative impact of various remedial scenarios and assumptions on timeframes, i.e., forecasting remedial performance, it is important to note that the full influences of aquifer heterogeneities on plume behavior, mass removal, reagent delivery and IRZ performance cannot be described or predicted prior to remedy implementation, and cannot be fully predicted with the solute transport model. Given the uncertainty in the remedial timeframe predictions, the large scale of this remedial effort, and the heterogeneous nature of the targeted aquifer, an adaptive management approach to promote efficient remediation over the life of the remediation project is recommended. Under an adaptive operations framework, remedy performance would be evaluated in comparison to the remedial forecast at established remedial forecast.

1. Introduction

In a letter dated February 19, 2014 (February 19 letter), the California Regional Water Quality Control Board, Lahontan Region (Water Board) requested that Pacific Gas and Electric Company (PG&E) provide an updated 2014 groundwater flow and solute transport computer model simulation to help evaluate cleanup effectiveness for hexavalent chromium (Cr [VI]) in groundwater at the PG&E Hinkley Compressor Station (the Site, Figure 1-1). The February 19 letter stated "Water Board staff will evaluate this information when developing interim cleanup requirements to be proposed in a draft cleanup and abatement order later this year." This report is being submitted in response to the Water Board's request.

1.1 Objective

The objective of this report is to develop a realistic range of remedial timeframes and to characterize the certainty of timeframe estimates to guide remedial goal development and cleanup requirements. As part of this effort, the groundwater flow and solute transport computer model has been updated based on experience at the Site with remedial implementation to date. This model was used to simulate future concentrations of Cr(VI) in groundwater beneath the Site assuming the remediation system design layout and schedule used for Alternative 4C-2 in the 2010 Feasibility Study (FS; Haley and Aldrich, 2010) and the currently planned remediation system layout and implementation schedule. Of equal importance, a more qualitative evaluation of remedial implementation performance is provided to characterize the uncertainty in modeling predictions. Based on the analysis of model output and observed results, an adaptive management approach to remedial goal establishment and remedy implementation is recommended.

1.2 Remediation Background

PG&E has been actively remediating chromium-impacted groundwater at the Site through a series of remedial actions starting in 1992. Currently, remedial systems are in place to contain and treat Cr(VI) in groundwater. Containment is achieved through groundwater extraction and application to Agricultural Treatment Units (ATUs), shown on Figure 1-1. Additionally, freshwater injection is conducted in the Northwest Freshwater Injection (NWFI) system, shown on Figure 1-1.

In the higher concentration portion of the plume south of Highway 58, In Situ Reactive Zone (IRZ) treatment is conducted to treat Cr(VI) in groundwater within the aquifer.

Groundwater is extracted, amended with a carbon source (ethanol), and re-injected into the aquifer where reducing conditions for reduction of Cr(VI) to relatively insoluble trivalent chromium (Cr[III]) are created. Cr(VI) is reduced to Cr(III) directly through the creation of anaerobic conditions or indirectly via chemical reduction by reduced iron and sulfide (which are produced under anaerobic conditions). Cr(III) is removed from groundwater by the precipitation of chromium hydroxides and iron-chromium hydroxides. There are currently three IRZ systems in operation: the Central Area, South Central Re-Injection Area (SCRIA), and the Source Area, shown on Figure 1-1.

1.3 Modeling Background

The FS evaluated a broad and comprehensive range of Cr(VI) treatment technologies and assembled the most potentially effective of these technologies into implementation alternatives (Haley and Aldrich, 2010, 2011a,b,c). The evaluation included the remedial technologies currently being implemented at the Site, as well as pump and treat. Solute transport modeling was used to help develop predicted timeframes to achieve remedial action objectives for the Site. As discussed in this report, while the solute transport model is a very useful tool to accomplish that goal, it is also important to recognize the key drivers that influence remedial timeframes, and understand the strengths and weaknesses of the groundwater flow and solute transport model to account for those drivers. Analysis of performance monitoring data over the past several years at the Site indicate that remedial timeframes are driven by a number of key factors, including:

- the distribution of Cr(VI) and total dissolved chromium (Cr[T]) within the aquifer sediments
- the ability to deliver treatment reagents
- the potential for concentrations of Cr(VI) and Cr(T) to increase ("rebound") after treatment
- uneven flushing (for hydraulic containment portions of the remedy).

These factors are, in turn, largely related to the overall heterogeneity of the aquifer. For example, the presence of relatively finer-grained sediment structures within the target aquifer can result in areas where remedy effectiveness is limited due to limited delivery of reagent and/or limited ability for pore-water flushing for a groundwater extraction approach. Such areas may need additional phases of remedial effort to complete treatment.

Performance monitoring data collected over the past several years has been used to develop an overall Conceptual Site Model that incorporates the influence of aquifer heterogeneities on remedy performance. Specific examples of the observed influence of local heterogeneities on remedy performance are discussed in Section 3.2.2. Certain model parameters were adjusted to account for the influence of aquifer heterogeneities, including:

- the incorporation of a lower-permeability model layer (layer 2), and
- varying the amount of total organic carbon (TOC) required as a threshold for IRZ treatment.

These variable model inputs were used to develop a range of remedial timeframe estimates.

While these model variations help develop more realistic timeframes, it is important to note that the influences of aquifer heterogeneities on plume behavior, mass removal, reagent delivery, and IRZ performance cannot be described or predicted prior to remedy implementation, and cannot be not be fully predicted with the solute transport model.

As discussed in Section 3.2 of this report, a comparison of simulated and observed data indicate that there is good agreement between the model results and the observed propagation of the clean water front from treated areas. However, the comparison also indicates that the presence of aquifer heterogeneities can result in discrepancies between observed and simulated results. As a result, the modeling analysis presented in this remedial timeframe assessment is intended to provide a guide for evaluation of remedy performance over time; it does not provide definitive predictions of remedy timeframe and should not be used in cleanup orders with the expectation of certainty.

As a result of these considerations, and as discussed in Section 5, an adaptive management approach to promote efficient remediation is recommended. Under an adaptive operations framework, remedy performance would be evaluated in comparison to the remediation forecast.

2. Summary of the Groundwater Flow and Solute Transport Models

A complete description of the groundwater flow and solute transport models used in this study were presented in the Feasibility Study, Addendum 3 (ARCADIS and CH2M Hill 2011). A brief summary is provided here for reference.

The groundwater flow model was designed to represent groundwater conditions over approximately 25 square miles of Hinkley Valley. The model domain extends approximately 5 miles in the north-south direction, from about 4,000 feet (ft) south of the PG&E compressor station to Red Rock Canyon, 4.5 miles north. The model is about 5 miles wide at the compressor station, extending 2 miles to the west and 3 miles to the east. The model domain narrows to the north of the compressor station to follow the structure of the alluvial valley. The model contains 610 rows, 425 columns, and 6 layers and includes a total of 1,483,990 active cells. The minimum cell size is 25 ft by 25 ft, occurring throughout most of the defined First Quarter 2014 the contiguous Cr(VI) plume south of Thompson Road. The largest sized cells are 500 by 1000 ft. These larger cell sizes are located at the periphery of the model domain.

Individual model layers were used to represent each of the significant hydrogeologic units. In general, layers 1 through 3 represent the Upper Aquifer, with layer 2 representing the low-transmissivity layer, where present, that divides the Upper Aquifer in places, particularly north of the Santa Fe Road (e.g., the “brown clay”). The bottoms of layers 3 and 4 represent the top and bottom of the blue clay where present, respectively. The bottoms of layer 4 and layer 5 represent the top and bottom of the lower aquifer, where present, respectively. The bottom of layer 5 represents the top of the bedrock contact except in areas of bedrock outcropping within the model domain. Model layer 6 represents the competent bedrock.

The boundaries of the groundwater flow model are specified to coincide with natural hydrogeologic boundaries, where possible, and the boundaries were set at a significant distance from the Site to minimize the influence of model boundaries on simulation results at the Site. The simulation program MODFLOW was selected for the construction and calibration of the numerical groundwater flow model at the Site. MODFLOW is a publicly available groundwater flow simulation program developed by the U.S. Geological Survey (McDonald and Harbaugh, 1988). MODFLOW is thoroughly documented, widely used by consultants, government agencies, and researchers, and is consistently accepted in regulatory and litigation proceedings. Additional details on the groundwater flow model construction, boundary conditions, hydraulic parameters, and calibration are provided in Appendix G of the FS Addendum #3 (ARCADIS and CH2M Hill, 2011 in Haley and Aldrich, 2011c).

The solute transport modeling was performed using the modular three-dimensional transport model referred to as MT3DMS (Zheng and Wang, 1999), where MS denotes the Multi-Species structure for accommodating add-on reaction packages. The MT3DMS code uses the same finite-difference grid structure, boundary conditions, and flows computed by MODFLOW in its transport calculations. MT3DMS has a comprehensive set of options and capabilities for simulating advection, dispersion/diffusion, and chemical reactions of contaminants in groundwater flow systems under a range of hydrogeologic conditions. Recent updates to MT3DMS have included the dual-domain formulation and the ability to incorporate site-specific processes. Additional details on the solute transport model construction and parameters are provided in Appendix G of the FS Addendum #3 (ARCADIS and CH2M Hill, 2011 in Haley and Aldrich, 2011c).

For the purpose of the predictive remedial timeframe analysis, the contiguous Cr(VI)/Cr(T) plume was updated to reflect the First Quarter 2014 Cr(VI)/total dissolved chromium (Cr[T]) plume delineation, as shown on Figure 3-1. South of Highway 58, the plume contouring was based on contours included on Figures 4-6 and 4-7 of the First Quarter 2014 IRZ report (CH2M Hill and ARCADIS, 2014) for the shallow and deep zones of the Upper Aquifer, respectively. Between Highway 58 and to just north of Thompson Road, plume contouring was based on contours included on Figures 5-1 and 5-2 of the First Quarter 2014 General Monitoring Program (GMP) report for the deep zone and shallow zone of the Upper Aquifer, respectively (CH2MHill, 2014). For reference, figures from the quarterly reports with the data and contouring are provided in Appendix A.

The plume associated with the shallow zone of the Upper Aquifer was initialized in model layer 1 while the plume associated with the deep zone of the Upper Aquifer Unit was initialized in model layer 3. Because there is limited Cr(VI) concentration data available for the discontinuous brown clay represented by model layer 2, the concentration data in deep zone was used for model layer 2 as a conservative representation of the Cr(VI) groundwater plume. In the south, the plume includes elevated Cr(VI) concentrations near the Source Area IRZ and the estimated extent of the clean water / low Cr(VI) concentration zones associated with the Central Area, SCRIA, and Source Area IRZ operations to date.

3. Evaluation of the Groundwater Model Used in the Feasibility Study Analysis

3.1 Summary of Remedial Alternative 4C-2 Modeled in Feasibility Study Remedial Timeframe Analysis

Groundwater flow and solute transport modeling were conducted to estimate times for 80 percent mass removal and to reach Cr(VI) concentrations of 50 µg/L, 3.1 µg/L, and 1.2 µg/L for various remedial scenarios in the FS. Estimated timeframes to meet these metrics were compared across alternatives as part of the effectiveness component of the analysis consistent with resolution 92-49. The initial FS indicated that Alternative 4 - Core In situ Treatment and Beneficial Agricultural Use - best met the evaluation criteria of effectiveness, implementability, and cost. Subsequent analysis of Alternative 4 was conducted in addenda and a technical memo that evaluated a range of scales of groundwater extraction and agricultural treatment and various seasonal pumping schemes within Alternative 4. These various alternatives were designated as 4B, 4C-1, 4C-2, etc. The Environmental Impact Report also evaluated a set of Alternative 4 variations to identify potential significant direct and indirect environmental impacts resulting from implementation of the project alternatives (ICF International, 2013).

The modeling presented in this report assumes implementation of a remedy analogous to Alternative 4C-2 from the FS to treat the contiguous plume core south of Thompson road depicted on Figure 1-1. For review and comparison, this section of the report presents a summary of the remedial operations and remedial timeframe predictions from the FS Alternative 4C-2 modeling. The remedial system layout assumed for Alternative 4C-2 is shown on Figure 3-1. Alternative 4C-2 adds additional extraction wells and ATUs and has planned optimizations at 5, 10, and 20 years after the initial build-out, as summarized in Table 2-1. The major components of the Alternative 4C-2 infrastructure are described below with additional details provided in Table 2-1:

- ATUs – groundwater extraction and treatment via ten ATUs, including four new pivots: the Northwest, two Bell pivots and the SCRIA Agricultural Unit total annual average extraction rate of 2,042 gallons per minute [gpm]).

- Central Area IRZ – groundwater extraction, amendment with carbon at 200 mg/L TOC average injection concentration and reinjection (140 gpm).

- SCRIA IRZ – Water from current SCRIA extraction north of Highway 58 (110 gpm) will be diverted to the Northwest Recharge Pivot instead of the SCRIA injection area. An additional 85 gpm is extracted east of the SCRIA injection area, dosed, and applied to SCRIA Injection. The total SCRIA injection equals 195 gpm. SCRIA in situ injections are amended with carbon at 200 mg/L TOC average injection concentration.

- Source Area IRZ – extracts, amends with carbon at an average TOC injection concentration of 200 mg/L, and reinjects 150 gpm.

- NWFI of up to 80 gpm remains in place until plume containment is no longer required.

Also included in Alternative 4C-2 was optimization of the initial build out and the addition of infrastructure over time to increase extraction related to plume capture; mitigate migration to the east; reduce the incidence of untreated areas in the IRZ area; and attempt to further reduce the overall remediation timeframe. Alternative 4C-2 added significant remediation effort and infrastructure compared with earlier Alternatives evaluated for the FS and relies on additional optimization that refocuses the remediation effort on the more “recalcitrant” areas of the chromium plume.

Alternative 4C-2 assumes use of winter crops (winter rye or similar crop) to most of the existing (Gorman, Yang, Cottrell, and Ranch) and new ATUs (Northwest, Bell and Southern SCRIA ATUs). The original Alternative 4C-2 utilized the shallow and deep Cr(VI) plume delineations based on the available data through February 2010. Additional details describing Alternative 4C-2 are presented in FS Addendum #3 (Haley and Aldrich, 2011).

The groundwater flow and solute transport model predicted that 80 percent of mass removal would occur in 7 years and that Cr(VI) concentrations would be reduced to less than 50 µg/L across 99 percent of the original 50 µg/L footprint in 6 years. Time to treat Cr(VI) concentrations to less than 10 µg/L were not estimated in the FS. The estimates from the FS were developed primarily for the purposes of comparison among alternatives, and were not intended to be definitive estimates of actual expected remedial timeframes. Rather, the estimates were intended to identify order-of-magnitude-type differences in performance among remedial alternatives. For example, model simulations indicated a 6 year predicted timeframe for treatment of the 50 µg/L footprint for Alternative 4C-2 versus a 50 year prediction for plume-wide pump and treat (Alternative 5).

It should also be noted that the treatment time estimates provided in the FS considered the results of model layers 1 and 3, which are considered representative of the majority of the permeable materials in the shallow zone and deep zones of the Upper Aquifer, with associated shorter remediation timeframes. Results of the lower- permeability layer 2 were not included, because that layer is not representative of the majority of the aquifer thickness. This assumption was appropriate for estimating timeframes for comparison purposes in the FS. However, to develop more realistic expected timeframes, it is important to also consider the potential influence of lower-permeable sediments within the Upper Aquifer on remediation effectiveness and cleanup timeframes.

3.2 Comparison of Feasibility Study Model Results to Field Data: 2007-2014

Beginning in 2009, modeling was conducted for the FS using the existing groundwater flow model and the solute transport model that was developed at that time for the FS. At the time, the DVD was the only hydraulic containment system operating and the Central Area and Source Area IRZs were in the infancy of operations. Since that time, several more remedial systems were brought on-line, including the NWFI, four ATUs, the SCRIA IRZ, and expansions of the Central and Source Area IRZs. In addition, 6 years of performance data has been collected.

As a first step to updating the model predicted remedial timeframes, the ability of the groundwater flow and solute transport model to predict the performance of the various remedy elements was evaluated. A model simulation using actual operational data from Fourth Quarter 2007 to First Quarter 2014 was run. For this run, the following adjustments were made:

- the Cr(VI) distribution was initialized with data from 2007,
- the operational inputs to this simulation were the actual locations and flow rates of remedial extraction and injection wells,
- the actual amounts of organic carbon substrate applied to the in situ injection wells were used,
- the actual volumes of extracted water applied to agricultural fields were used, and
- the timing of each remedial element in the model was updated to reflect actual timing of installation and start-up.

The results of this comparison of model predictions to actual results for the period from 2007 to 2014 is discussed in the following two sections for the area north of Highway 58, where hydraulic containment activities have been conducted to date, and south of Highway 58, where IRZ treatment has been conducted to date.

3.2.1 North of Highway 58: Groundwater Extraction, Agricultural Application, and Freshwater Injection

Simulated plume maps depicting the distribution of Cr(VI) in the shallow zone of the Upper Aquifer (model layer 1) and the deeper zone of the Upper Aquifer (represented by model Layer 3) north of Highway 58 under current conditions are shown Figures 3-2 and 3-3, respectively. In the area north of the Santa Fe Road, the brown clay separates the shallow portion and deeper portion of the Upper Aquifer, and these are referred to as two distinct aquifer units, the A1 and A2 aquifers, respectively. For comparison with simulated results, Figures 3-2 and 3-3 also illustrate the distribution of Cr(VI) in the shallow (A1) and deeper (A2) zones of the Upper Aquifer as contoured for the First Quarter 2014 GMP report (CH2M Hill, 2014).

The following sections present a comparison of simulated and contoured data for different areas of the northern portion of the plume.

Downgradient Extent of Cr(VI)-Affected Groundwater

In general, comparison of the plume outlines shown on Figures 3-2 and 3-3 indicate a good agreement between simulated results and contoured data. For example, the northernmost (furthest downgradient) extent of Cr(VI) in the A1 aquifer (Figure 3-2) simulated by the model is very similar to the contoured data and lies in the vicinity of Thompson Road. The simulated downgradient extent of Cr(VI) in the deep zone of the Upper Aquifer (A2 aquifer) (Figure 3-3) also indicates a generally good agreement with the contoured data, and lies just to the north of Alcudia Road and south of Thompson Road. Both the simulated and the contoured data reflect the influence of the groundwater extraction system in limiting downgradient migration of Cr(VI)-affected groundwater.

Lateral Extent to the Northwest

Simulated and contoured data both reflect the limited extent of Cr(VI)-affected groundwater to the west of the NFWI system. As shown on Figures 3-2 and 3-3, simulated and contoured data indicate a very similar western extent of Cr(VI)-affected groundwater between the simulations and actual data. These simulated and contoured data reflect the influence of the NWFI system, combined with groundwater extraction in the east, in limiting the western migration and extent of Cr(VI) affected groundwater in this portion of the Site.

Extent of greater-than-10- and 50- µg/L in the Deep Zone of the Upper Aquifer (A2 Aquifer)

As shown on Figure 3-3, the simulated extents of groundwater with concentrations of Cr(VI) greater than 10 µg/L and greater than 50 µg/L in the northern area agrees well with GMP contoured data. Both simulated and contoured data indicate that the downgradient extent of Cr(VI)-bearing groundwater greater than 50 µg/L is limited to the immediate vicinity of the Santa Fe Road. The simulated results indicate a slightly greater downgradient extent of groundwater with concentrations of Cr(VI) greater than 10 µg/L. The lateral extent of groundwater with concentrations of Cr(VI) greater than 10 and 50 µg/L is also similar in the simulated and contoured data.

Lateral Extent of Groundwater with Cr(VI) Less than 10 and Greater than 3.1 µg/L

In both the shallow zone and deep zone (A1 and A2 aquifers), the contoured data for groundwater with concentrations of Cr(VI) less than 10 and greater than 3.1 µg/L extends further to the east than the simulated results (Figures 3-2 and 3-3). GMP contoured data for the extent of groundwater with Cr(VI) greater than 3.1 µg/L extends east to the vicinity of Summerset Road, while the simulated eastern extent is more limited (Figures 3-2 and 3-3). The difference between the simulated and contoured result for the low concentrations in the east is not considered significant for this analysis of remedial timeframe assessment for cleanup to below 50 µg/L and below 10 µg/L.

The lateral extent of groundwater with Cr(VI) greater than 3.1 µg/L also is more limited to the west in the simulated versus the contoured data (Figure 3-2). For example, simulated results indicate that groundwater immediately north of the Santa Fe Road on the western edge of the plume (i.e., beneath the vicinity of the DVD), does not have concentrations of Cr(VI) greater than 3.1 µg/L, while the contoured data indicate concentrations of Cr(VI) in excess of 3.1 µg/L in this area. The lack of simulated Cr(VI) concentrations in the shallow zone of the Upper Aquifer in this portion of the Site in part reflects the simulated influence of recharge of treated groundwater from the DVD into the shallow zone of the Upper Aquifer and the reduction of simulated saturated thickness in this area due to the proximity of the northwestern bedrock outcrop. This potential influence is indicated by monitoring data from select monitoring wells in the area that are screened in the uppermost portion of the aquifer that are not included in the GMP and are therefore not considered in the contoured data. For example, concentrations of Cr(VI) and Cr(T) in upper zone monitoring wells DW-01 and MW-21A (adjacent to EX-34, Figure 5-1 in Appendix A) are consistently below 10 µg/L, but are interpreted to be within the greater-than-10 contour. As a result, the plume extent contoured from GMP data may over-estimate the actual extent of Cr(VI) impacts in the shallow zone of the Upper Aquifer (A1 aquifer).

The difference between simulated and contoured results in this portion of the Site is not considered significant for predicting time to reach concentrations less than 50 µg/L and less than 10 µg/L for this analysis.

In summary, with the exceptions discussed above, the simulated downgradient and lateral extent of Cr(VI) impacts above 3.1 µg/L agree very well with the contoured data, and reflect the simulated and actual influence of the groundwater extraction and injection systems in limiting the migration of Cr(VI)-affected groundwater.

3.2.2 South of Highway 58: In Situ Reactive Zone Area

Simulated plume maps depicting the distribution of Cr(VI) in the shallow zone of the Upper Aquifer (represented by model layer 1) and the deep zone of the Upper Aquifer (represented by model layer 3) south of Highway 58 under current conditions are shown on Figures 3-4 and 3-5, respectively. These figures also illustrate the distribution of Cr(VI) in the shallow and deep zones of the Upper Aquifer as contoured for the First Quarter 2014 report for the IRZ (CH2M Hill and ARCADIS, 2014, included in Appendix A) to allow comparison of simulated results and actual performance of the IRZs.

The following sections present a comparison of the performance of the IRZ system as simulated by the model versus the actual IRZ performance.

Propagation of the Clean Water Front

As shown on Figures 3-4 and 3-5, there is a good agreement between the model results and the observed propagation of the clean water front (white and light grey areas, contours of less than 3.1 and 10 µg/L Cr[VI]) downgradient from the IRZ injection locations (shown as yellow triangles). In particular, the model results and observed data indicate treatment extending over 3,000 ft downgradient from the

Central Area and SCRIA IRZ injection line in the shallow zone of the Upper Aquifer (annotated as Locations 1 and 2 on Figure 3-4). In the original Source Area (Location 4 respectively, on Figure 3-5), the downgradient extent of treatment predicted by the model is also similar to the monitoring data. The agreement is generally not as good in the deep zone depicted on Figure 3-5, for example in the Central Area (Location 1, Figure 3-5) and Source Area Expansion (Location 3 on Figure 3-5), but does approximate the downgradient extent observed near the original Source Area IRZ (Location 4, Figure 3-4).

Lateral Extent of Treatment

The lateral extent of IRZ treatment from injection points tends to be overpredicted by the model simulation. This means that the observed radius of influence achieved at each injection location is generally smaller than that predicted by the model. For example, in the SCRIA IRZ Area (Location 2 on Figures 3-4 and 3-5), where injection wells were installed on 300 ft spacing, the lateral extent of treatment achieved at each location is generally less than 100 ft from the injection well, resulting in “stripes” of treated areas rather than the continuous treatment zone predicted by the simulated results. Such an area in the shallow zone of the Upper Aquifer around SC-IW-34 is depicted on Figure 3-6, and an area in the deep zone around SC-IW-24 is depicted on Figure 3-7. The over prediction of lateral treatment would result in an under prediction of remedial timeframes, as simulated treatment would occur more quickly than actual performance indicates. The potential causes of model over prediction are discussed in Section 3.2.3.

Complexities beyond the Predictive Capabilities of the Model

The Upper Aquifer is a complex hydrogeological environment with very fine-scale heterogeneities that cannot be accounted for in the groundwater flow and solute transport model. Local areas within the IRZ project area that have not been treated to date where the model results predict a greater extent of treatment reflect these heterogeneities. Three examples of such areas follow:

- **Deep Source Area High Concentration Area.** In the Source Area, the simulated results do not identify an area of the deep zone of the Upper Aquifer where Cr(VI) concentrations persist above 500 µg/L (Location 5 on Figure 3-5). While this area continues to contain the maximum Cr(VI) concentrations at the Site (4,600 µg/L in First Quarter 2014 and 7,300 µg/L in Fourth Quarter 2013 at SA-MW-05D), the simulated results predict complete treatment in this area. As presented in the report titled In-Situ Reactive Zone Design and Construction Status Report – Response to California Regional Water Quality Board, Lahontan Region Letter dated February 19, 2014 (referred to as the May 29 status report; ARCADIS, 2014a), investigation is currently underway in this area to determine whether the lack of treatment at SA-MW-05D reflects lower-permeability lithology with limited hydraulic communication with the upgradient injection locations or limited lateral delivery of carbon, which may result in narrow bands of treatment discussed previously.

- **Deep SCRIA High Concentration Area**. Similar to the deep high Cr(VI) concentration area in the Source Area, the simulated results in the SCRIA do not predict the persistence of an area of Cr(VI) concentration greater than 500 µg/L that is observed in the deep zone of the Upper Aquifer (Location 2, Figure 3-5). The limited extent of treatment in this area compared to simulated results is partially attributed to preferential distribution of the injection fluid into the shallow zone of the Upper Aquifer, as discussed in the May 29 status report (ARCADIS, 2014a). For example, the model overpredicts the lateral and downgradient extent of deep treatment in the vicinity of SC-IW-24 (Figure 3-7). Preferential distribution of the injection fluid into the shallow zone occurred when initial injections at SC-IW-24 were conducted with screens open across both the shallow and deep zones, as indicated by the arrival of treated water at shallow unit monitoring wells MW-11A and SC-MW-26S (see Figures 4-6 and 4-7 in Appendix A) in comparison with the slower or minimal arrival of treated water at wells screened into the deeper unit of the Upper Aquifer at PT2-MW-08, PT2-MW-09, and SC-MW-26D (CH2MHill and ARCADIS, 2014).

- **Central Area CA-RW-19 Area.** The IRZ in the deep zone of the Upper Aquifer in the Central Area started operation in late 2012. The results to date demonstrate aquifer heterogeneity and resulting variability in IRZ performance. Good reagent distribution resulting in Cr(VI) treatment was achieved at six of seven deep injection locations with nearby dose response monitoring wells (i.e., CA-RW-01R, CA-RW-03R, CA-RW-05R, CA-RW-07B, CA-RW-09R, and CA-RW-11R; Figure 3-8). In the 7th location near CA-RW-19, distribution was limited as reflected in persistent presence of Cr(VI) at CA-MW-107D and CA-MW-109D. The lack of reagent distribution and treatment in the CA-RW-19 area is likely a result of local hydrogeologic conditions.

These three examples reflect the potential for aquifer heterogeneities to influence IRZ treatment performance that are not captured by the groundwater flow and solute transport model. Such aquifer heterogeneities are difficult to assess and predict prior to remediation. As illustrated for these three examples, areas that are more difficult to remediate become apparent through operation of the remedial system and are not accurately simulated by the solute transport model . Accordingly, model predicted remedial timeframe results must be tempered with the knowledge that the model cannot predict the full impacts of aquifer heterogeneity on remedy performance. To effectively address such areas during remedy implementation, an adaptive management approach is recommended that uses performance monitoring data to identify recalcitrant areas, with response actions to optimize remedial implementation to address those recalcitrant areas.

3.2.3 Evaluation of Select Solute Transport Modeling Parameters

The comparison of model predictions to actual performance presented in Section 3.2.2 indicated that while the overall model predictions of the hydraulic containment system performance and IRZ clean water front migration agree well with observed data, the model consistently overpredicts the extent of lateral treatment from IRZ injection points. This simulated over prediction of lateral treatment results in an under prediction of remedial timeframes.

An analysis of various model input parameters that influence the simulated lateral extent of treatment output was conducted. The influence of solute transport parameters, for example organic carbon substrate degradation rate, mass transfer coefficients, and chromium sorption parameters, on prediction of lateral treatment from IRZ injection points was considered. One solute transport parameter in particular, the amount of organic carbon substrate needed to initiate Cr(VI) reduction reactions in the model, controls the extent of lateral treatment from the injection points in the model. This value of TOC that the model assumes is needed to initiate Cr(VI) reduction is referred to as the “TOC threshold.” In the FS modeling, the TOC threshold was assumed to be 0.1 mg/L. To evaluate the effect of this parameter on the model predictions, a new model run using actual 2007-2014 operational conditions with an increased TOC threshold of 1 mg/L was conducted.

The results of the 2007-2014 actual operations runs using the 0.1 mg/L and 1 mg/L TOC thresholds are presented along with the actual contoured data from the First Quarter 2014 for the shallow and deep zones of the Upper Aquifer on Figures 3-9 and 3-10. A comparison of the results for the area south of Highway 58 shows that the model run using the 1 mg/L TOC threshold results in a better agreement with the lateral distribution and the “streakiness” of treatment observed in actual results better than the 0.1 mg/L TOC threshold run (see Locations 1 and 2 on Figure 3-9 and Location 1 on Figure 3-10). However, downgradient migration of the clean water front is underpredicted in some cases, for instance downgradient from the eastern end of the Central Area IRZ in the shallow zone of the Upper Aquifer (Location 3 on Figure 3-9) and downgradient from the original Source Area IRZ in the deep zone of the Upper Aquifer (Location 2 on Figure 3-10). Also of note, the model continued to predict complete treatment in the high concentration area in the deep zone of the Upper Aquifer in the Source Area, regardless of the TOC threshold concentration (Location 3 on Figure 3-10), indicating that variation in this parameter alone cannot account for all of the discrepancies between model predictions and actual performance.

Given that the higher TOC threshold value improved prediction of some aspects of actual performance, while underpredicting other aspects of actual performance, it was decided to conduct modeling with both TOC threshold values to provide a range of remedial timeframe estimates for the updated remedy timeframe assessment runs.

4. Modeling of Updated Remedial Design and Implementation Schedule

As part of the remedial timeframe estimates update in response to the February 19 Letter, model runs were conducted considering updated remedial designs and implementation plans. Sections 4.1 and 4.2 describe the updated designs and implementation plans for the ATUs and IRZs, respectively. Section 4.3 describes the updated modeling scenarios and results.

4.1 Updated ATU design

The ATU design has been refined since the submittal of FS Alternative 4C-2 in Addendum #3 to the Feasibility Study (Haley and Aldrich, 2011c). The ATU design used for current modeling incorporates plans presented in the Revised Report of Waste Discharge (ROWD) for Proposed Agricultural Treatment Units (ARCADIS, 2014b). As in Alternative 4C-2, additional agricultural treatment capacity is included, compared to the current layout. Differences between Alternative 4C-2 and planned ATU design include acreages and layout of ATU fields that will be added over time, total flow rates, seasonal pumping plans, and extraction well layout.

As shown in Table 2-2 and Figure 4-1, the ATU field layout used for updated modeling includes a total of eight ATUs, compared to 10 ATUs in Alternative 4C-2 (Table 2-1). Four proposed ATUs in Alternative 4C-2 (SCRIA ATU, Northwest ATU, and two Bell

ATUs) have been replaced by the planned Community East and Fairview ATUs and planned expansion of the Ranch ATU.

The total extraction rate used in Alternative 4C-2 was 2,041 gpm. Alternative 4C-2 maximized pumping year-round by both incorporating a second winter crop and including overapplication. The recently issued Waste Discharge Requirements for the ATUs (Water Board, 2014) require that ATUs be operated above agronomic rates for no more than 4 months of the year. Accordingly, 2014 remedial timeframe modeling assumed overapplication above agronomic rates would occur only at the DVD for 4 months of the year. The other ATUs are assumed to be operated at agronomic rates with winter flow rates optimized by including cold-tolerant grasses in the crop mix, which is the current operational plan. In addition, lower extraction rates are used in 2014 remedial timeframe modeling in the southern ATU area (330 gpm for Community East and Fairview) than in Alternative 4C-2 (531 gpm for SCRIA and Bell ATUs) due to the change in layout and acreages. The total annual average extraction rate for the updated modeling is 1,748 gpm.

Finally, the extraction well configuration has been updated to reflect current and planned systems. In particular, the extraction wells supplying the northern ATU area (DVD, Gorman, Cottrell, and Yang ATUs) have been updated to reflect system installations since the FS addenda were issued in 2011. Also, assumed extraction wells which were planned to supply the SCRIA and Bell ATUs have been replaced by a set of southern extraction wells shown on Figure 4-1.

4.2 Updated IRZ Design

The conceptual IRZ design considered for Alternative 4C-2 during the FS is presented on Figure 4-2. The FS modeling assumed that this IRZ layout would be fully constructed and start-up across the entire system would occur simultaneously at time zero. This section evaluates practical considerations to system installation, including property access, permitting and biological clearance, as well as changes in design and operational strategy that have evolved since the FS conceptual design was generated.

4.2.1 Property Access

Figure 4-2 shows the PG&E owned properties as of March 31, 2014 shaded in yellow. These are the areas for which property access has been obtained and the IRZ can be expanded. Two of the proposed IRZ injection well locations west of Fairview Road and south of Community Boulevard in the northern part of the Source Area fall within an area for which property access has not been obtained. Additionally, these two locations fall outside of the currently permitted IRZ area and also within area of good biological habitat. For these reasons, this area was not considered for immediate buildout between 2014 and 2018 in the updated modeling scenarios. IRZ Permitting and biological clearance is discussed in further detail below.

4.2.2 IRZ Permitting

IRZ injections are currently permitted under the Notice of Applicability (NOA) dated July 10, 2010 against the General Waste Discharge Requirements (WDRs), R6V-2008-0014. The currently permitted area for IRZ injections under the 2010 IRZ NOA, shown on Figure 4-2, is bounded by the following:

- The western boundary is defined by Fairview Road, south of Frontier Road, and out to 1,900 ft west of Fairview Road in the vicinity of Frontier Road, north of Community Boulevard;
- The southern boundary is defined Highcrest Road;
- The eastern boundary is defined by Summerset Road; and
- The northern boundary is just north of the Central Area IRZ.

As shown on Figure 4-2, proposed IRZ injection wells west of Fairview Road fall outside of the currently permitted area. Expansions in these areas outside of the currently permitted area will require a new NOA against the current general WDRs to expand the permitted area of the IRZ. Additionally, the area west of Fairview also fall within areas of good biological habitat which would require issuance of the Habitat Conservation Plan (HCP, expected in 2018) prior to buildout, discussed in the next section. For these reasons, the areas west of Fairview Road were not considered for immediate buildout during the 2014 through 2018 period in the updated modeling scenarios.

4.2.3 Biological Clearance

To assess the timing of installation of potential IRZ infrastructure in relation to the HCP, Transcon Environmental biologist Michael Shrum reviewed habitat in the SCRIA and Source Area potential IRZ expansion areas. Surveys were conducted on three separate dates, May 6, 2014, May 26, 2014, and June 12, 2014. Species specific protocol surveys were not conducted; however, habitat was reviewed on a broad scale for its potential to support sensitive species, including the desert tortoise, Mohave ground squirrel (MGS), and burrowing owl (BUOW).

Natural habitat in the area is composed primarily of Mojave desert scrub, dominated by several species of saltbush. This habitat is broken up by various areas of disturbance, including large ruderal (former agricultural) areas. Ruderal areas generally have varying levels of non-native vegetation growth, primarily Russian thistle. Habitat was categorized into three groups, based on the existing levels of disturbance and amount and type of vegetation present. These categories were defined as:

- High quality habitat (shown in yellow on Figure 4-3) – These areas are composed of primarily undisturbed habitat, with few roads crossing through them. Habitat in these areas would be suitable for desert tortoise, MGS, or BUOW, and removal of this habitat could be considered a take of desert tortoise habitat.

- Medium quality habitat (shown in orange on Figure 4-3) – These areas are primarily ruderal areas, with a moderate level of native vegetation regrowth, mixed with non-native vegetation. Work within these areas should be restricted to areas of previous disturbance, where possible, and all disturbance should be minimized. Specific work locations should be reviewed for the presence of sensitive species; however, this presence is unlikely.

- No habitat or minimal habitat (shown in green on Figure 4-3) – These areas are primarily ruderal areas with little to no native vegetation regrowth. Work within these areas is unlikely to result in impacts to sensitive species; however, work areas should be reviewed to ensure none are present.

These areas are shown on Figure 4-3. In general, high quality habitat should be avoided where possible, and restricted to existing roadways if it cannot be avoided entirely. The high quality habitat areas would require the HCP prior to buildout. Medium quality habitat should be reviewed on a case by case basis, but in general small projects (such as individual wells) could occur with minimal impacts to habitat, if the locations are flexible, and larger projects (such as pipelines) will be difficult to implement without resulting in impacts to habitat. Work in no habitat or minimal habitat areas can generally occur without impacts to sensitive species habitat. For the purpose of this evaluation, both the high quality habitat and medium quality habitat areas in the SCRIA IRZ and Source Area IRZ west of Fairview Rd. were considered for buildout following issuance of the HCP in 2018 and initiating operations in 2019 after buildout is completed. The Source Area IRZ replacement wells located in areas of medium quality habitat can be built out along the existing alignment prior to the HCP.

4.2.4 Other Changes to IRZ layout and operational assumptions

Figure 4-4 shows the updated proposed IRZ layout used in the current model. IRZ layouts and operational parameters were updated in the current model to better reflect the current and future operation of the IRZs.

Changes to IRZ Layouts

Expansion of the Central Area system was completed in 2012 to further address Cr(VI) concentrations in the Central Area, as requested by Investigative Order No. R6V-2011-0053 and R6V-2011-0084, dated July 29, 2011 and November 23, 2011, respectively. The Central Area system was expanded to the west and east to target elevated Cr(VI) concentrations in the shallow zone of the Upper Aquifer. Additionally, the Central Area system was expanded to target treatment of the deep zone of the Upper Aquifer, including expansion to the east as requested by Investigative Order No. R6V-2011-0084. The Central Area IRZ expansion included installation of fifteen new injection wells and six new extraction wells. This installed system is shown on Figure 4-4 and is slightly different than the set of IRZ wells that was assumed in the FS (shown on Figure 4-1).

Injection wells in the eastern area of the SCRIA IRZ between the existing northern and southern line were proposed in the FS. This area will now be used for extraction wells for the southern ATUs (Fairview and Community East). A set of extraction wells will be designated to feed the southern ATUs and SCRIA injection wells in different locations than the SCRIA-EX wells proposed in the FS. The three SCRIA-EX wells proposed in the FS are shown on Figure 4-2 along Summerset Road. These wells will be installed within the currently proposed southern ATU infrastructure so they can feed either the ATUs or SCRIA based on seasonal flow rates.

The FS design and modeling was also updated to include additional Source Area injection wells that will supplement and replace the existing Source Area injection wells along the northern line as presented in the June 1 Status Report. This includes a total of 10 injection wells to replace the nine injection wells currently operated as the Source Area Expansion system, where effectiveness has been decreased as a result of biofouling. Additionally, in the February 19 letter, the Water Board requested new injection wells at closer spacing near existing SCRIA injection wells SC-IW-24, -25, and

-26. In the June 1 Status Report, PG&E proposed to install up to three new injection wells between the current injection wells, resulting in 150 foot spacing, similar to the wells pacing that has been used for successful treatment in the Central Area IRZ. Although these three wells were not included in the updated model, these additional wells will target Cr(VI) concentrations above 500 µg/L which have not been treated to date in this area and may improve cleanup timeframes.

Operational Parameters

The target average TOC concentrations modeled in the FS was approximately 200 mg/L for all IRZ areas. However, a lower average target TOC concentration of 30 mg/L is planned for the Central Area IRZ. During recent startup of the expanded Central Area IRZ in November 2012, a TOC concentration of 5 mg/L was initially targeted in an effort to prevent generation of dissolved manganese downgradient from the IRZ. As reducing conditions were established in the immediate vicinity of the Central Area injection wells, the TOC concentration was gradually increased to a target concentration of 30 mg/L. The updated model assumes the Central Area IRZ will continue to be operated at 30 mg/L TOC. The Source Area and SCRIA IRZ will be operated at a target TOC concentration of 200 mg/L, similar to the FS.

In the FS model, it was assumed that a subset of injection wells would be operated on average for 3 consecutive months and then rotated to a new subset of injection wells. Historical IRZ operation has shown that wells generally need to be operated approximately 9 to 12 months consecutively to fully establish reducing conditions and maintain chromium treatment. This rotation schedule has been applied to the expanded Central Area IRZ and has resulted in sustained chromium treatment in the deep where Cr(VI) concentrations were initially up to 430 µg/L. Six months after injection wells were rotated, concentrations were maintained below or near 10 µg/L at five response wells located lateral to the injection wells. The current model was updated to reflect this rotation schedule for the Central Area, SCRIA and Source Area IRZs to optimize reagent distribution and establish Cr(VI) treatment. Additionally, injection flow balance was increased in the current model to ensure all injection wells are operating at flow rates greater than 15 gpm for newly installed systems. Historical operation of the IRZs has shown that a minimum flow rate of 10 to 15 gpm is generally needed to distribute TOC and establish Cr(VI) treatment within the IRZs.

4.2.5 Construction Sequencing and Operational Plan

Given the current plans for ATU construction and the constraints for IRZ construction discussed in Sections 4.2.1 through 4.2.3, a preliminary construction sequencing and operational plan was used for the updated modeling, as summarized below:

- **Time 0** = assumed to be January 1, 2015. During this time, the existing IRZ systems will be operated, including operation of the existing Source Area wells at current, low flow rates (average of 5 to 10 gpm, currently low due to fouling of the system). Additionally, southern extraction will be operated and applied to the Community East ATU, which is anticipated to be brought on-line in Fall 2014.

- **Time 0.5 year** = June 1, 2015. During this time, the new Source Area replacement wells in the north and new injection wells in the southwest will be turned on to meet the May 15, 2015 timeframe requested in the February 19 letter. IRZ operations during this time will be limited to areas within the existing IRZ NOA permitted area and within biologically cleared areas that do not require the HCP. Additionally, build-out will be completed and operation of southern Fairview ATU will be initiated.

- **Time 1.5 years** = June 1, 2016. Operations will remain the same through this time.

- **Time 2 years** = January 1, 2017. Construction of the southern and south-eastern Source Area will be completed at this time. This assumes wells currently proposed in the southern Source Area which fall underneath the compressor station will be approved for construction. Additionally, new western SCRIA injection wells will be installed.

- **Time 3 years** = January 1, 2018. The HCP is anticipated to be approved in May 2018. Once obtained, final buildout of the IRZs will begin.

- **Time 4 years** = January 1, 2019. Operations will continue, with the addition of operation of the IRZ injection wells built post- HCP.

- **Time 5 years** = January 1, 2020. At this time, the Source Area extraction wells will be converted to injection wells. Operation of these six wells as injection wells will be initiated.

4.3 Modeling of Updated Remedy Design

Three scenarios were run for the modeling updates presented in this assessment:

- Scenario 1: Feasibility Study (FS) Alternative 4C-2, with an updated baseline Cr(VI) distribution
- Scenario 2: Updated Remedy Layout
- Scenario 3: Updated Remedy Layout, with Increased TOC Threshold

This section summarizes the modeled scenarios and results.

4.3.1 Scenario 1: FS Alternative 4C-2, First Quarter 2014 Baseline

For the first modeling scenario, the FS Alternative 4C-2 was re-run with an updated baseline Cr(VI) distribution to provide a direct point of comparison to updated modeling scenarios. The Alternative 4C-2 operational parameters described in Section 3.1 and summarized in Table 2-1 were used for this scenario. In short, the scenario assumed nine ATUs operating at an annual average rate of 2,042 gpm and simultaneous start-up of the entire IRZ buildout at time zero. Consistent with the FS modeling, the TOC threshold used in this scenario was 0.1 mg/L.

Modeling predictions over time for this scenario are presented on Figures 4-5 through 4-9. A comparison of results over times indicates that layer 1 of the model, where more of the IRZ treatment has been conducted to date, is treated more rapidly than layers 2 and 3 and that after 20 years of simulation, Cr(VI) concentrations remain above 10 µg/L in some portions of layer 2. As discussed in Section 3.1, model layers 1 and 3 are considered representative of the majority of the permeable materials in the shallow zone and deep zones of the Upper Aquifer, particularly south of the Santa Fe Road where the brown clay is not present. Results from Layer 2 in this scenario and the other scenarios discussed in this section may represent some of the tighter lithologies at the Site and indicate longer timeframes for treating those portions of the aquifer.

Model predicted remedial timeframes and treated areas are presented in Tables 4-1 and 4-2, respectively and are summarized as follows:

- The model predicted time to reduce the total mass by 80 percent is 6 years.

- The model predicted time to reduce Cr(VI) concentrations to less than 50 µg/L across 99 percent of the initial 50 µg/L footprint range from 4 to 6 years across the majority of the aquifer represented by model layers 1 and 3, with less permeable portions of the aquifer predicted to be treated in 8 years, as represented by model layer 2.

- The model predicted time to reduce Cr(VI) concentrations to less than 10 µg/L across 99 percent of the initial 10 µg/L footprint range from 7 to 20 years across the majority of the aquifer represented by model layers 1 and 3, with less permeable portions of the aquifer predicted to be treated in 26 years as, represented by model layer 2.

4.3.2 Scenario 2: Updated Remedy Layout

The second modeling scenario was run with the updated remedy layout, implementation timing and operational strategy presented in Sections 4.1 and 4.2 along with model predicted remedial timeframes and treated areas. The TOC threshold used in this run was kept at 0.1 mg/L for comparison to the FS.

Modeling predictions over time for this scenario are presented on Figures 4-10 through 4-14. A comparison of Scenarios 1 and 2 at 4 years and 8 years shows the following:

- More mass remains at these time points in Scenario 2 west of Fairview Road from south of Community Boulevard to Highway 58, as a result of delaying IRZ infrastructure installation west of Fairview Road until after the presumed issuance of the HCP.

- More mass remains at these time points in Scenario 2 in the deep zone of the Upper Aquifer in the north and northeast of the IRZ area, due to the delay of IRZ infrastructure installation in the northeast quadrant of the SCRIA IRZ until after the presumed issuance of the HCP.

As a result of the staggered implementation timing in Scenario 2, model predicted remedial timeframes are generally longer for Scenario 2 than for Scenario 1 and are shown in Tables 4-1 and 4-2 and summarized as follows:

- The model predicted time to reduce the total mass by 80 percent is 8 years. Although this is longer than predicted for Scenario 1, these results are not considered significantly different within the context of the accuracy of the model.

- The model predicted time to reduce Cr(VI) concentrations to less than 50 µg/L across 99 percent of the initial 50 µg/L footprint range from 6 to 10 years across the majority of the aquifer represented by model layers 1 and 3, with less permeable portions of the aquifer predicted to be treated in 15 years, as represented by model layer 2.

- The model predicted time to reduce Cr(VI) concentrations to less than 10 µg/L across 99 percent of the initial 10 µg/L footprint range from 11 to 19 years across the majority of the aquifer represented by model layers 1 and 3, with less permeable portions of the aquifer predicted to be treated in 37 years as, represented by model layer 2.

4.3.3 Scenario 3: Updated Remedy Layout, Increased TOC threshold

The third modeling scenario was conducted with the same remedy design and operational strategy as Scenario 2. For this scenario, the TOC threshold was increased an order of magnitude to 1 mg/L.

Modeling predictions over time for this scenario are presented on Figures 4-15 through 4-19. A comparison of Scenarios 2 and 3 at 4 years and 8 years shows more mass remaining in Scenario 3 and more streakiness in the migration of the clean water front, due to the more limited extent of lateral and downgradient Cr(VI) reduction with the increased TOC threshold.

Model predicted remedial timeframes and treated areas are presented in Tables 4-1 and 4-2. As a result of the increased TOC threshold in Scenario 3, model predicted remedial timeframes are generally longer for Scenario 3 than for Scenario 2 and are summarized as follows:

- The model predicted time to reduce the total mass by 80 percent is 13 years.

- The model predicted time to reduce Cr(VI) concentrations to less than 50 µg/L across 99 percent of the initial 50 µg/L footprint range from 9 to 13 years across the majority of the aquifer represented by model layers 1 and 3, with less permeable portions of the aquifer predicted to be treated in 23 years, as represented by model layer 2.

- The model predicted time to reduce Cr(VI) concentrations to less than 10 µg/L across 99 percent of the initial 10 µg/L footprint range from 17 to 27 years across the majority of the aquifer represented by model layers 1 and 3, with less permeable portions of the aquifer predicted to be treated in 50 years as, represented by model layer 2.

These results illustrate that the certainty of removing the majority of the mass is greater, i.e. there is a smaller range of predicted treatment times, than the certainty associated with treatment of the last 20 percent of the mass down to less than10 µg/L.

5. Model Predicted Remedy Timeframe Estimates and Uncertainty Analysis

The modeling analysis presented in this remedial timeframe assessment provides a guide for evaluation of remedy performance over time. As with all mathematical models of natural systems, the groundwater flow and solute transport model is limited by factors such as scale, accuracies in estimated hydraulic properties, solute transport parameters, and/or boundary conditions, and the underlying simplifications and assumptions incorporated into the models. These factors result in limitations to the model's appropriate uses and to the interpretations that may be made of simulation results. These modeling results do not provide definitive predictions and should not be used in cleanup orders with the expectation of certainty.

This model, like all models, includes simplifying fundamental assumptions and data uncertainties; therefore, this model has inherent limitations and uncertainties when used to predict behavior and responses for real systems. The amount of uncertainty associated with these model results is directly related to the degree that actual site conditions and processes deviate from model assumptions and input parameter values. The numerical model approximates the current conceptual model, which has been developed in the context of available geologic, hydrologeologic, and chemical data and this model reasonably reproduces observed groundwater elevations, hydraulic responses for existing conditions, and impact on the hexavalent chromium plume distribution. Therefore, the model is a useful tool in evaluating the relative predicted impact of various remedial scenario layouts on remediation performance. As discussed in the comparison of modeling predictions and actual performance in Section 3.2.2, the influences of aquifer heterogeneities on plume behavior, mass removal, reagent delivery and IRZ performance cannot be described or predicted prior to remedy implementation, and cannot be not be fully predicted with the solute transport model. In addition, the model cannot fully describe the heterogeneity in the Cr(VI) distribution and areas where there may be more mass loaded into tighter lithologies or the immobile pore space or areas which may not be in communication with the rest of the aquifer. Such areas may be more difficult to treat or may show rebound after treatment and require additional remediation.

Considering these uncertainties, and in response to the request from the Water Board, the model estimated treatment times for the Cr(VI) contiguous plume core south of Thompson Road under the remedial alternative scenarios evaluated in this study are summarized below:

- The model predicted time to reduce the total mass by 80 percent ranges from 8 to 13 years.

- The model predicted time to reduce Cr(VI) concentrations to less than 50 µg/L across 99 percent of the initial 50 µg/L footprint ranges from 6 to 13 years in given layers across the majority of the aquifer represented by model layers 1 and 3, with treatment of the less permeable portions of the aquifer predicted between 15 and 23 years (represented by model layer 2).

- The model predicted time to reduce Cr(VI) concentrations to less than 10 µg/L across 99 percent of the initial 10 µg/L footprint ranges from 11 to 27 years in given layers across the majority of the aquifer represented by model layers 1 and 3, with less permeable portions of the aquifer predicted between 37 and 50 years represented by model layer 2.

It should be noted that these modeling estimates were made assuming that a given regulatory framework is in place, including current assumptions of the byproduct management framework for ATUs and IRZs. Timeframes may vary if remedial operations differ from those modeled, due to changes in the regulatory requirements for the remedial systems or operational changes are needed for byproduct management. The timeframes also assume a particular schedule for remedy buildout. If buildouts are delayed, for instance due protracted time to get wildlife agency approvals for system upgrades, timeframes would be extended. For example, if new permits are prepared for the IRZs that require biological consultation prior to buildout, a 1 to 2 year delay could be experienced.

Given the uncertainty in the remedial timeframe predictions, the large scale of this remedial effort, and the heterogeneous nature of the targeted aquifer, and adaptive management approach to promote efficient remediation is recommended. Under an adaptive management framework, actual remedy performance would be evaluated in comparison to the predicted remedial performance or “remedial forecast” at established review cycles. A review cycle could be established which would allow time for cycles of remedial component design, installation, operation and performance evaluation. To illustrate this approach, a remedial forecast, based on a 4 year review cycle and the updated model results under Scenarios 2 and 3, is presented in Table 5-1. Every 4 years, a review would be conducted and report submitted assessing progress toward the remedial forecast. The evaluation could include, but would not be limited to:

- Evaluation of area treated to average Cr(VI) concentration of less than 10 µg/L, relative to the treated areas predicted by the model.

- Evaluation of Cr(VI) concentrations trends and other redox indicators, particularly in areas where treatment is not occurring within expectations, to determine if trends are expected to improve.

If remedial progress is not within expectations, PG&E would prepare a report that would identify actions to improve treatment and provide a schedule for implementation. If previously treated areas show increasing concentrations, the report would identify actions to improve treatment and provide a timeframe for implementation or an explanation of why trends are not an issue relative to overall cleanup.

6. References

ARCADIS. 2014a. In-Situ Reactive Zone Design and Construction Status Report – Response to California Regional Water Quality Board, Lahontan Region Letter dated February 19, 2014. May 29.

ARCADIS. 2014b. Revised Report of Waste Discharge (ROWD) for Proposed Agricultural Treatment Units (ATUs), Hinkley Compressor Station, Hinkley, California. May 28.

ARCADIS and CH2M Hill. 2011. Development of a Groundwater Flow and Solute Transport Model, Pacific Gas & Electric, Hinkley, California. September. Submitted as Appendix G of the Feasibility Study Addendum #3 (Haley and Aldrich, 2011c).

CH2M Hill 2014. First Quarter 2014 Groundwater Monitoring Report and Domestic Well Sampling Results, Site-Wide Groundwater Monitoring Program, Pacific Gas and Electric Company, Hinkley Compressor Station, Hinkley, CA. April 30.

CH2M Hill and ARCADIS. 2014. First Quarter 2014 Monitoring Report for the In Situ Reactive Zone and the Northwest Freshwater Injection Projects, Pacific Gas and Electric Company, Hinkley Compressor Station, Hinkley, California. April 15.

Haley and Aldrich. 2010. Feasibility Study, Pacific Gas and Electric Company Hinkley Compressor Station, Hinkley, California. August 30.

Haley and Aldrich. 2011a. Addendum # 1 to the Feasibility Study, Pacific Gas and Electric Company Hinkley Compressor Station, Hinkley, California. January 31.

Haley and Aldrich. 2011b. Addendum # 2 to the Feasibility Study, Pacific Gas and Electric Company Hinkley Compressor Station, Hinkley, California. March 3.

Haley and Aldrich. 2011c. Addendum # 3 to the Feasibility Study, Pacific Gas and Electric Company Hinkley Compressor Station, Hinkley, California. September 15.

California Regional Water Quality Control Board, Lahontan Region (Water Board). 2014. *Waste Discharge Requirements for Pacific Gas and Electric Company Groundwater Remediation Project Agricultural Treatment Units. San Bernardino California*. March 12.

ICF International. 2013. Final Environmental Impact Report: Comprehensive Groundwater Cleanup Strategy for Historical Chromium Discharges from PG&E's Hinkley Compressor Station, San Bernardino County. May.

McDonald, M.G., and A.W. Harbaugh. 1988. A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model, Techniques of Water-Resources Investigations, Book 6, Chapter A1. U. S. Geological Survey. Reston, Virginia.

Zheng, C., and P. Wang. 1999. MT3DMS: A Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems. Prepared for the U.S. Army Corps of Engineers, Washington, DC. University of Alabama, Tuscaloosa, AL.

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Tables

Table2-1. Implementation Details for Scenario 1: FS Alternative 4C-2
Remedial Timeframe Assessment
PG&E Hinkley Compressor Station, Hinkley, California

Alternative Components	Optimization Periods[1]			
	0-5 years	**5-10 years**	**10-20 years**	**20+**
Rationale for Optimization	***Initial Build-out***	§ ***Focus dosed injection in areas of highest remaining mass in SCRIA and Source Area***	§ ***Focus extraction in areas of highest remaining mass in OU2*** § ***Focus dosed injection in areas of highest remaining mass in SCRIA and Source Area***	§ ***Focus extraction in areas of highest remaining mass in OU2*** § ***Focus dosed injection in areas of highest remaining mass in SCRIA and Source Area***
Agricultural Units and Estimated Application	§ 2 Gorman ATUs (324.5 gpm) § 1 Cottrell ATU (177 gpm) § 1 Yang ATU (177 gpm) § 1 Ranch ATU (177 gpm) § 1 Northwest Recharge Pivot ATU (135 gpm) § 1 Southern SCRIA ATU (177 gpm) § 2 Bell ATUs (354 gpm) § DVD (520 gpm) § Total extraction[2] = 2,042 gpm § Select AUs will be operated year-round, supporting a second crop in the winter time (6 months of the year)	§ No change from previous period	§ Install 12 new extraction wells in the plume toe to support Cottrell and Yang AUs and shift extraction (+118 gpm) to target recalcitrant areas; net extraction remains the same § Reduce extraction (-118 gpm) from select wells in areas where extraction is no longer beneficial; net extraction remains the same § Total AU-related extraction = 2,042 gpm	§ 2 Bell AU pivots and associated extraction wells are turned off (-354 gpm) § Shift extraction within wells installed during year 10 optimization to target recalcitrant areas. As noted below, some of this additional flow is sent to the combined SCRIA and Source Area dosed injection system § Total extraction = 1,688 gpm
Central Area IRZ	§ Total recirculation = 140 gpm	§ No change from previous period	§ No change from previous period	§ Central Area IRZ turned off
SCRIA IRZ	§ SCRIA not receiving extracted water from north of Highway 58 § New extraction wells located in the SCRIA provide 110 gpm for dosed injection as well as 150 gpm for the South SCRIA Pivot as shown above § Additional 85 gpm extracted east of SCRIA is dosed and injected § Total SCRIA dosed injection = 195 gpm	§ SCRIA dosed injection (195 gpm) now being shared with Source Area injection	§ 3 new extraction wells added north of Highway 58 for additional dosed injection shared by SCRIA and Source Area § SCRIA dosed injection (255 gpm) being shared with Source Area injection	§ Eastern SCRIA extraction wells turned off § Portion of flow (30 gpm) applied to combined SCRIA and Source area dosed injection system extracted from wells installed in the plume toe at year 10 § SCRIA dosed injection (170 gpm) being shared with Source Area injection § Reduced carbon dose (from 125 to 25 mg/L)
Source Area IRZ	§ Source Area dosed injection = 150 gpm	§ All source Area extraction wells converted to dosed injection wells § SCRIA dosed injection (195 gpm) now being shared with Source Area injection	§ SCRIA dosed injection (255 gpm) being shared with Source Area injection	§ SCRIA dosed injection (170 gpm) being shared with Source Area injection § Reduced carbon dose (from 125 to 25 mg/L)
Northwest Freshwater Injection	§ 80 gpm clean water injection	§ No change from previous period	§ No change from previous period	§ No change from previous period

Notes:
1 Only changes are shown for each consecutive period
2 All flows are on an annual average basis

Abbreviations:
ATU- Agricultural Treatment Unit
DVD- Desert View Dairy
gpm- gallons per minute
IRZ- In Situ Reactive Zone
mg/L- milligrams per liter
OU- Operable Unit
SCRIA- South Central Re-Injection Area

Table 2-2. Implementation Details for Scenarios 2 and 3 Updated Remedy Layouts
Remedial Timeframe Assessment
PG&E Hinkley Compressor Station, Hinkley, California

Alternative Components	**Optimization Periods[1]**			
	0-5 years	**5-10 years**	**10-20 years**	**20+**
Rationale for Optimization	***Initial Build-out***	§ ***Focus dosed injection in areas of highest remaining mass in SCRIA and Source Area***	§ ***Focus extraction in areas of highest remaining mass in OU2*** § ***Focus dosed injection in areas of highest remaining mass in SCRIA and Source Area***	§ ***Focus extraction in areas of highest remaining mass in OU2*** § ***Focus dosed injection in areas of highest remaining mass in SCRIA and Source Area***
Agricultural Treatment Units and Estimated Application	§ 2 Gorman ATUs (125 gpm) § 1 Cottrell ATU (265.5 gpm) § 1 Yang ATU (24 gpm) § 1 Ranch ATU (548 gpm) § 2 Southern ATUs: Fairview (180 gpm) and Community (155 gpm) § DVD ATU (451 gpm) § Total extraction[2] = 1,748 gpm § Select AUs will be operated year-round, supporting a second crop in the winter time (6 months of the year) •ATUs are operated at agronomic rates throughout the year, with the exception of the DVD operated above agronomic rates for 4 months a year	§ No change from previous period	§ Install 12 new extraction wells in the plume toe to support Cottrell and Yang AUs and shift extraction (+118 gpm) to target recalcitrant areas; net extraction remains the same § Reduce extraction (-118 gpm) from select wells in areas where extraction is no longer beneficial; net extraction remains the same § Total AU-related extraction = 1,748 gpm	§ No change from previous period
Central Area IRZ	§ Total recirculation = 114 gpm, comprised of 35 gpm from the Northwest extraction wells, 79 gpm from Central Area extraction wells	§ No change from previous period	§ No change from previous period	§ Central Area IRZ turned off
SCRIA IRZ	§ Total SCRIA dosed injection = 35 gpm to 175 gpm, comprised of 35 gpm from Northwest extraction wells and 0-140 gpm from SCRIA extraction wells	§ SCRIA dosed injection (123 gpm to 179 gpm) now being shared with Source Area injection	§ SCRIA dosed injection (126 gpm to 182 gpm) shared with Source Area injection	§ SCRIA dosed injection (164 gpm to 220 gpm)extraction wells shared wth Source Area injection
Source Area IRZ	§ Source Area dosed injection = 150 gpm	§ All source Area extraction wells converted to dosed injection wells § SCRIA dosed injection (123 gpm to 179 gpm) now being shared with Source Area injection	§ SCRIA dosed injection (126 gpm to 182 gpm) being shared with Source Area injection	§ SCRIA dosed injection (164 gpm to 220 gpm) being shared with Source Area injection
Northwest Freshwater Injection	§ 80 gpm clean water injection	§ No change from previous period	§ No change from previous period	§ No change from previous period

Notes:
1 Only changes are shown for each consecutive period
2 All flows are annual averages

Abbreviations:
ATU- Agricultural Treatment Unit
DVD- Desert View Dairy
gpm- gallons per minute
IRZ- In Situ Reactive Zone
mg/L- milligrams per liter
OU- Operable Unit
SCRIA- South Central Re-Injection Area

Table 4-1 Summary of Model Estimated Remedial Timeframes

Remedial Timeframe Assessment

PG&E Hinkley Compressor Station, Hinkley, California

Scenario	Time to Reduce Total Mass by 80% (years)	Time to Reach 1% of Initial 50 µg/L Contour Area Remaining (years)			Time to Reach 1% of Initial 10 µg/L Contour Area Remaining (years)		
		Model Layer 1	Model Layer 3	Model Layer 2	Model Layer 1	Model Layer 3	Model Layer 2
Scenario 1: FS Alternative 4C-2, First Quarter 2014 Baseline	6	6	4	8	7	20	26
Scenario 2: Updated Remedy Layout	8	10	6	15	11	19	37
Scenario 3: Updated Remedy Layout, Increased TOC threshold	13	13	9	23	17	27	50

Timeframe estimates are for treatment of the contiguous plume core south of Thompson Road

Abbreviations

µg/L- micrograms per liter

FS- Feasibility Study

TOC- total organic carbon

Table 4-2. Model Estimated Areas of 10 and 50 μg/L Contours Treated over Time

Remedial Timeframe Assessment

PG&E Hinkley Compressor Station, Hinkley, California

Model Estimated Percent of Initial 10 μg/L Contour Area Treated									
Time (years)	Scenario 1: FS Alternative 4C-2, First Quarter 2014 Baseline			Scenario 2: Updated Remedy Layout			Scenario 3: Updated Remedy Layout, Increased TOC Threshold		
	Model Layer 1	Model Layer 2	Model Layer 3	Model Layer 1	Model Layer 2	Model Layer 3	Model Layer 1	Model Layer 2	Model Layer 3
4	94%	48%	59%	83%	24%	39%	76%	13%	23%
8	99%	64%	79%	96%	41%	62%	92%	25%	39%
12	100%	73%	87%	99%	59%	80%	98%	38%	59%
16	100%	82%	93%	100%	80%	95%	99%	62%	80%
20	100%	89%	99%	100%	90%	100%	99%	79%	96%

Model Estimated Percent of Initial 50 μg/L Contour Area Treated									
Time (years)	Scenario 1: FS Alternative 4C-2, First Quarter 2014 Baseline			Scenario 2: Updated Remedy Layout			Scenario 3: Updated Remedy Layout, Increased TOC Threshold		
	Model Layer 1	Model Layer 2	Model Layer 3	Model Layer 1	Model Layer 2	Model Layer 3	Model Layer 1	Model Layer 2	Model Layer 3
4	93%	84%	98%	83%	75%	94%	78%	63%	90%
8	100%	99%	100%	97%	94%	100%	93%	86%	98%
12	100%	100%	100%	100%	98%	100%	99%	94%	100%
16	100%	100%	100%	100%	99%	100%	99%	97%	100%
20	100%	100%	100%	100%	99%	100%	100%	98%	100%

Areas treated estaimates are for the contiguous plume core south of Thompson Road.

Abbreviations:

μg/L- micrograms per liter

FS- Feasibility Study

TOC- total organic carbon

Table 5-1. Remedial Forecast

Remedial Timeframe Assessment

PG&E Hinkley Compressor Station, Hinkley, California

Year	Remedial Forecast
4	• Anticipate average Cr(VI) concentrations of 10 μg/L across the following percentages of the initial 10 μg/L footprint: 75-80% of the shallow zone and 20-40% in the deep zone of the Upper Aquifer. • Areas may remain untreated where remedial infrastructure was not installed pending Habitat Conservation Plan. • Areas within certain lithologies may remain untreated due to aquifer heterogeneity.
8	• Anticipate average Cr(VI) concentrations of 10 μg/L across the following percentages of the initial 10 μg/L footprint: 90-95% of the shallow zone and 40-60% in the deep zone of the Upper Aquifer. • Areas within certain lithologies may remain untreated due to aquifer heterogeneity. • Cr(VI) concentrations may increase in previously treated areas due to diffusion from immobile porespace or migration of upgradient mass.
12	• Anticipate average Cr(VI) concentrations of 10 μg/L across the following percentages of the initial 10 μg/L footprint: 100% of the shallow zone and 60-80% in the deep zone of the Upper Aquifer. • Areas within certain lithologies may remain untreated due to aquifer heterogeneity. • Cr(VI) concentrations may increase in previously treated areas due to diffusion from immobile porespace or migration of upgradient mass.
16	• Anticipate average Cr(VI) concentrations of 10 μg/L across the following percentages of the initial 10 μg/L footprint: 100% of the shallow zone and 80-95% in the deep zone of the Upper Aquifer. • Fewer areas remain untreated due to aquifer heterogeneity. • Fewer Cr(VI) concentration increases in previously treated areas.
20	• Anticipate average Cr(VI) concentrations of 10 μg/L across the following percentages of the initial 10 μg/L footprint: 100% of the shallow zone and 95-100% in the deep zone of the Upper Aquifer. • Fewer areas remain untreated due to aquifer heterogeneity. • Fewer Cr(VI) concentration increases in previously treated areas.

The remedial forecast is for the contiguous plume core south of Thompson Road.

Abbreviations

μg/L- micrograms per liter

Cr(VI)- hexavalent chromium

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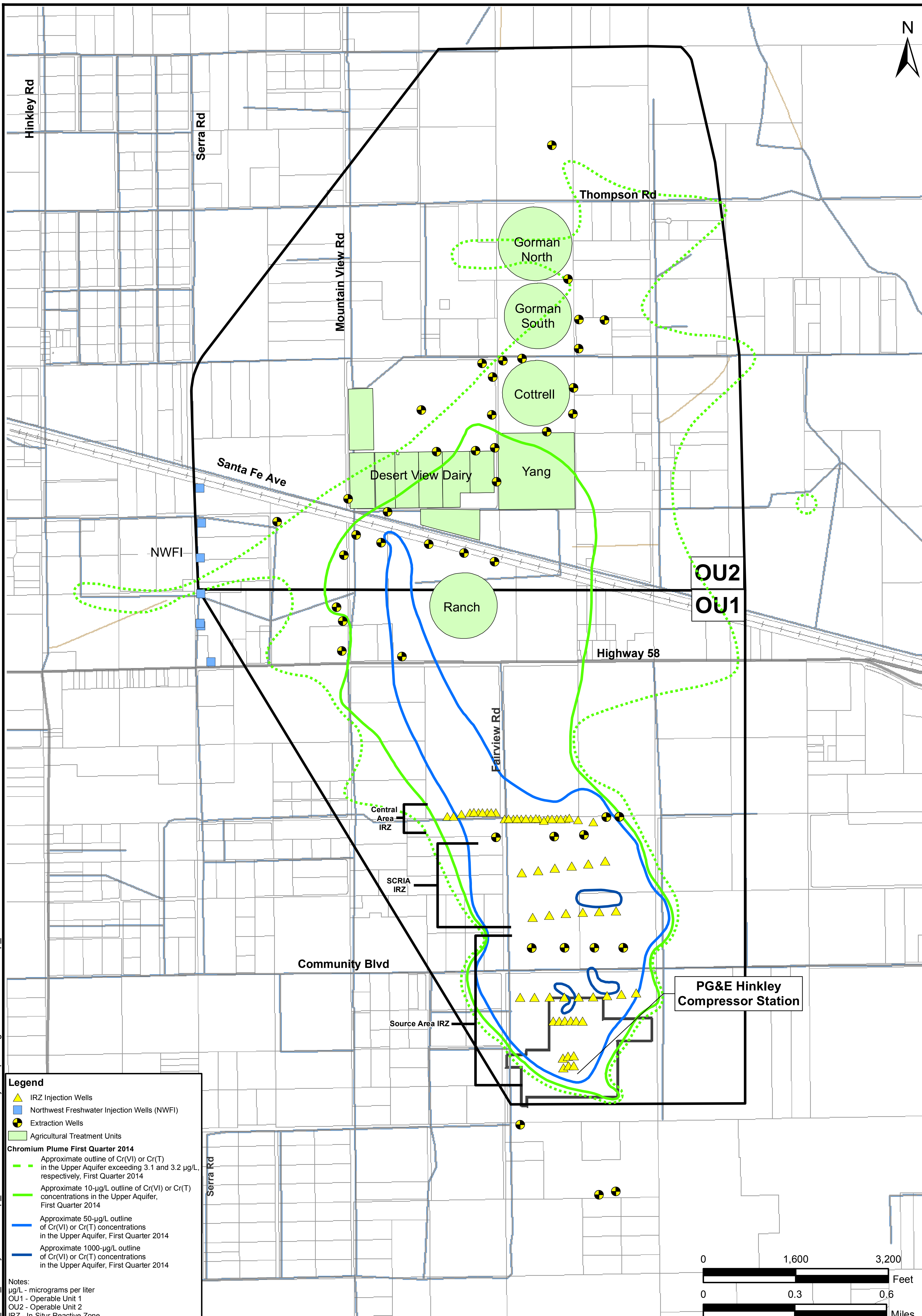
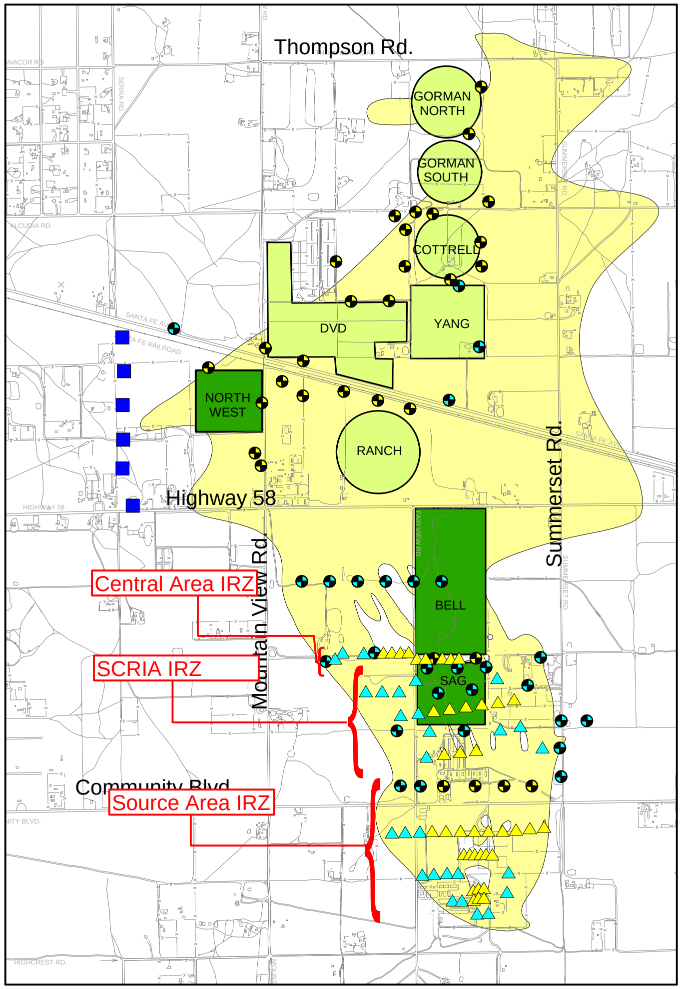
Figures



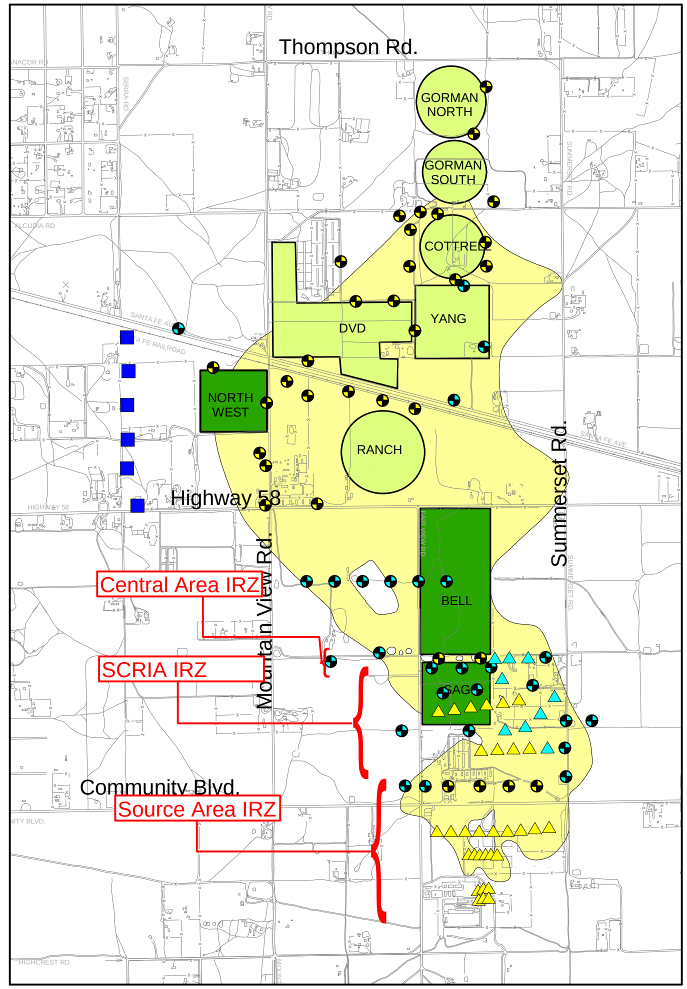
Drafter: BCG Path: I:\RC000699.0001_PGE_Hinkley\GIS\ArcMap_MXD\SiteWide\2014\July 1 Report\Fig 1-1 SiteLocationMap_v2.mxd Date: 6/30/2014 Time: 10:52:36 AM

Program Manager Lisa Cope	ARCADIS 100 Montgomery Street, Suite 300 San Francisco, California 94104 Tel: 415 374 2744 Fax: 415 374 2745 www.arcadis-us.com	Site Location Map Pacific Gas and Electric Company Hinkley, California	Project Number RC000699.0117
Project Manager Jenifer Beatty			Date 6/30/2014
Task Manager Margaret Gentile			Figure 1-1

SHALLOW ZONE OF THE UPPER AQUIFER



DEEP ZONE OF THE UPPER AQUIFER



N

Scale in feet

0 2,000 4,000

LEGEND

- PG&E Compressor Station and non-PG&E Extraction Well
- PG&E Remediation Injection Well
- Northwest Freshwater Injection Well
- Approximate outline of Cr(VI) or Cr(T) in the Upper Aquifer exceeding 3.1 and 3.2 micrograms per liter, respectively, First Quarter 2014
- PG&E Remediation Extraction Well
- Potential Extraction Well
- Potential Injection Well
- Existing Agricultural Treatment Units
- Areas for Potential Future Agricultural Treatment Units

Notes:
PG&E - Pacific Gas and Electric

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

ALTERNATIVE 4C-2 LAYOUT

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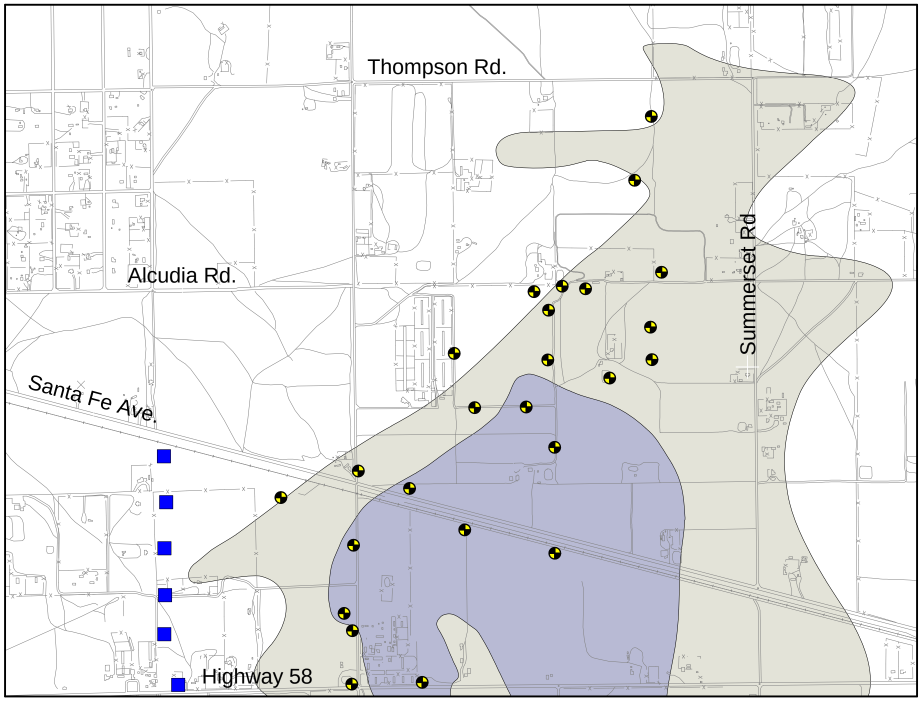
FIGURE
3-1

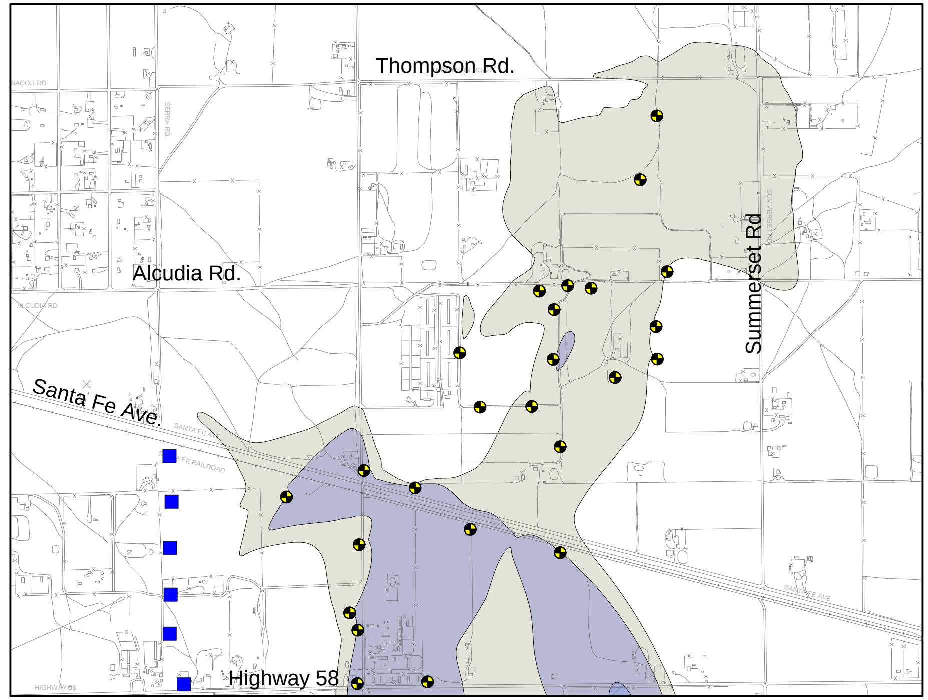
N

CONTOURED FROM MONITORING DATA



Shallow Zone of the Upper Aquifer, First Quarter 2014

SIMULATED



Model Layer 1

LEGEND

Chromium Concentration (ug/L)

0 3.1 10 50 100 500

PG&E Remediation Extraction Well

PG&E Remediation Injection Well

Northwest Freshwater Injection Well

Scale in feet

0 2,000 4,000

Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric
Contoured data reference, Figure 5-1 (CH2MHill 2014), included in Appendix A for reference.
Simulated contour initalized with Fourth Quarter 2007 data and run with actual operating conditions for 7 years

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

COMPARISON OF MODEL TO ACTUAL RESULTS
NORTH OF HIGHWAY 58,
SHALLOW ZONE OF THE UPPER AQUIFER

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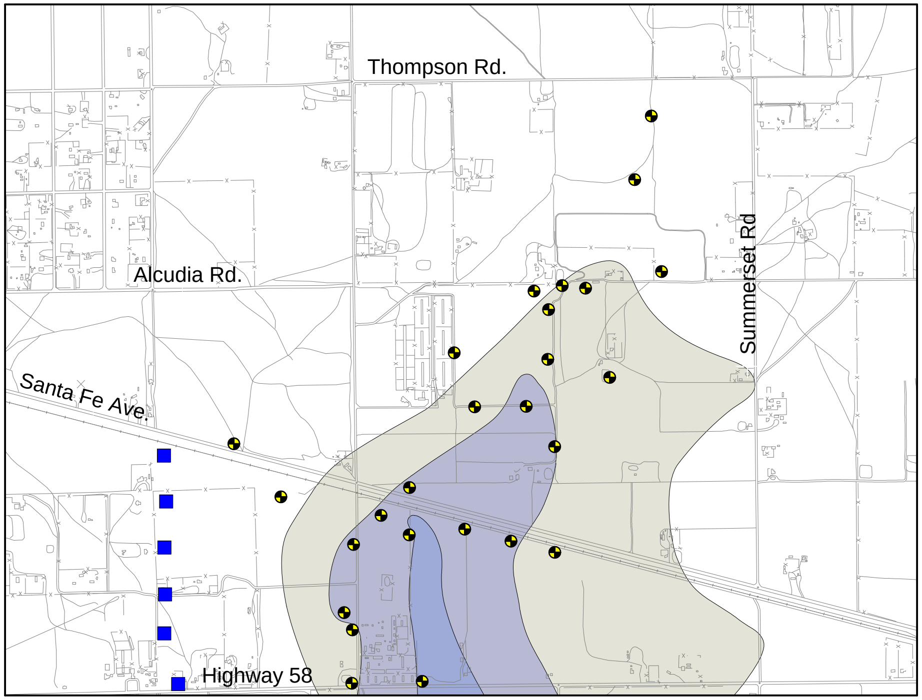
FIGURE
3-2

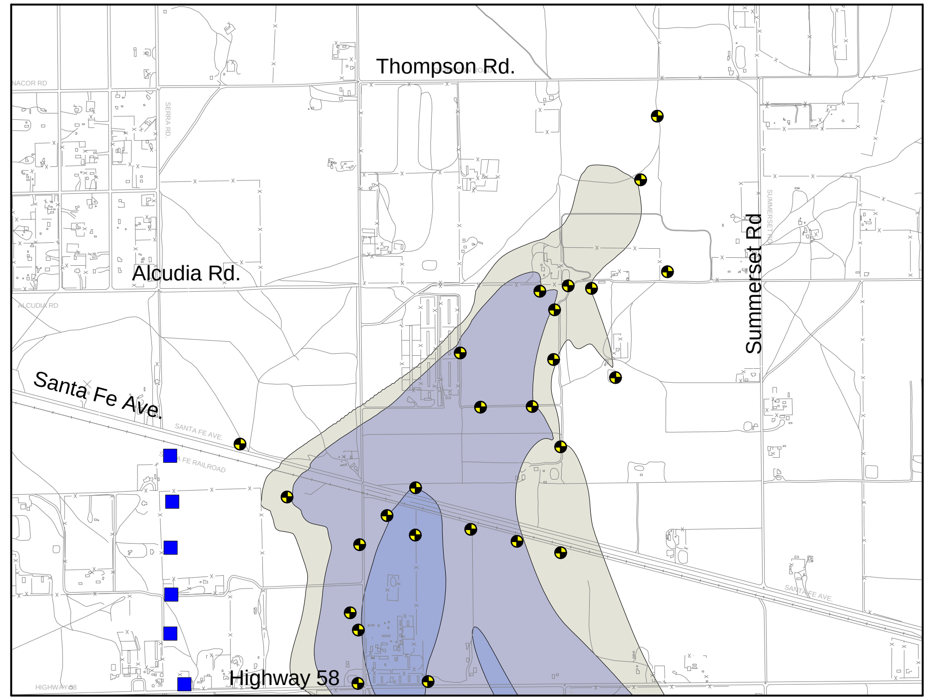
N

CONTOURED FROM MONITORING DATA



Deep Zone of the Upper Aquifer, First Quarter 2014

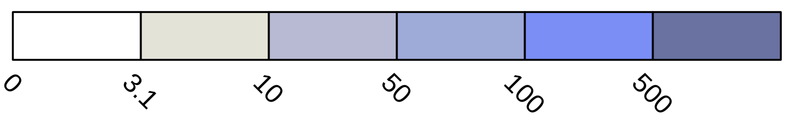
SIMULATED



Model Layer 3

LEGEND

Chromium Concentration (ug/L)



PG&E Remediation Extraction Well

PG&E Remediation Injection Well

Northwest Freshwater Injection Well

Scale in feet

0 2,000 4,000

Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric
Contoured data reference, Figure 5-2 (CH2MHill 2014), included in Appendix A for reference.
Simulated contour initalized with Fourth Quarter 2007 data and run with actual operating conditions for 7 years

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

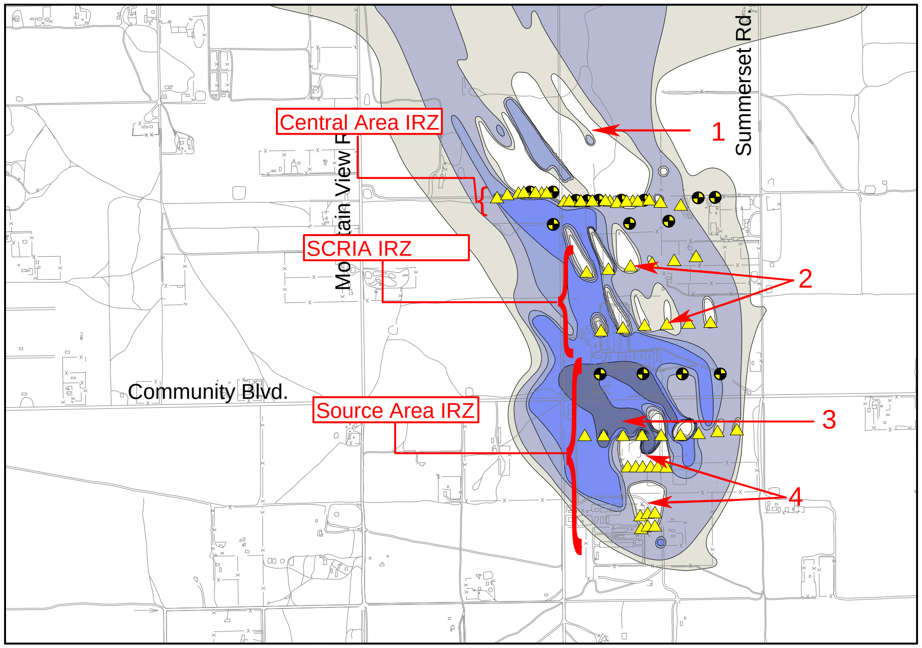
COMPARISON OF MODEL TO ACTUAL RESULTS
NORTH OF HIGHWAY 58,
DEEP ZONE OF THE UPPER AQUIFER

ARCADIS

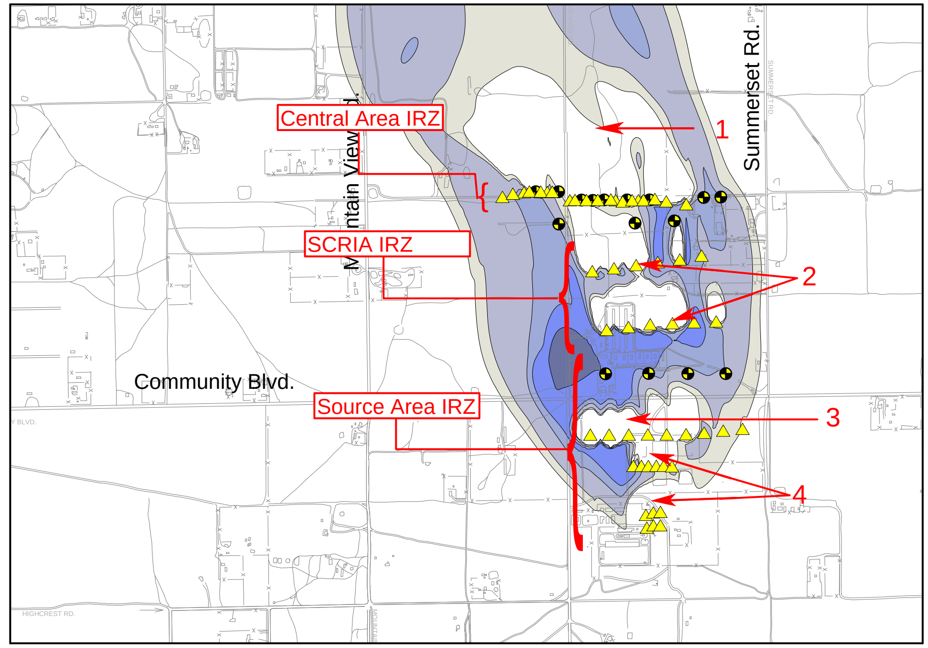
FIGURE
3-3

CONTOURED FROM MONITORING DATA

SIMULATED



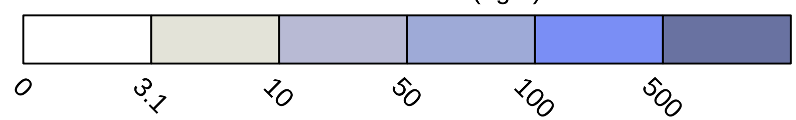
Shallow Zone of the Upper Aquifer, First Quarter 2014



Model Layer 1

LEGEND

Chromium Concentration (ug/L)



PG&E Remediation Extraction Well

PG&E Remediation Injection Well

Northwest Freshwater Injection Well

Scale in feet

0 2,000 4,000

Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric
Contoured data reference, Figure 4-6 (CH2MHill and ARCADIS 2014), included in Appendix A for reference.
Simulated contour initalized with Fourth Quarter 2007 data and run with actual operating conditions for 7 years

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

COMPARISON OF MODEL TO ACTUAL RESULTS
SOUTH OF HIGHWAY 58,
SHALLOW ZONE OF THE UPPER AQUIFER

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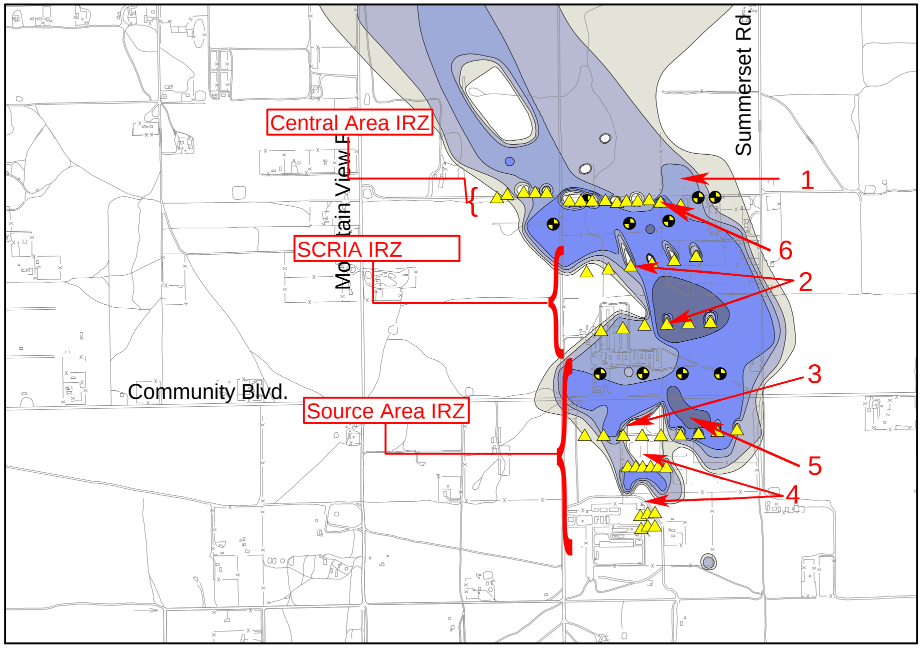
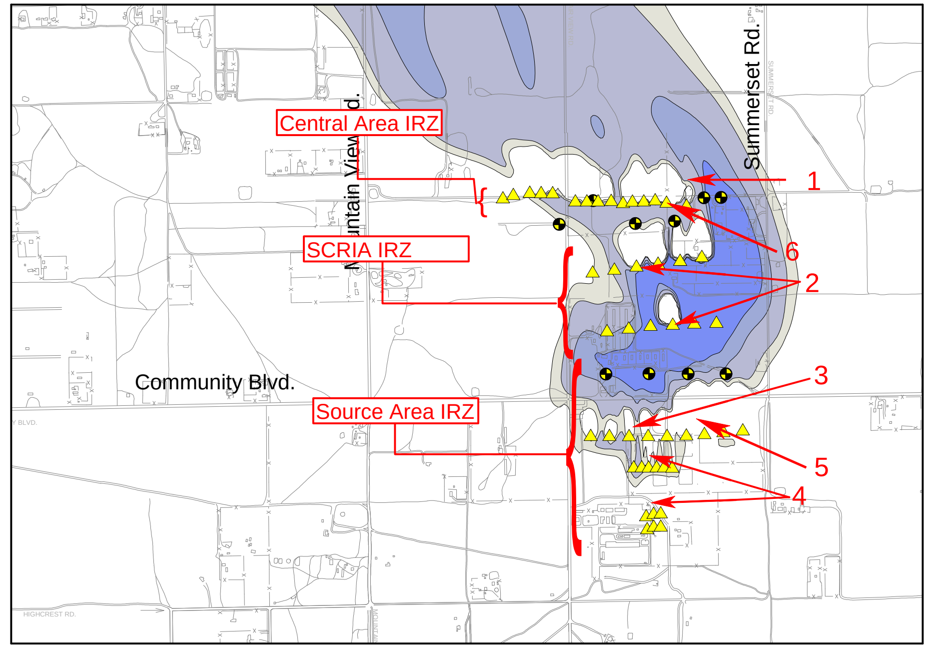
FIGURE
3-4

CONTOURED FROM MONITORING DATA



Deep Zone of the Upper Aquifer, First Quarter 2014

SIMULATED



Model Layer 3

LEGEND

Chromium Concentration (ug/L)

0 | 3.1 | 10 | 50 | 100 | 500

PG&E Remediation Extraction Well

PG&E Remediation Injection Well

Northwest Freshwater Injection Well

Scale in feet

0 2,000 4,000

Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric
Contoured data reference, Figure 4-7 (CH2MHill and ARCADIS 2014), included in Appendix A for reference.
Simulated contour initalized with Fourth Quarter 2007 data and run with actual operating conditions for 7 years

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

COMPARISON OF MODEL TO ACTUAL RESULTS
SOUTH OF HIGHWAY 58,
DEEP ZONE OF THE UPPER AQUIFER

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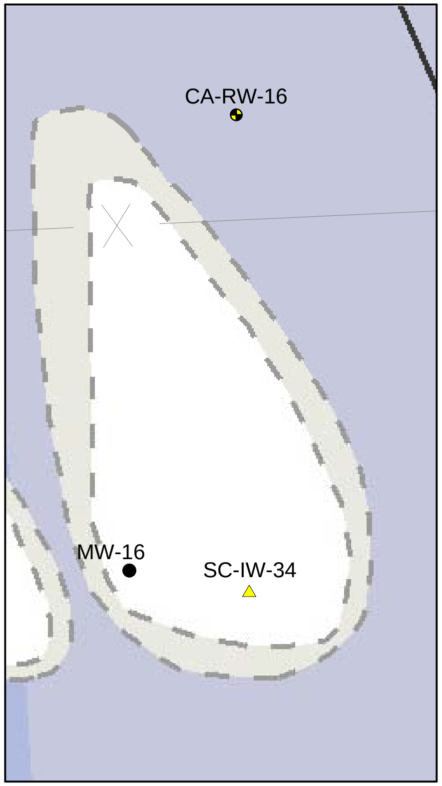
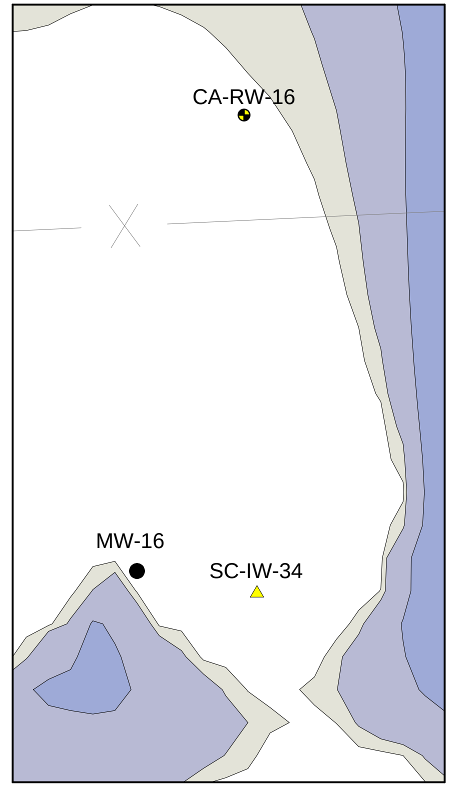
FIGURE
3-5

CONTOURED FROM MONITORING DATA



Shallow Zone of the Upper Aquifer, First Quarter 2014

SIMULATED



Model Layer 1

N

LEGEND

Chromium Concentration (ug/L)

0 | 3.1 | 10 | 50 | 100 | 500

PG&E Remediation Extraction Well

PG&E Remediation Injection Well

Monitoring Well

Scale in feet

0 200 400

Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric
Contoured data reference, Figure 4-6 (CH2MHill and ARCADIS 2014), included in Appendix A for reference.
Simulated contour initalized with Fourth Quarter 2007 data and run with actual operating conditions for 7 years

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

COMPARISON OF MODEL TO ACTUAL RESULTS,
SC-IW-34
SHALLOW ZONE OF THE UPPER AQUIFER

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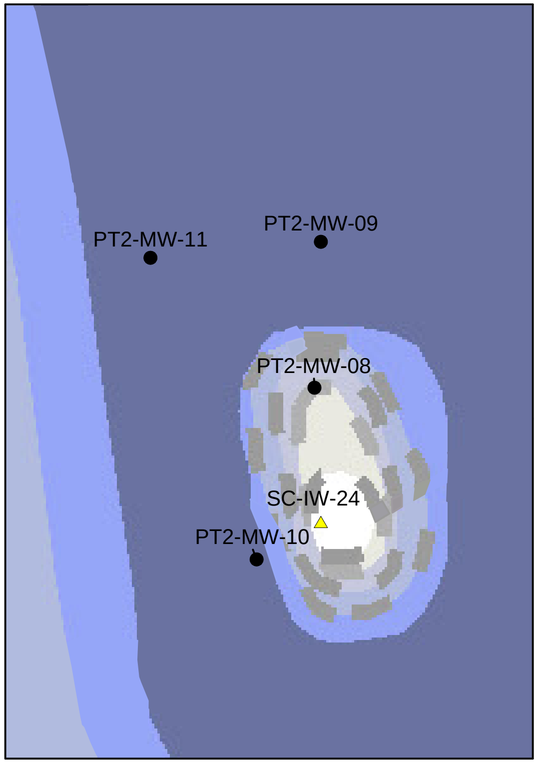
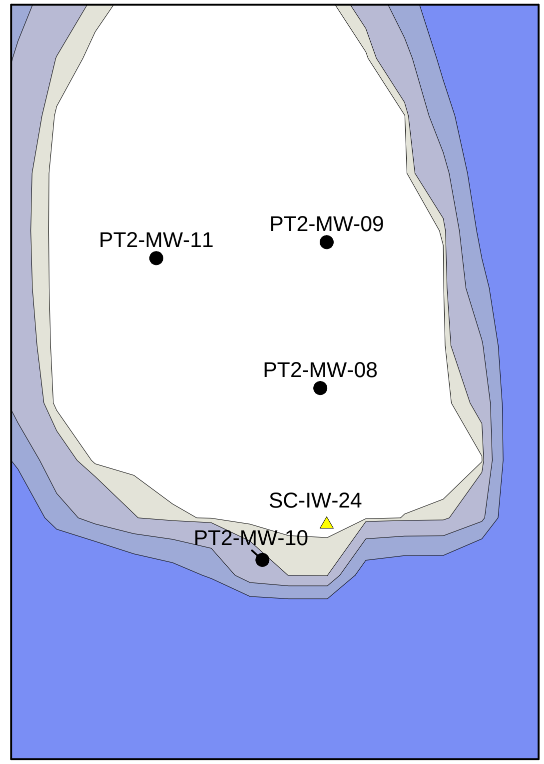
FIGURE
3-6

CONTOURED FROM MONITORING DATA



Deep Zone of the Upper Aquifer, First Quarter 2014

SIMULATED



Model Layer 3

N

LEGEND

Chromium Concentration (ug/L)

0 3.1 10 50 100 500

PG&E Remediation Extraction Well

PG&E Remediation Injection Well

Monitoring Well

Scale in feet

0 100 200

Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric
Contoured data reference, Figure 4-7 (CH2MHill and ARCADIS 2014), included in Appendix A for reference.
Simulated contour initalized with Fourth Quarter 2007 data and run with actual operating conditions for 7 years

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

COMPARISON OF MODEL TO ACTUAL RESULTS,
SC-IW-24
DEEP ZONE OF THE UPPER AQUIFER

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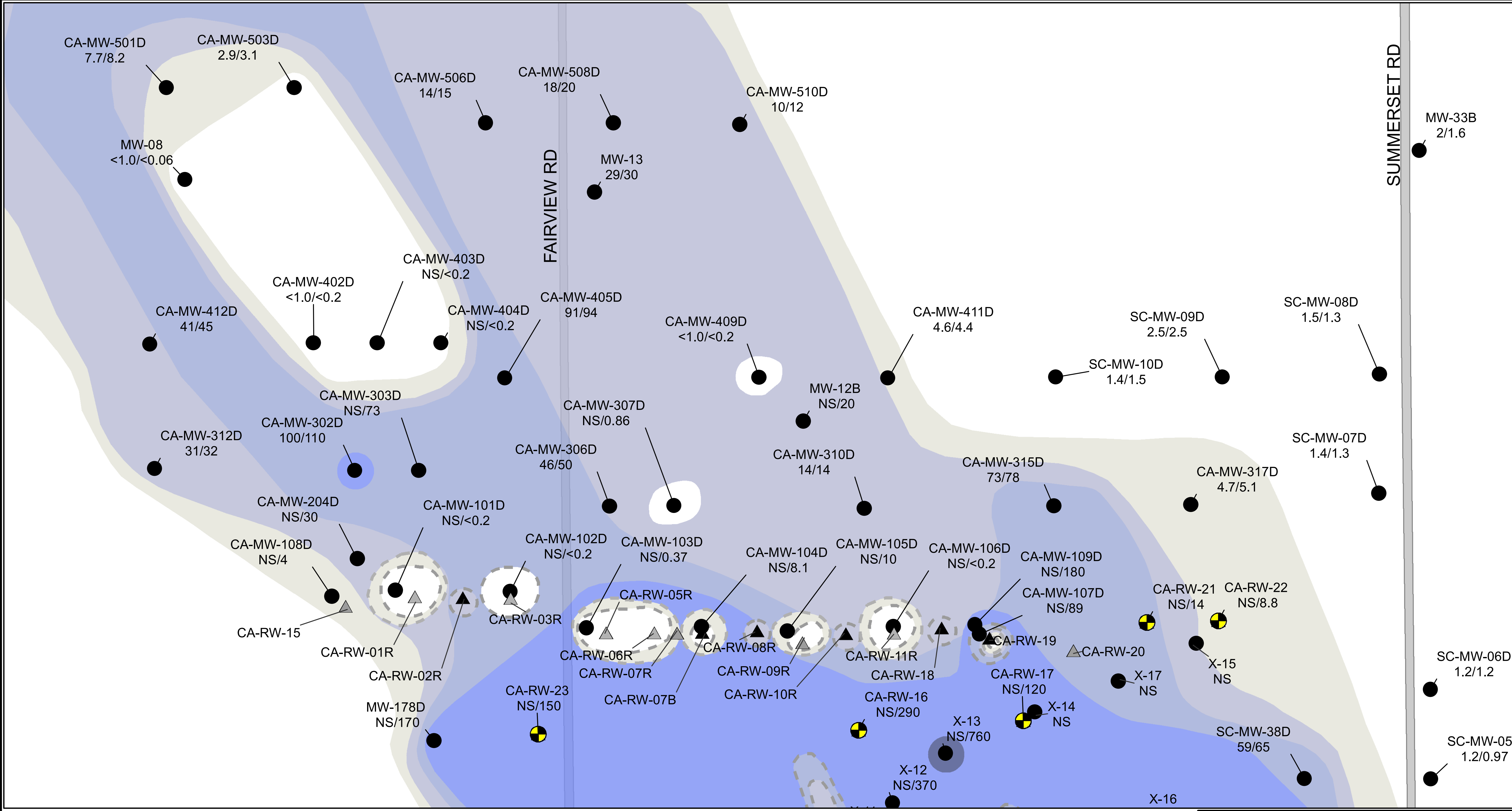
FIGURE
3-7



Legend

- Monitoring Wells
- PG&E Remediation Extraction Wells
- Active IRZ Injection Well
- Inactive IRZ Injection Well

- Chromium Concentrations Less Than 3.1 µg/L
- Chromium Concentrations Between 3.1 and 10 µg/L
- Chromium Concentrations Between 10 and 50 µg/L
- Chromium Concentrations Between 50 and 100 µg/L
- Chromium Concentrations Between 100 and 500 µg/L
- Chromium Concentrations Greater Than 500 µg/L

CA-MW-101D NS/<0.2 — Total Dissolved Chromium/Hexavalent Chromium Concentrations January and February 2014

Notes:
NS = not sampled
µg/L = micrograms per liter

N

0 300 600
SCALE IN FEET

PACIFIC GAS AND ELECTRIC COMPANY
HINKLEY, CALIFORNIA

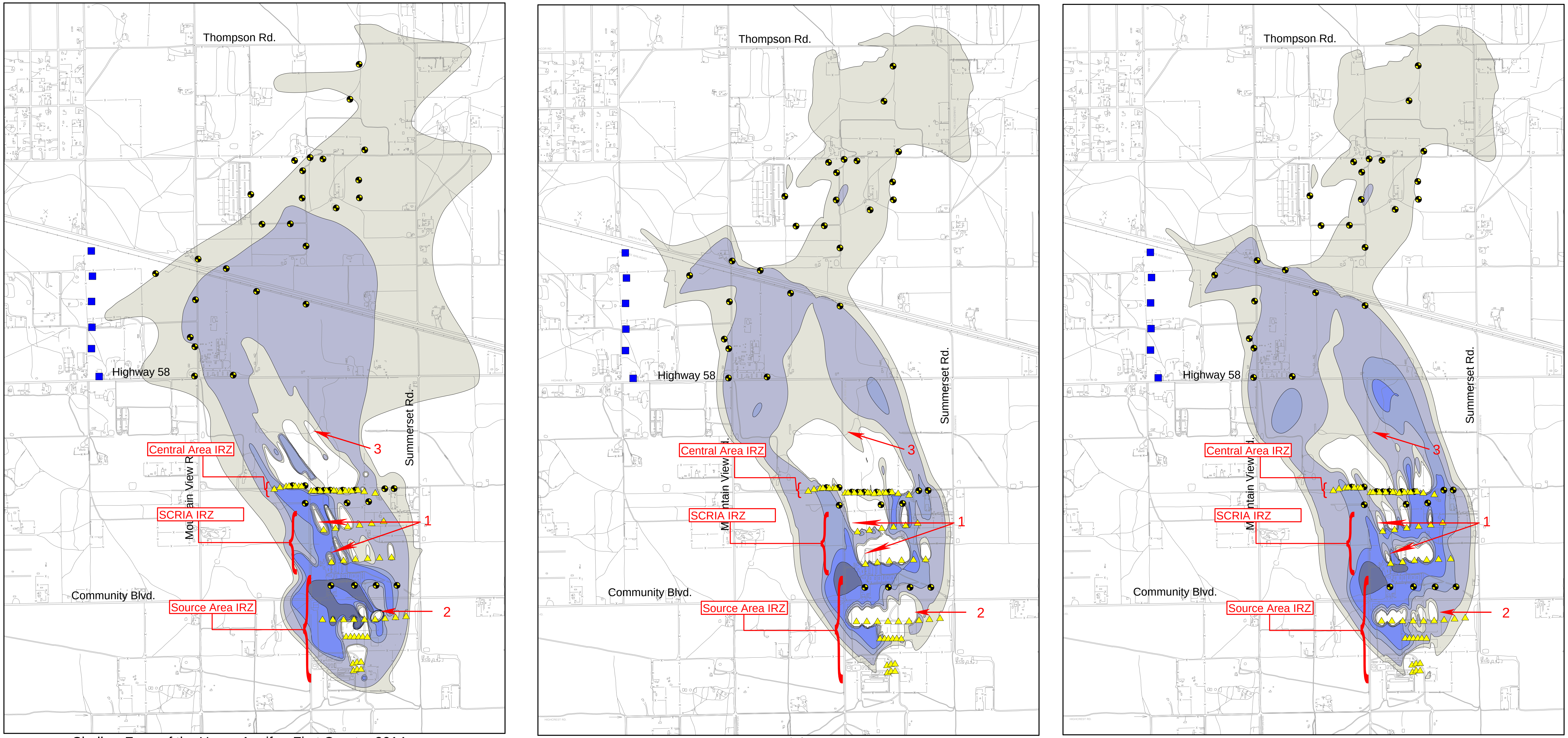
CHROMIUM CONCENTRATIONS, CENTRAL AREA IRZ DEEP ZONE OF THE UPPER AQUIFER, FIRST QUARTER 2014

ARCADIS

FIGURE
3-8

CITY:(DEN-TECH) DIV/GROUP:(ENV/GIS) DB: BGRIFFITH LD: PIC: PM: TM:
PROJECT: PATH: G:\GIS\RC000699.0001_PGE_Hinkley\GIS\ArcMap_MXD\SiteWide\2014\July 1 Report\Fig 3-8 ChromiumCon_CAIRZ_Deep.mxd

CONTOURED FROM MONITORING DATA | 0.1 mg/L TOTAL ORGANIC CARBON THRESHOLD | 1.0 mg/L TOTAL ORGANIC CARBON THRESHOLD



Shallow Zone of the Upper Aquifer, First Quarter 2014 | Model Layer 1 | Model Layer 1

LEGEND

Chromium Concentration (ug/L)

0 | 3.1 | 10 | 50 | 100 | 500

PG&E Remediation Extraction Well

PG&E Remediation Injection Well

Northwest Freshwater Injection Well

Scale in feet

0 | 2,000 | 4,000

Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric
Contoured data reference, Figure 4-6 (CH2MHill and ARCADIS 2014), included in Appendix A for reference.
Simulated contour initalized with Fourth Quarter 2007 data and run with actual operating conditions for 7 years

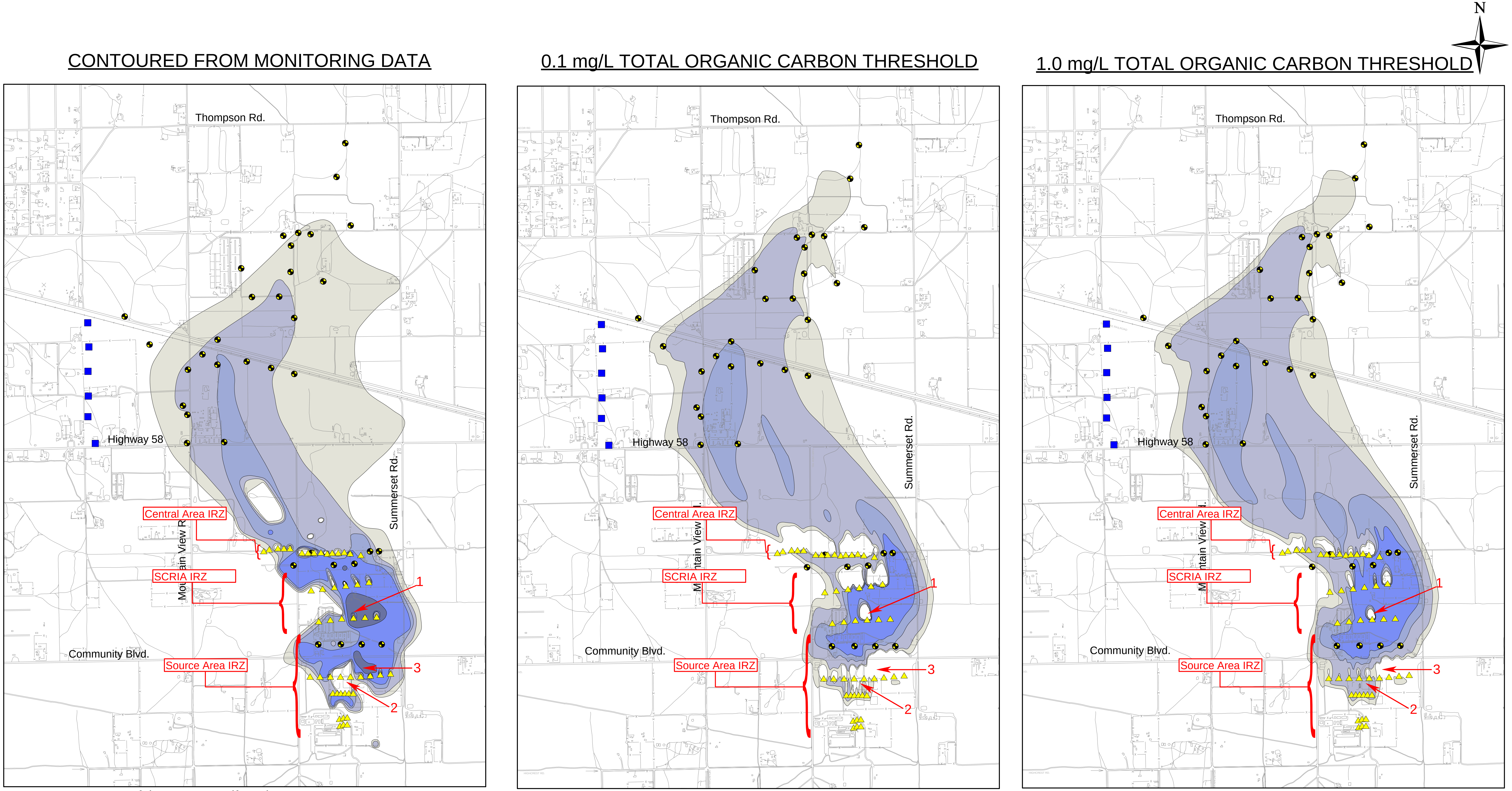
PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

SHALLOW ZONE (MODEL LAYER 1)
OF THE UPPER AQUIFER

ARCADIS

FIGURE
3-9

CONTOURED FROM MONITORING DATA | 0.1 mg/L TOTAL ORGANIC CARBON THRESHOLD | 1.0 mg/L TOTAL ORGANIC CARBON THRESHOLD



Deep Zone of the Upper Aquifer, First Quarter 2014 | Model Layer 3 | Model Layer 3

LEGEND

Chromium Concentration (ug/L)

0, 3.1, 10, 50, 100, 500

PG&E Remediation Extraction Well

PG&E Remediation Injection Well

Northwest Freshwater Injection Well

Scale in feet

0 2,000 4,000

Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric
Contoured data reference, Figure 4-7 (CH2MHill and ARCADIS 2014), included in Appendix A for reference.
Simulated contour initalized with Fourth Quarter 2007 data and run with actual operating conditions for 7 years

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

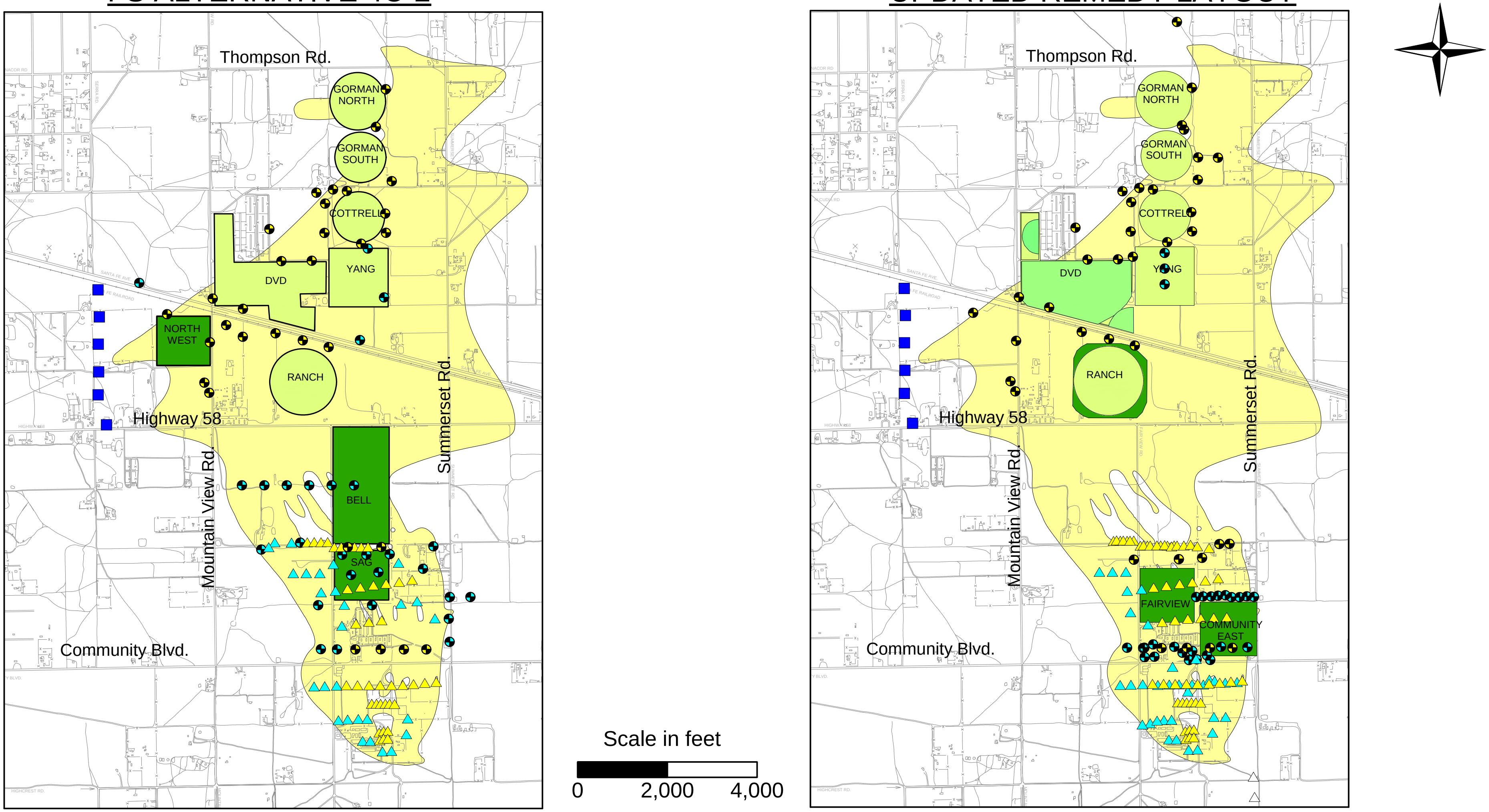
DEEP ZONE (MODEL LAYER 3)
OF THE UPPER AQUIFER

ARCADIS

FIGURE
3-10

FS ALTERNATIVE 4C-2

UPDATED REMEDY LAYOUT



LEGEND

- △ PG&E Compressor Station and non-PG&E Extraction Well
- PG&E Remediation Injection Well
- Northwest Freshwater Injection Well
- Approximate outline of Cr(VI) and Cr(T) exceeding 3.1 and 3.2 micrograms per liter, respectively, in the Shallow Zone of the Upper Aquifer, First Quarter 2014
- Proposed DVD Conversion Areas
- PG&E Remediation Extraction Well
- Potential Extraction Well
- Potential Injection Well
- Existing Agricultural Treatment Units
- Areas for Potential Future or Expanded Agricultural Treatment Units

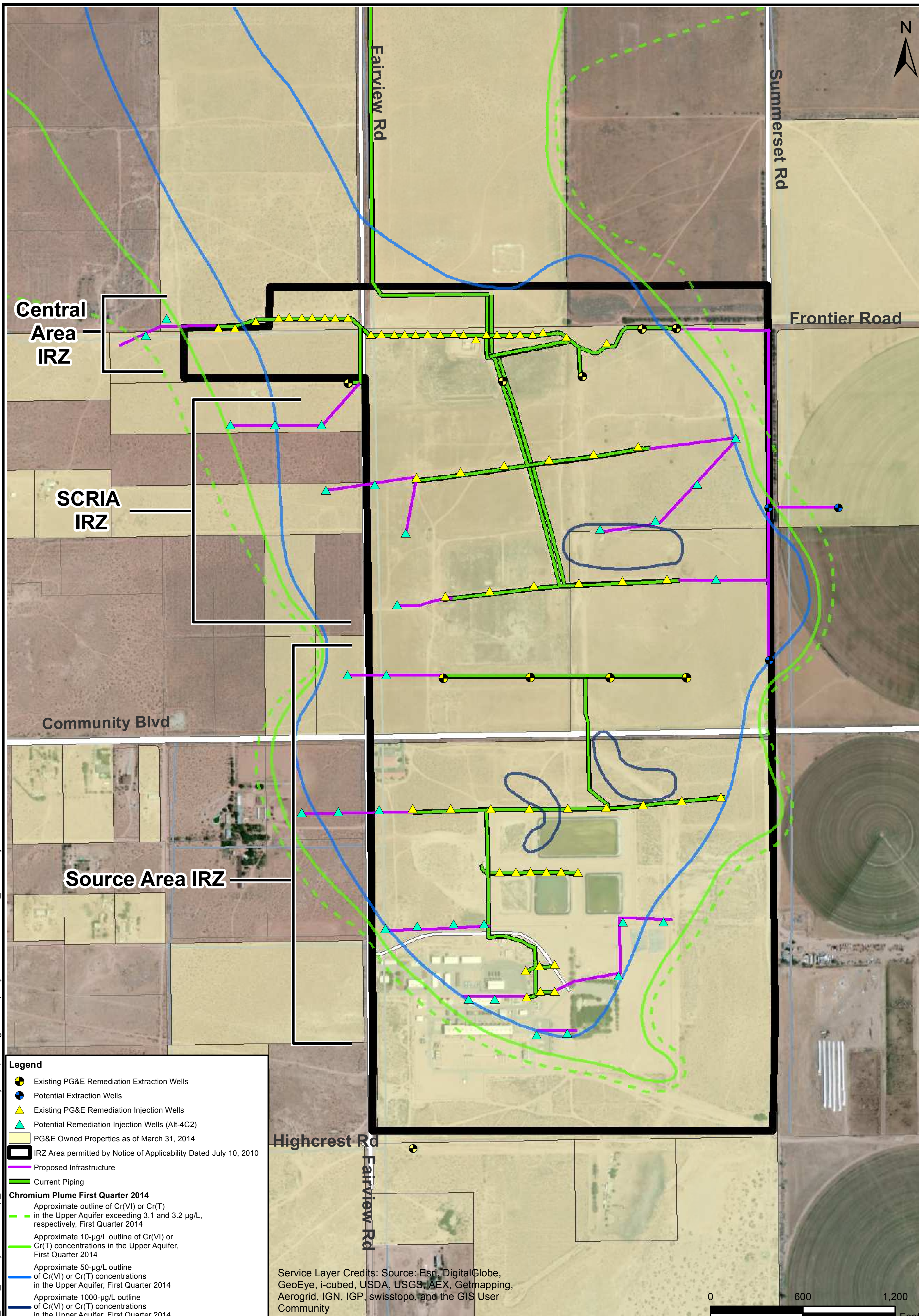
Notes:
PG&E - Pacific Gas and Electric

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

AGRICULTURAL TREATMENT UNIT
LAYOUTS FOR MODELING

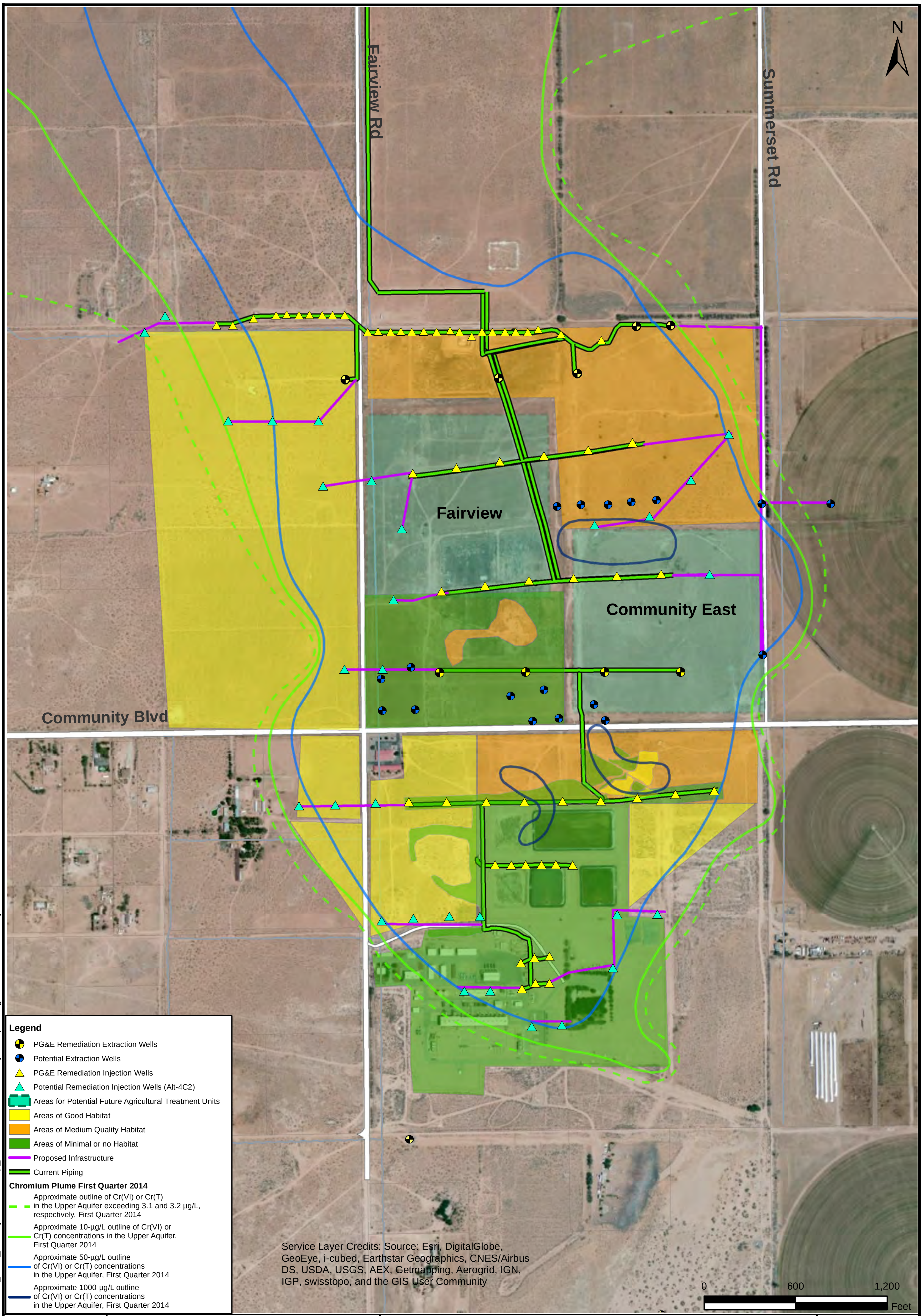
ARCADIS

FIGURE
4-1



Program Manager	ARCADIS	Property Access and Permit Area for Feasibility Study IRZ Layout	Project Number
Lisa Cope			RC000699.0099
Project Manager		Pacific Gas and Electric Company	Date
Jenifer Beatty		Hinkley, California	6/30/2014
Task Manager	100 Montgomery Street, Suite 300 San Francisco, California 94104 Tel: 415 374 2744 Fax: 415 374 2745 www.arcadis-us.com		Figure
Margaret Gentile			4-2

Drafter: BCG Path: I:\RC000699.0001_PGE_Hinkley\GIS\ArcMap_MXD\SiteWide\2014\July 1 Report\Fig 4-2 PropertyAccessPermitArea_FeasStudyIRZ.mxd Date: 6/30/2014 Time: 1:07:47 PM



Drafter: BCG Path: G:\GIS\RC000699.0001_PGE_Hinkley\GIS\ArcMap_MXD\SiteWide\2014\July 1 Report\Fig 4-3 PrelimBioSurveyIRZ.mxd Date: 6/20/2014 Time: 12:49:13 PM

Program Manager
Lisa Cope

Project Manager
Jenifer Beatty

Task Manager
Margaret Gentile

ARCADIS

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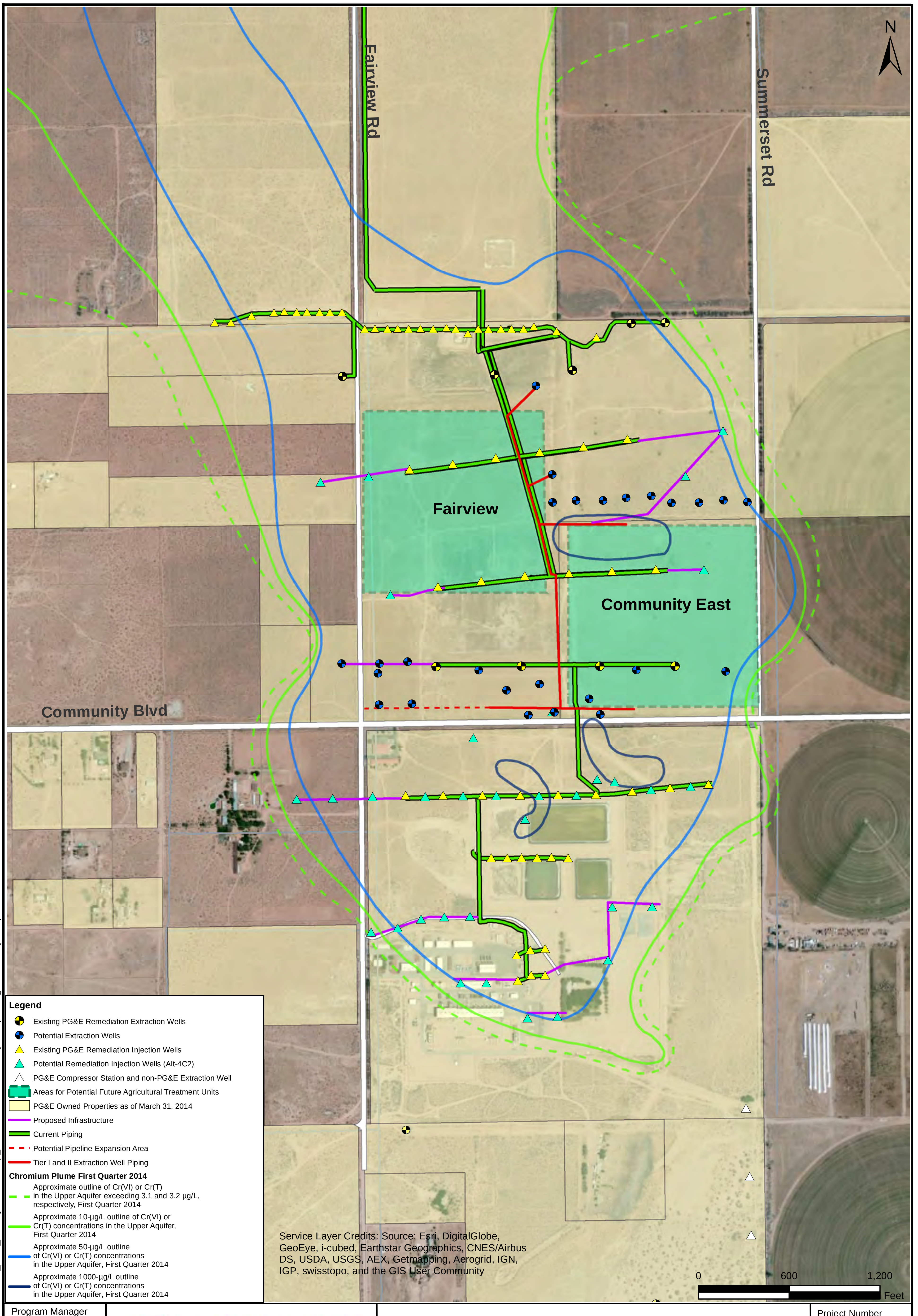
Preliminary Biological Survey Results in IRZ Area

Pacific Gas and Electric Company
Hinkley, California

Project Number
RC000699.0099

Date
6/20/2014

Figure
4-3



Program Manager Lisa Cope Project Manager Jenifer Beatty Task Manager Margaret Gentile	ARCADIS 100 Montgomery Street, Suite 300 San Francisco, California 94104 Tel: 415 374 2744 Fax: 415 374 2745 www.arcadis-us.com	**IRZ Layout for Updated Modeling** Pacific Gas and Electric Company Hinkley, California	Project Number RC000699.0099 Date 6/18/2014 Figure **4-4**

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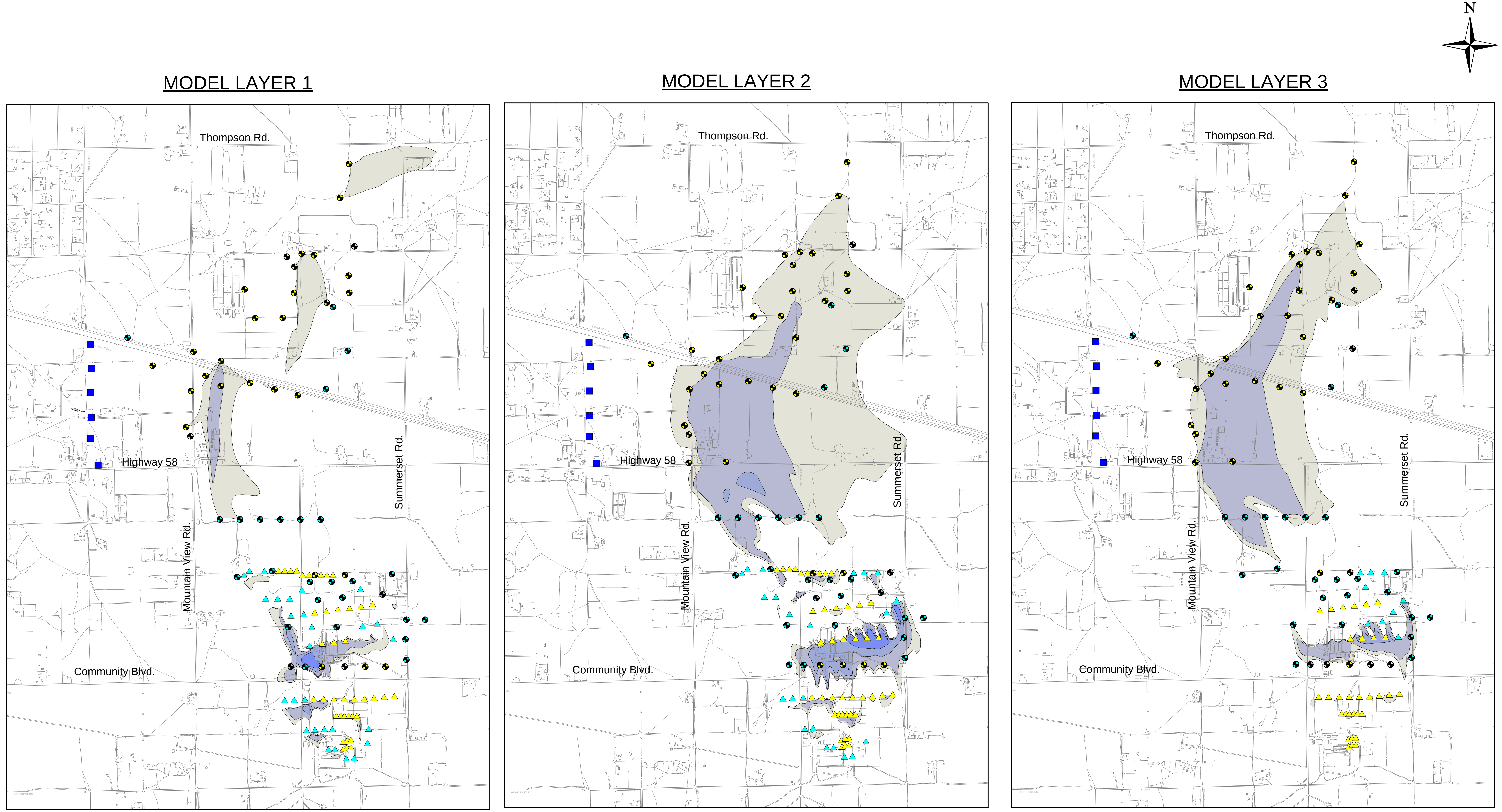


LEGEND

Chromium Concentration (ug/L)

0 | 3.1 | 10 | 50 | 100 | 500

- PG&E Compressor Station and non-PG&E Extraction Well
- PG&E Remediation Injection Well
- Northwest Freshwater Injection Well
- PG&E Remediation Extraction Well
- Potential Extraction Well
- Potential Injection Well

Scale in feet

0 2,000 4,000

Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric

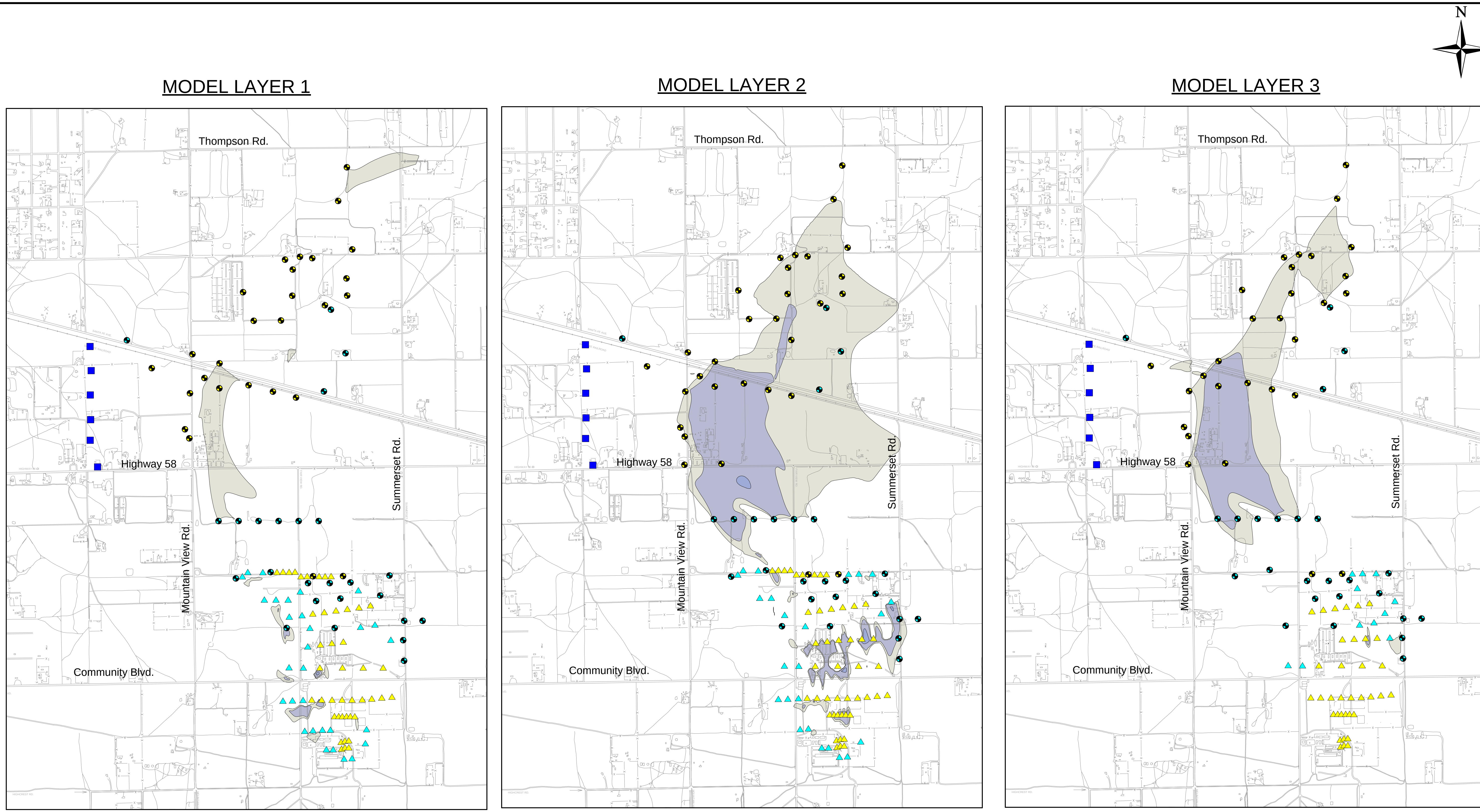
PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

MODELING RESULTS:
SCENARIO 1- FS ALTERNATIVE 4C-2,
FIRST QUARTER 2014 BASELINE
AFTER 4 YEARS OF SIMULATION

ARCADIS

FIGURE
4-5

MODEL LAYER 1 MODEL LAYER 2 MODEL LAYER 3



LEGEND

Chromium Concentration (ug/L)

0 3.1 10 50 100 500

- PG&E Compressor Station and non-PG&E Extraction Well
- PG&E Remediation Injection Well
- Northwest Freshwater Injection Well
- PG&E Remediation Extraction Well
- Potential Extraction Well
- Potential Injection Well

Scale in feet

0 2,000 4,000

Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

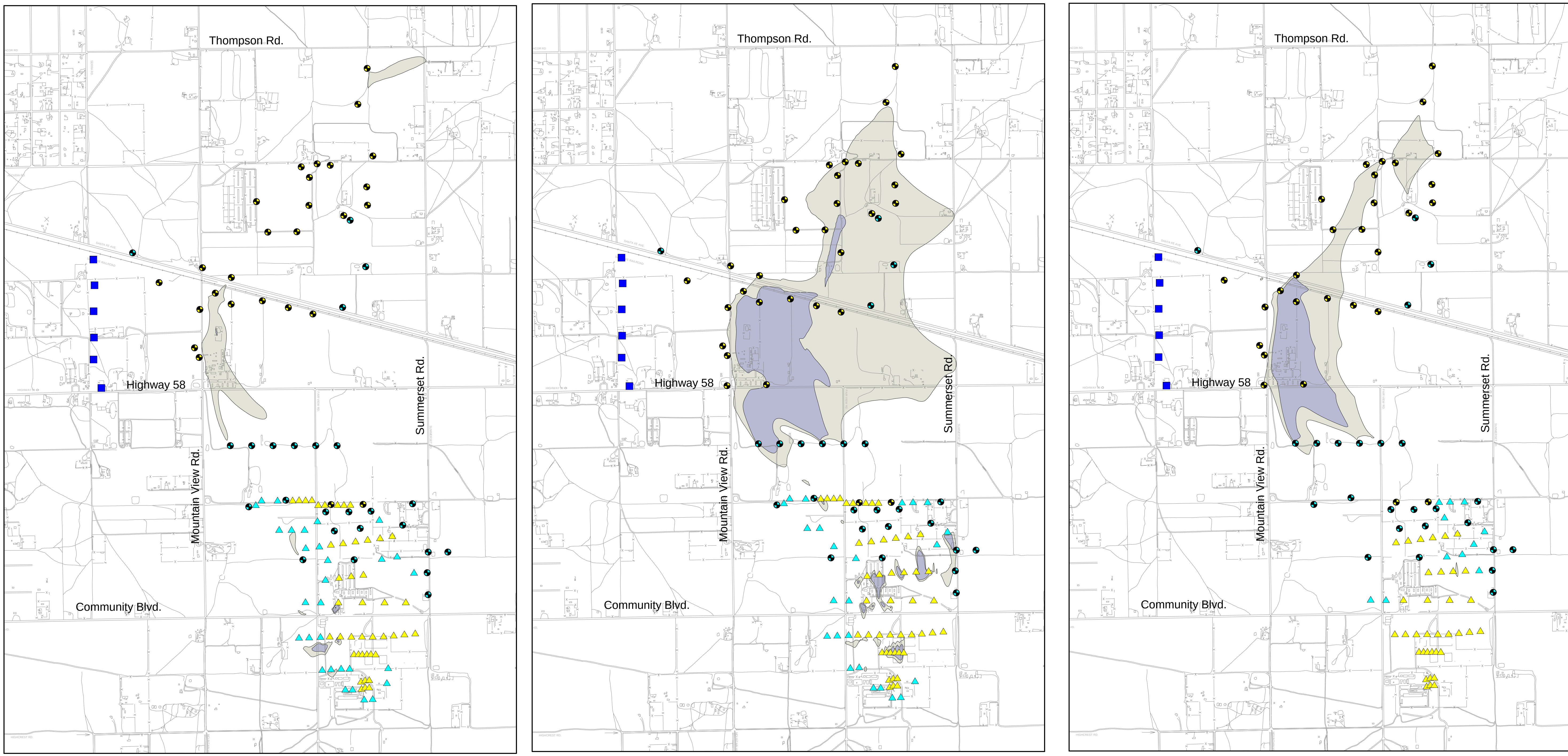
MODELING RESULTS:
SCENARIO 1- FS ALTERNATIVE 4C-2,
FIRST QUARTER 2014 BASELINE
AFTER 8 YEARS OF SIMULATION

ARCADIS

FIGURE
4-6

N

MODEL LAYER 1 | MODEL LAYER 2 | MODEL LAYER 3



LEGEND

Chromium Concentration (ug/L)

0 3.1 10 50 100 500

- PG&E Compressor Station and non-PG&E Extraction Well
- PG&E Remediation Injection Well
- Northwest Freshwater Injection Well
- PG&E Remediation Extraction Well
- Potential Extraction Well
- Potential Injection Well

Scale in feet

0 2,000 4,000

Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric

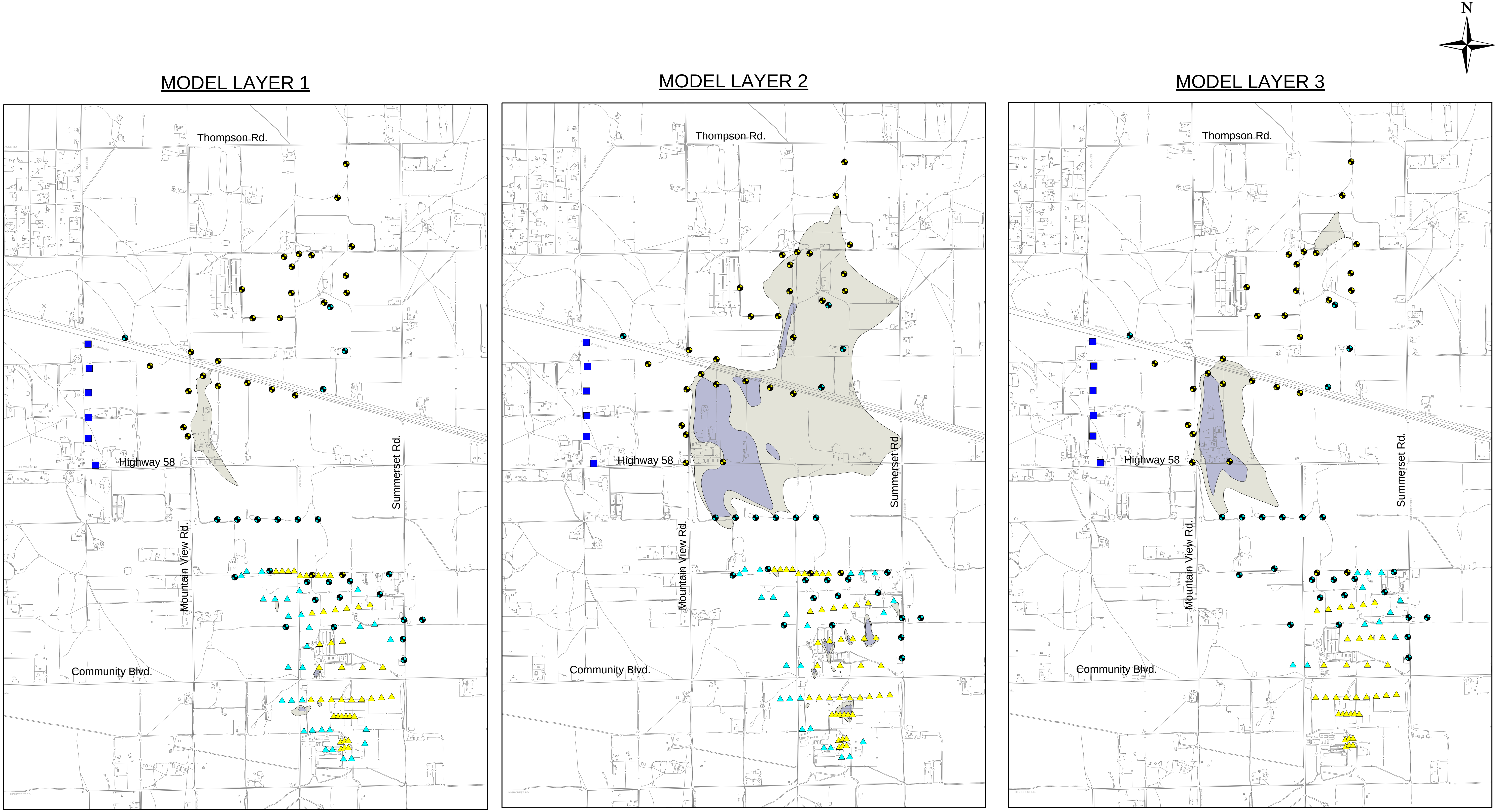
PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

MODELING RESULTS:
SCENARIO 1- FS ALTERNATIVE 4C-2,
FIRST QUARTER 2014 BASELINE
AFTER 12 YEARS OF SIMULATION

ARCADIS

FIGURE
4-7

MODEL LAYER 1   MODEL LAYER 2   MODEL LAYER 3



LEGEND

Chromium Concentration (ug/L)

0   3.1   10   50   100   500

- PG&E Compressor Station and non-PG&E Extraction Well
- PG&E Remediation Injection Well
- Northwest Freshwater Injection Well
- PG&E Remediation Extraction Well
- Potential Extraction Well
- Potential Injection Well

Scale in feet

0   2,000   4,000

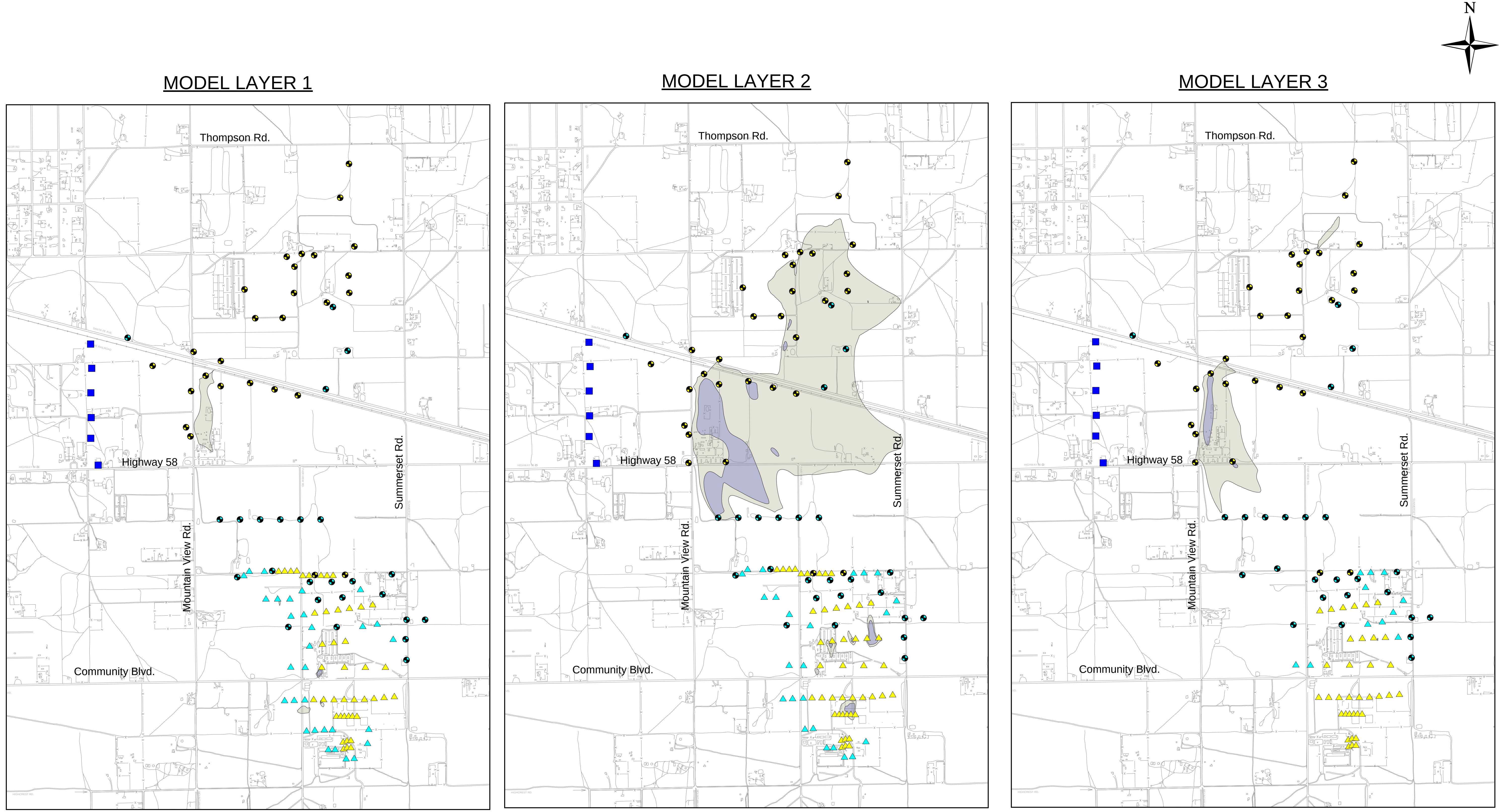
Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

MODELING RESULTS:
SCENARIO 1- FS ALTERNATIVE 4C-2,
FIRST QUARTER 2014 BASELINE
AFTER 16 YEARS OF SIMULATION

ARCADIS

FIGURE
4-8



LEGEND

Chromium Concentration (ug/L)

0, 3.1, 10, 50, 100, 500

- PG&E Compressor Station and non-PG&E Extraction Well
- PG&E Remediation Injection Well
- Northwest Freshwater Injection Well
- PG&E Remediation Extraction Well
- Potential Extraction Well
- Potential Injection Well

Scale in feet

0 2,000 4,000

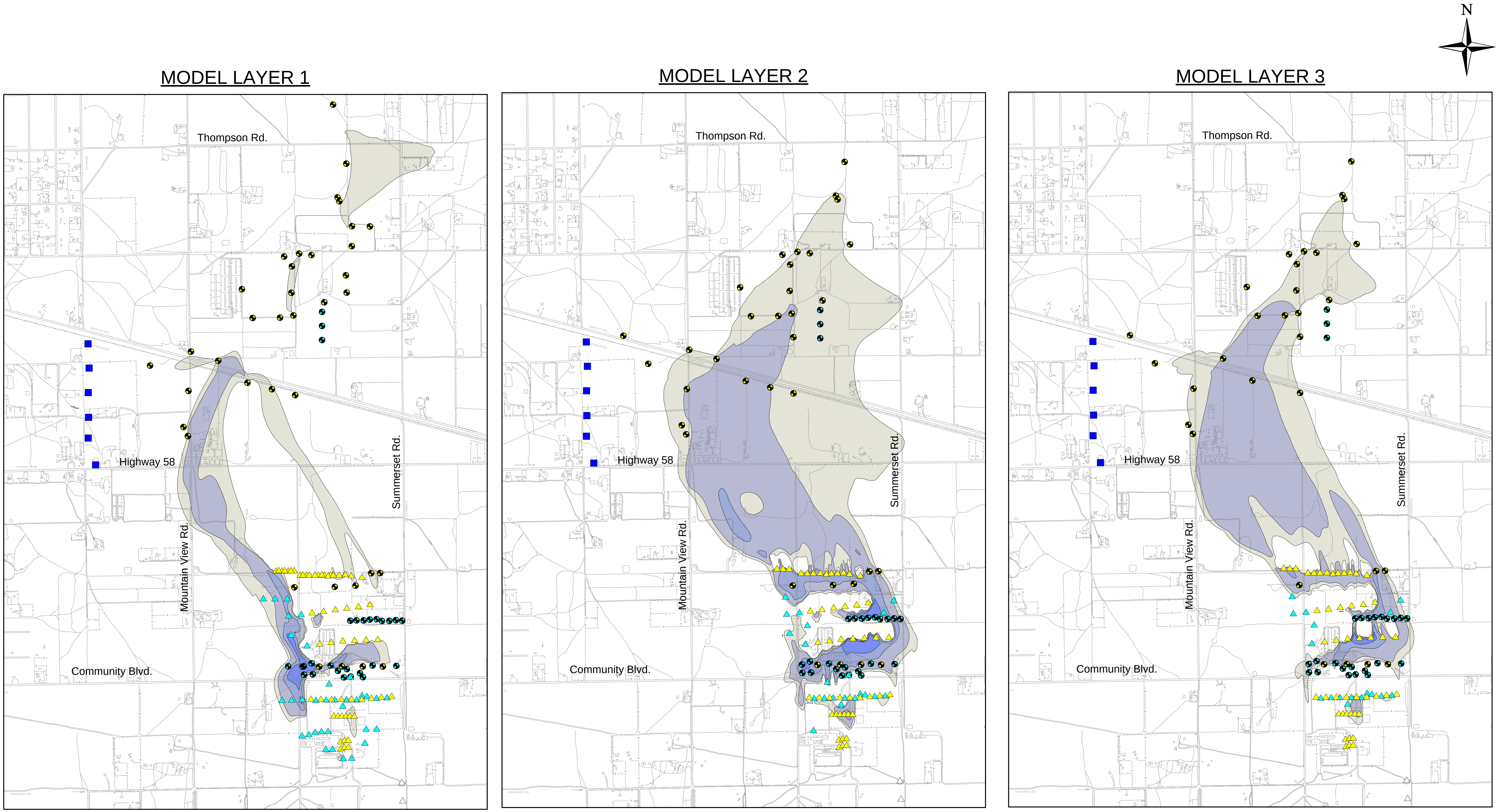
Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

MODELING RESULTS:
SCENARIO 1- FS ALTERNATIVE 4C-2,
FIRST QUARTER 2014 BASELINE
AFTER 20 YEARS OF SIMULATION

ARCADIS

FIGURE
4-9



LEGEND

Chromium Concentration (ug/L)

0 3.1 10 50 100 500

- PG&E Compressor Station and non-PG&E Extraction Well
- PG&E Remediation Injection Well
- Northwest Freshwater Injection Well
- PG&E Remediation Extraction Well
- Potential Extraction Well
- Potential Injection Well

Scale in feet

0 2,000 4,000

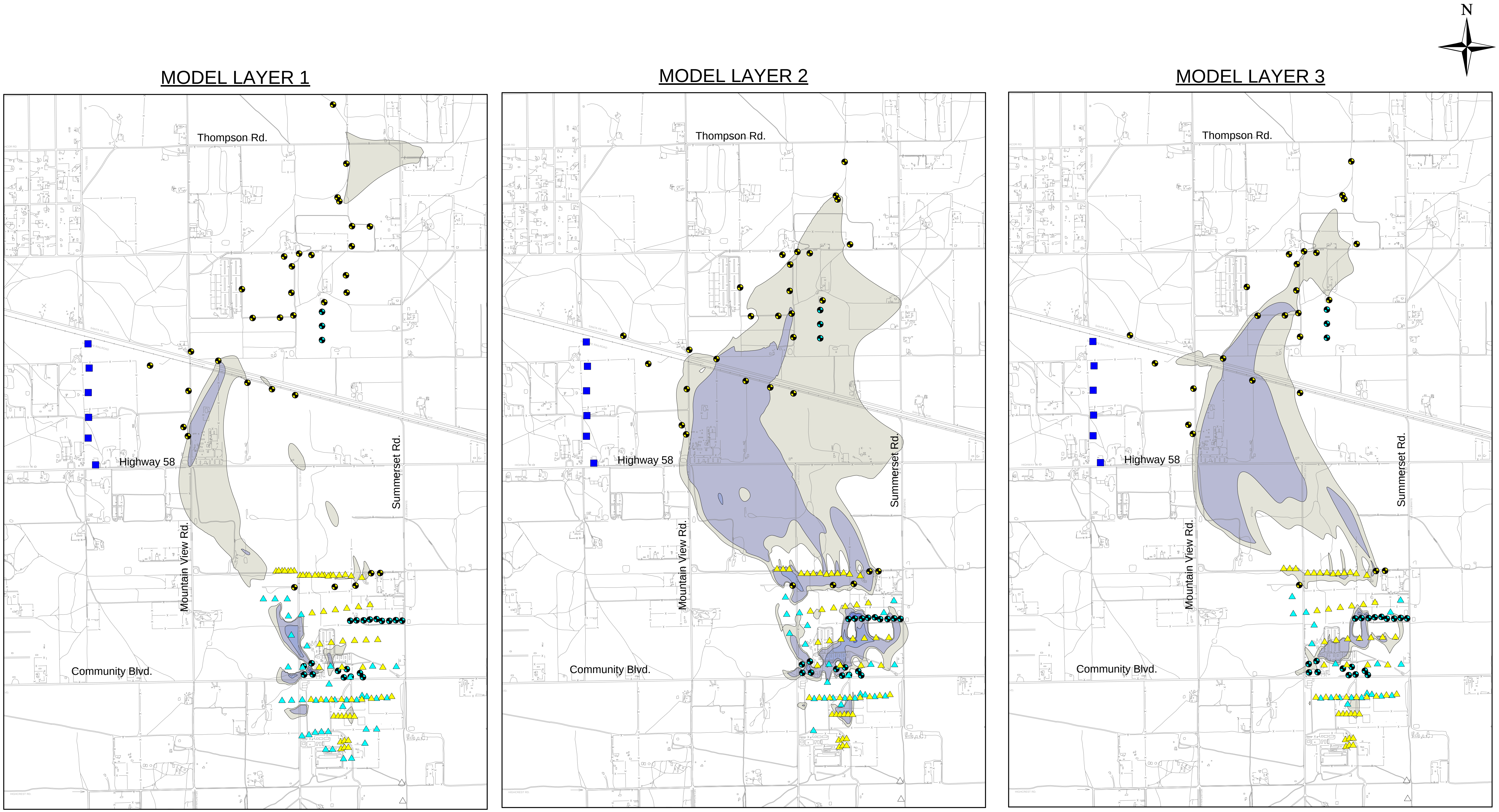
Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

MODELING RESULTS:
SCENARIO 2- UPDATED REMEDY LAYOUT
AFTER 4 YEARS OF SIMULATION

ARCADIS

FIGURE
4-10



LEGEND

Chromium Concentration (ug/L)

0 | 3.1 | 10 | 50 | 100 | 500

PG&E Compressor Station and non-PG&E Extraction Well

PG&E Remediation Injection Well

Northwest Freshwater Injection Well

PG&E Remediation Extraction Well

Potential Extraction Well

Potential Injection Well

Scale in feet

0 2,000 4,000

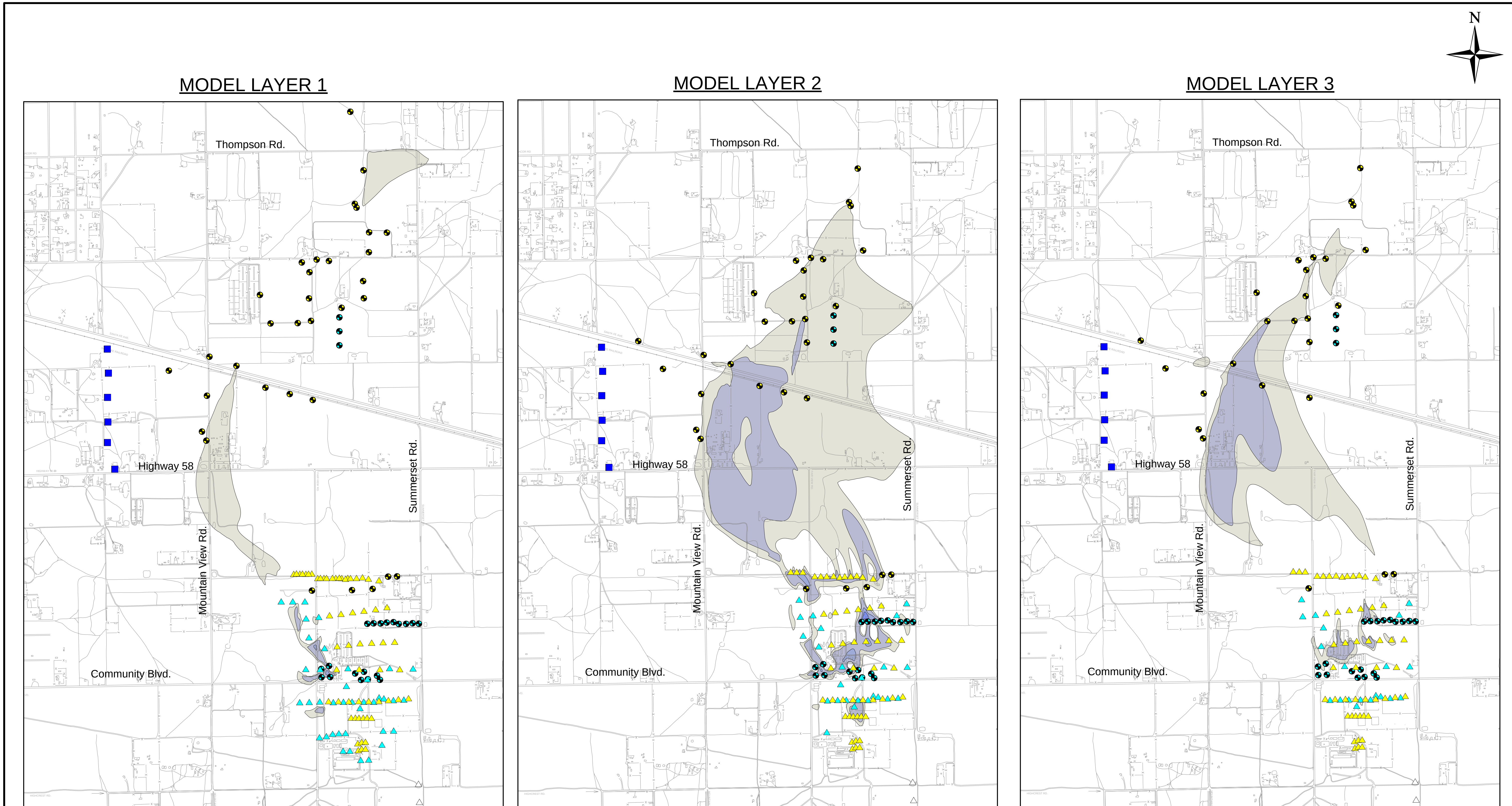
Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

MODELING RESULTS:
SCENARIO 2- UPDATED REMEDY LAYOUT
AFTER 8 YEARS OF SIMULATION

ARCADIS

FIGURE
4-11



LEGEND

Chromium Concentration (ug/L)

0 | 3.1 | 10 | 50 | 100 | 500

- PG&E Compressor Station and non-PG&E Extraction Well
- PG&E Remediation Extraction Well
- PG&E Remediation Injection Well
- Potential Extraction Well
- Northwest Freshwater Injection Well
- Potential Injection Well

Scale in feet

0 | 2,000 | 4,000

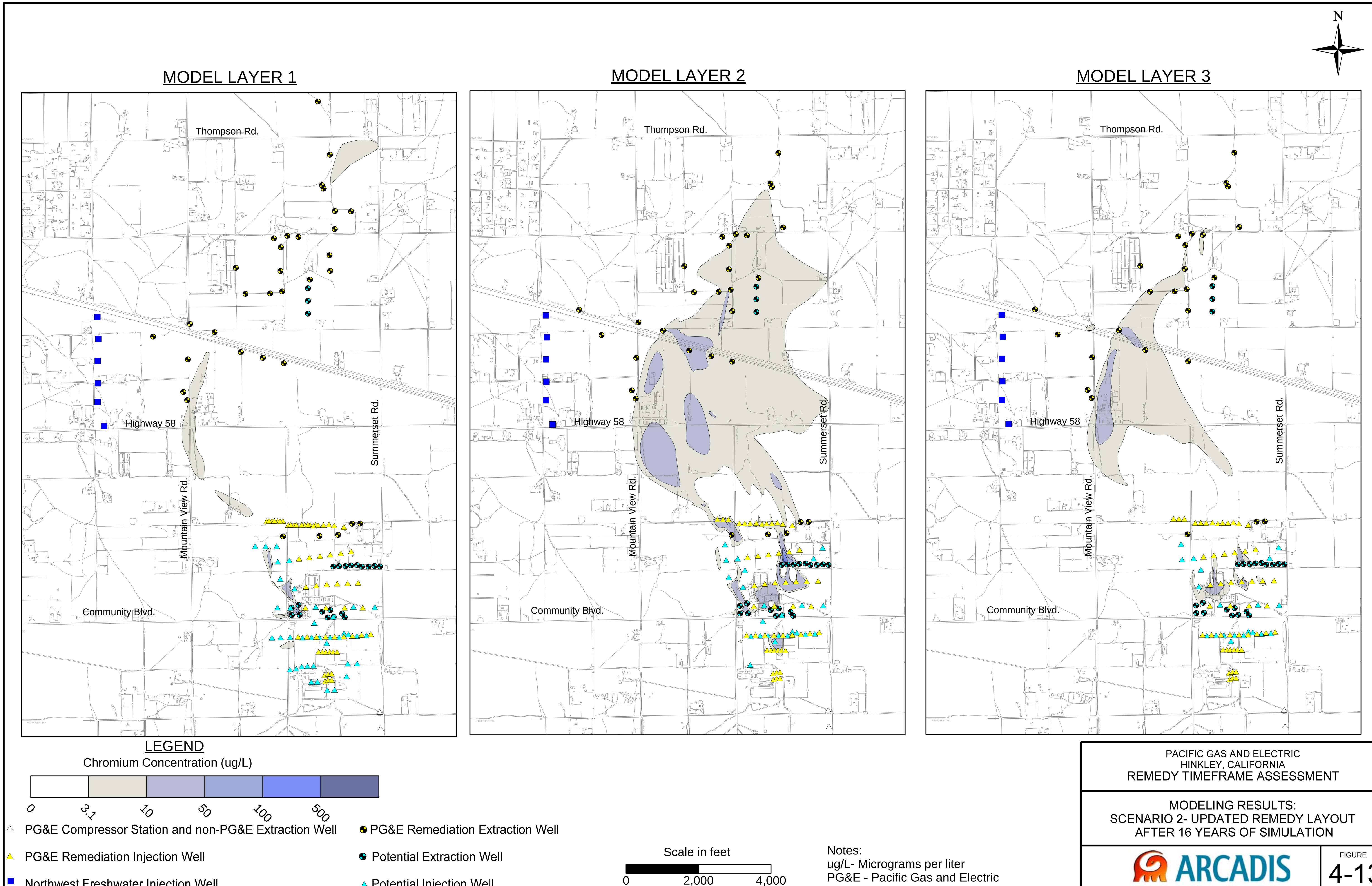
Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

MODELING RESULTS:
SCENARIO 2- UPDATED REMEDY LAYOUT
AFTER 12 YEARS OF SIMULATION

ARCADIS

FIGURE
4-12



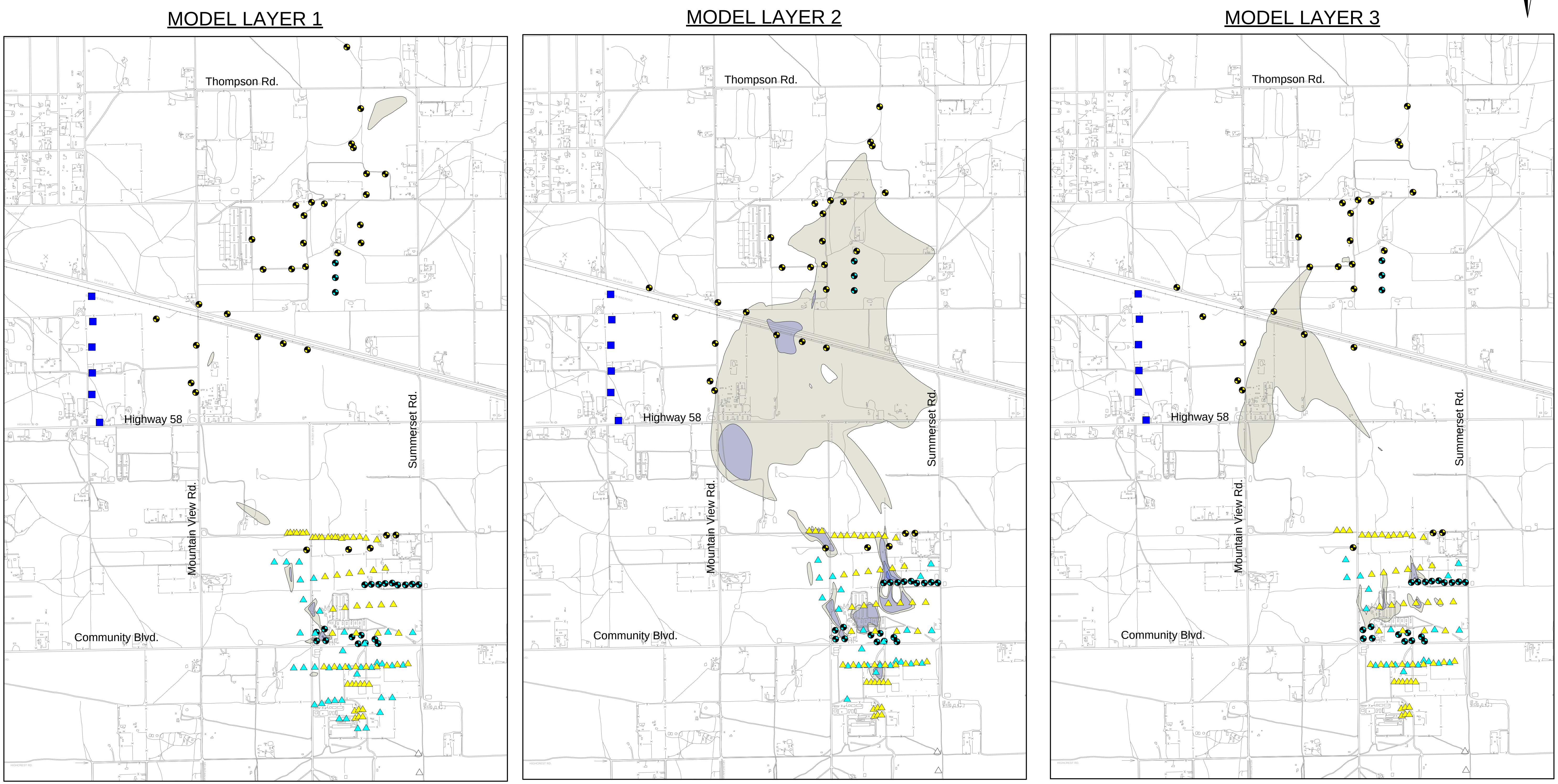
Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

MODELING RESULTS:
SCENARIO 2- UPDATED REMEDY LAYOUT
AFTER 16 YEARS OF SIMULATION

ARCADIS

FIGURE
4-13



LEGEND

Chromium Concentration (ug/L)

0 3.1 10 50 100 500

- PG&E Compressor Station and non-PG&E Extraction Well
- PG&E Remediation Injection Well
- Northwest Freshwater Injection Well
- PG&E Remediation Extraction Well
- Potential Extraction Well
- Potential Injection Well

Scale in feet

0 2,000 4,000

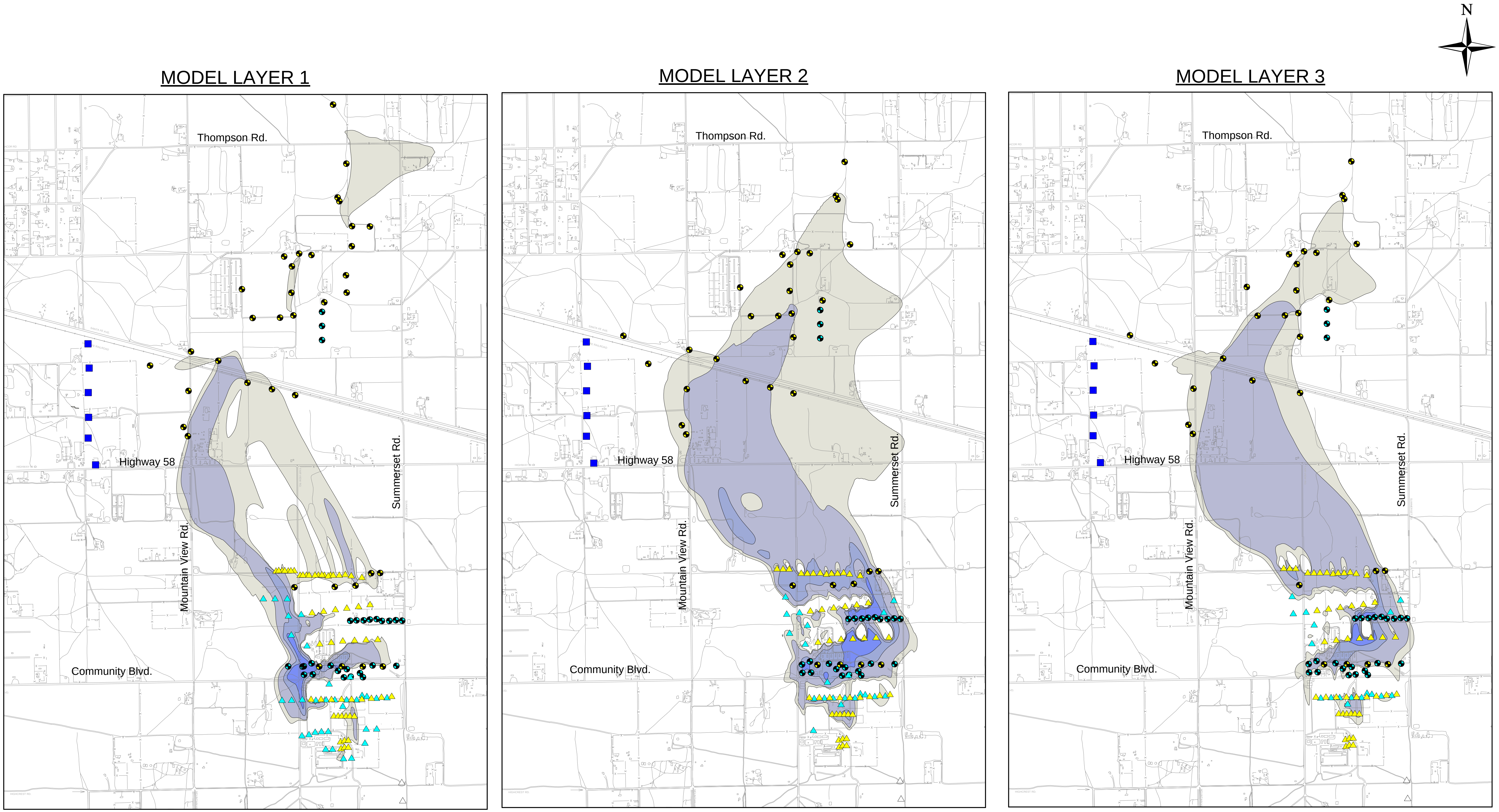
Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

MODELING RESULTS:
SCENARIO 2- UPDATED REMEDY LAYOUT
AFTER 20 YEARS OF SIMULATION

ARCADIS

FIGURE
4-14



LEGEND

Chromium Concentration (ug/L)

0 | 3.1 | 10 | 50 | 100 | 500

- PG&E Compressor Station and non-PG&E Extraction Well
- PG&E Remediation Injection Well
- Northwest Freshwater Injection Well
- PG&E Remediation Extraction Well
- Potential Extraction Well
- Potential Injection Well

Scale in feet

0 | 2,000 | 4,000

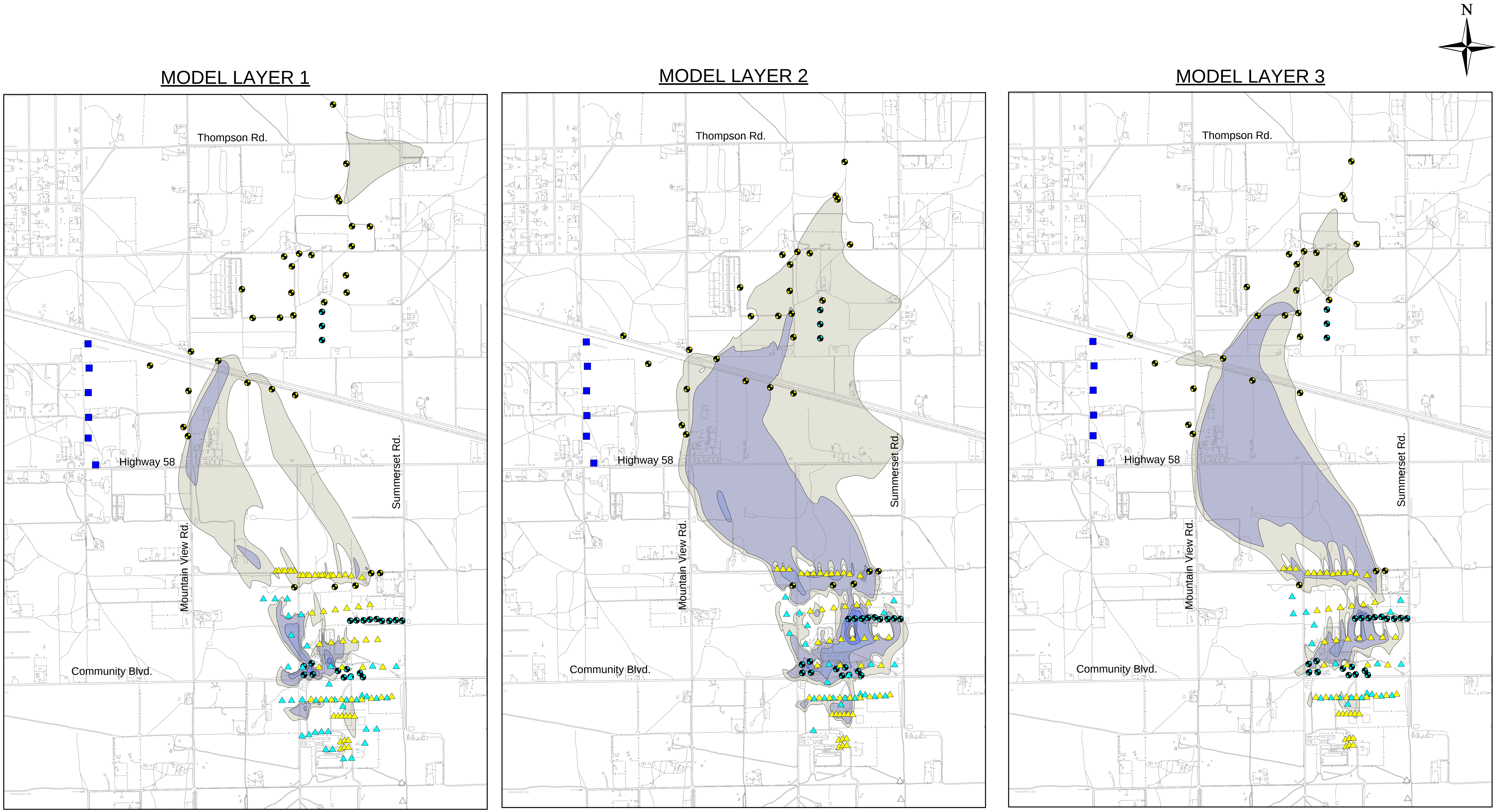
Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

MODELING RESULTS:
SCENARIO 3- UPDATED REMEDY LAYOUT,
INCREASED TOC THRESHOLD
AFTER 4 YEARS OF SIMULATION

ARCADIS

FIGURE
4-15



LEGEND

Chromium Concentration (ug/L)

0 | 3.1 | 10 | 50 | 100 | 500

- △ PG&E Compressor Station and non-PG&E Extraction Well
- PG&E Remediation Injection Well
- Northwest Freshwater Injection Well
- PG&E Remediation Extraction Well
- Potential Extraction Well
- Potential Injection Well

Scale in feet

0 2,000 4,000

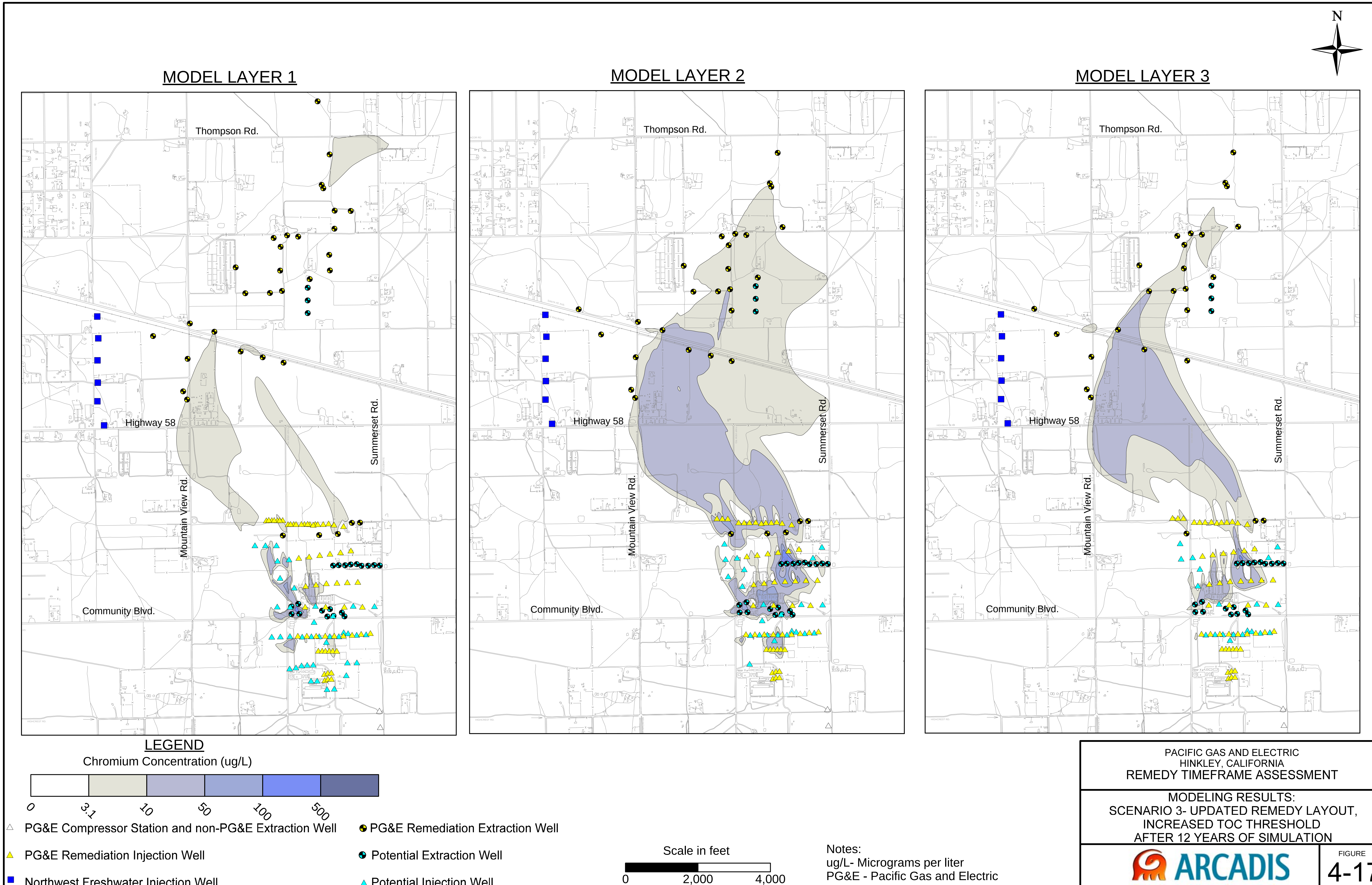
Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric

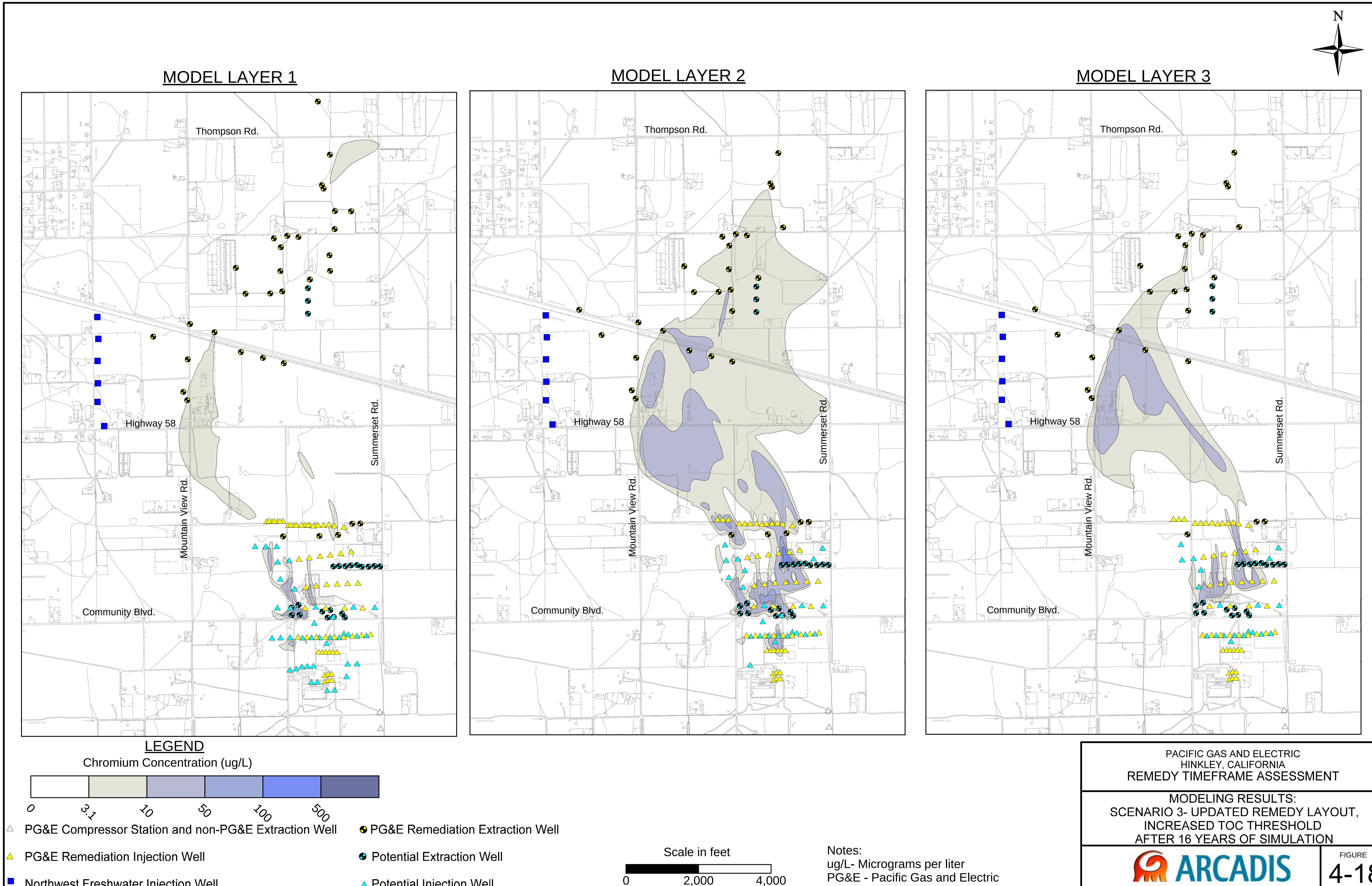
PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

MODELING RESULTS:
SCENARIO 3- UPDATED REMEDY LAYOUT,
INCREASED TOC THRESHOLD
AFTER 8 YEARS OF SIMULATION

ARCADIS

FIGURE
4-16


N
MODEL LAYER 1
MODEL LAYER 2
MODEL LAYER 3
Thompson Rd.
Highway 58
Summerset Rd.
Mountain View Rd.
Community Blvd.
LEGEND
Chromium Concentration (ug/L)
0
3.1
10
50
100
500
PG&E Compressor Station and non-PG&E Extraction Well
PG&E Remediation Injection Well
Northwest Freshwater Injection Well
PG&E Remediation Extraction Well
Potential Extraction Well
Potential Injection Well
Scale in feet
0
2,000
4,000
Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric
PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT
MODELING RESULTS:
SCENARIO 3- UPDATED REMEDY LAYOUT,
INCREASED TOC THRESHOLD
AFTER 12 YEARS OF SIMULATION
ARCADIS
FIGURE
4-17



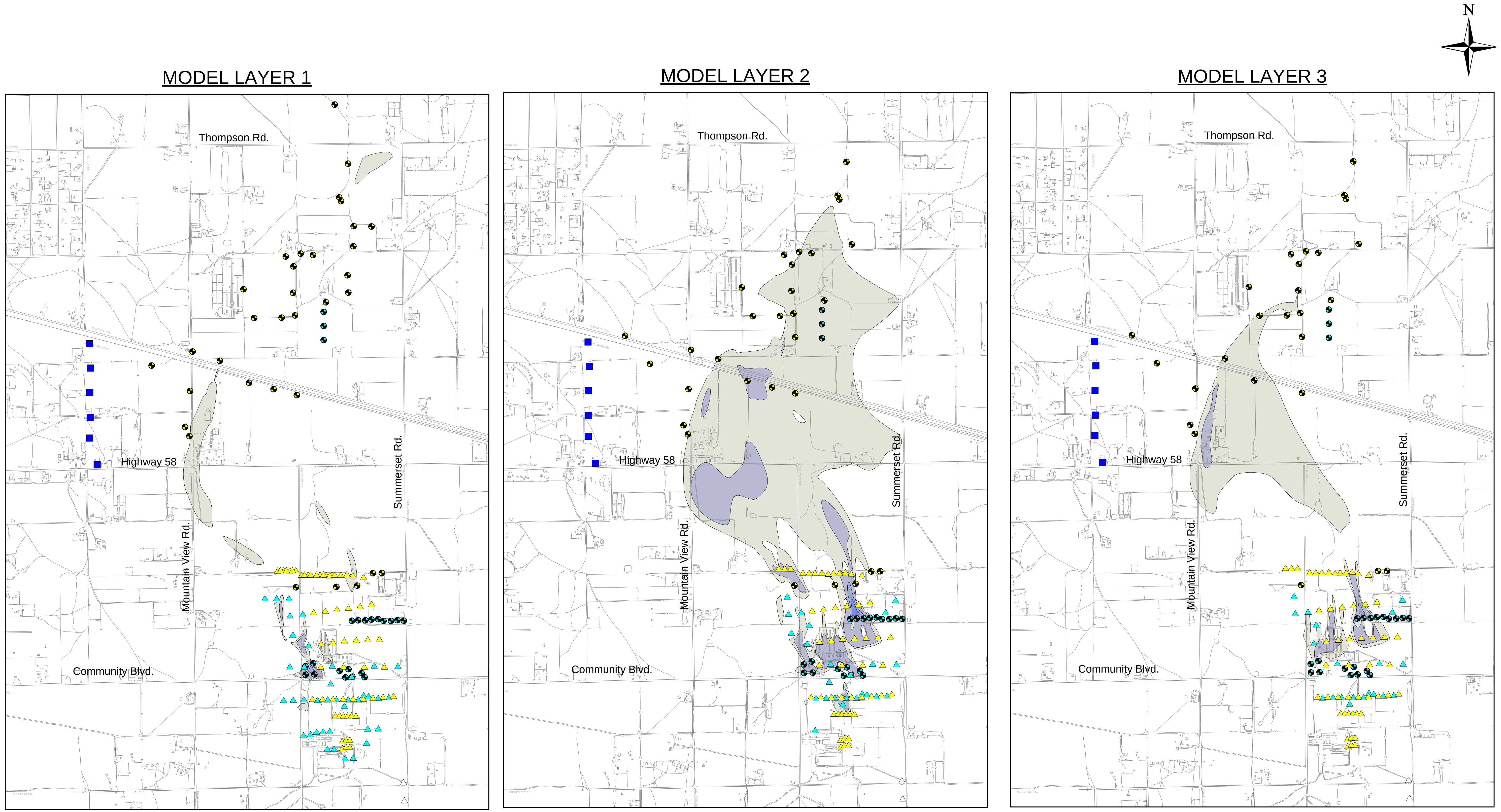
Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

MODELING RESULTS:
SCENARIO 3- UPDATED REMEDY LAYOUT,
INCREASED TOC THRESHOLD
AFTER 16 YEARS OF SIMULATION

ARCADIS

FIGURE
4-18



LEGEND

Chromium Concentration (ug/L)

0 | 3.1 | 10 | 50 | 100 | 500

- PG&E Compressor Station and non-PG&E Extraction Well
- PG&E Remediation Injection Well
- Northwest Freshwater Injection Well
- PG&E Remediation Extraction Well
- Potential Extraction Well
- Potential Injection Well

Scale in feet

0 2,000 4,000

Notes:
ug/L- Micrograms per liter
PG&E - Pacific Gas and Electric

PACIFIC GAS AND ELECTRIC
HINKLEY, CALIFORNIA
REMEDY TIMEFRAME ASSESSMENT

MODELING RESULTS:
SCENARIO 3- UPDATED REMEDY LAYOUT,
INCREASED TOC THRESHOLD
AFTER 20 YEARS OF SIMULATION

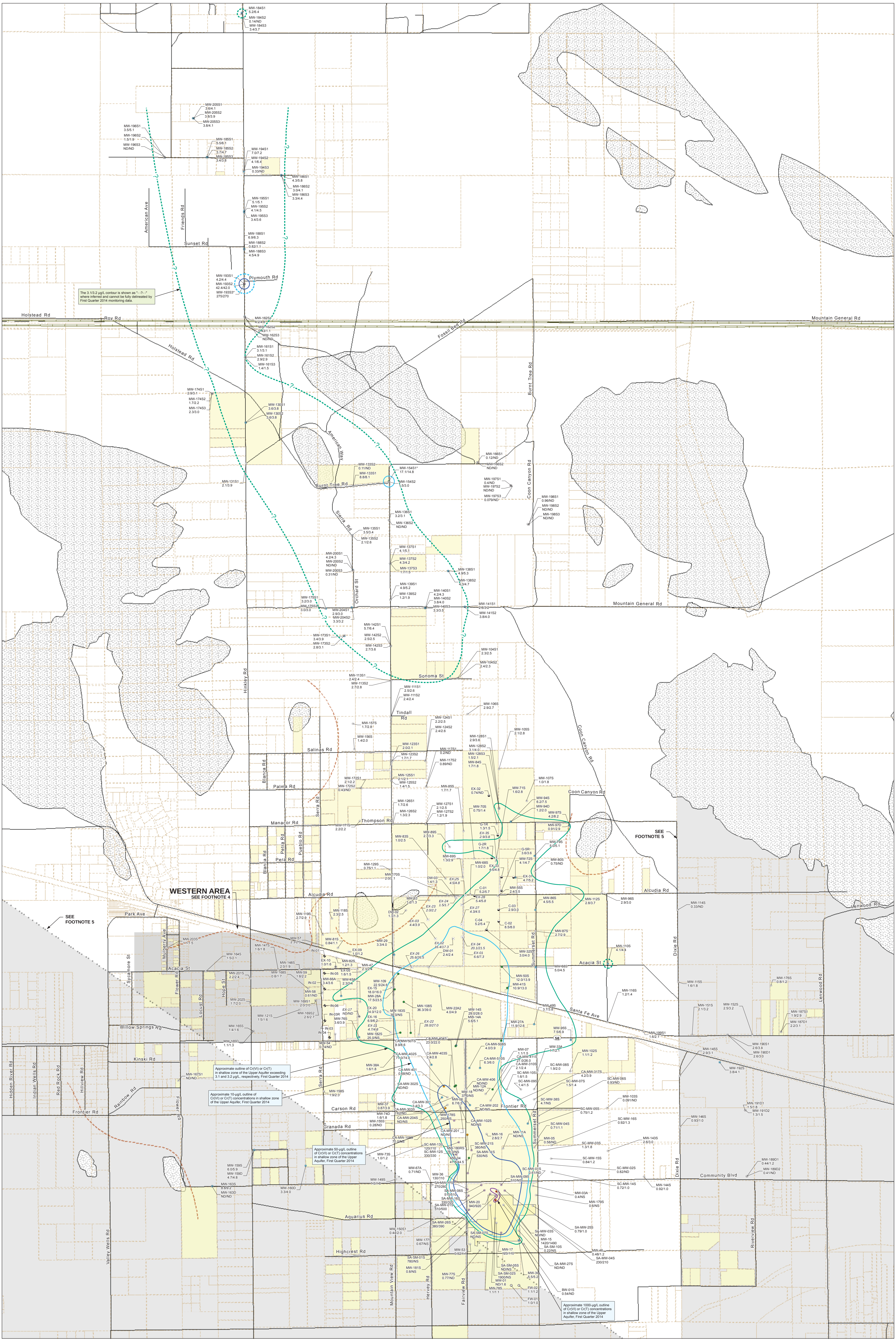
ARCADIS

FIGURE
4-19

ARCADIS

Appendix A

First Quarter 2014 Chromium Contour Maps



LEGEND:

- Groundwater monitoring well
- Agricultural supply well
- Other supply well
- Groundwater extraction well (active)
- Multiuse test well, or inactive extraction/injection well
- Freshwater injection well
- PG&E-owned property
- PG&E Compressor Station
- County parcels
- Transmission lines
- Approximate limit of saturated alluvium Upper Aquifer
- Approximate location of Lockhart Fault; fault trace is inferred, and there is no surface expression (Stamos et al., 2001)
- Bedrock exposed at ground surface

MW-77S — Well ID
0.79/1.3 — Cr(VI)/Cr(T) concentrations in µg/L; maximum of primary and duplicate samples during First Quarter 2014 sampling.

ABBREVIATIONS:

µg/L	micrograms per liter
Cr(VI)	hexavalent chromium
Cr(T)	total dissolved chromium
ND	not detected
NS	not sampled
PG&E	Pacific Gas and Electric Company

Groundwater Cr(VI) concentrations in monitoring wells:

- More than 1,000 µg/L
- 100 to 1,000 µg/L
- 50 to 100 µg/L
- 10 to 50 µg/L
- 3.1 to 10 µg/L
- Less than 3.1 µg/L or ND

NOTES:

1. The concentration contours shown on this map are based on First Quarter 2014 chromium results for groundwater monitoring wells, extraction wells, and agricultural supply wells completed in the shallow zone of the Upper Aquifer.

2. Concentration contours represent the maximum extent of either Cr(VI) or Cr(T) in the shallow zone of the Upper Aquifer. Some chromium results for wells within the 50-, 10-, and 3.1/3.2-µg/L chromium contours are less than the contoured concentrations.

3. Based on well screen depth and hydraulic data, wells MW-74D, MW-94D, MW-97D, MW-159D, MW-160D, MW-163D, and MW-165D are assigned to the shallow zone monitoring well network.

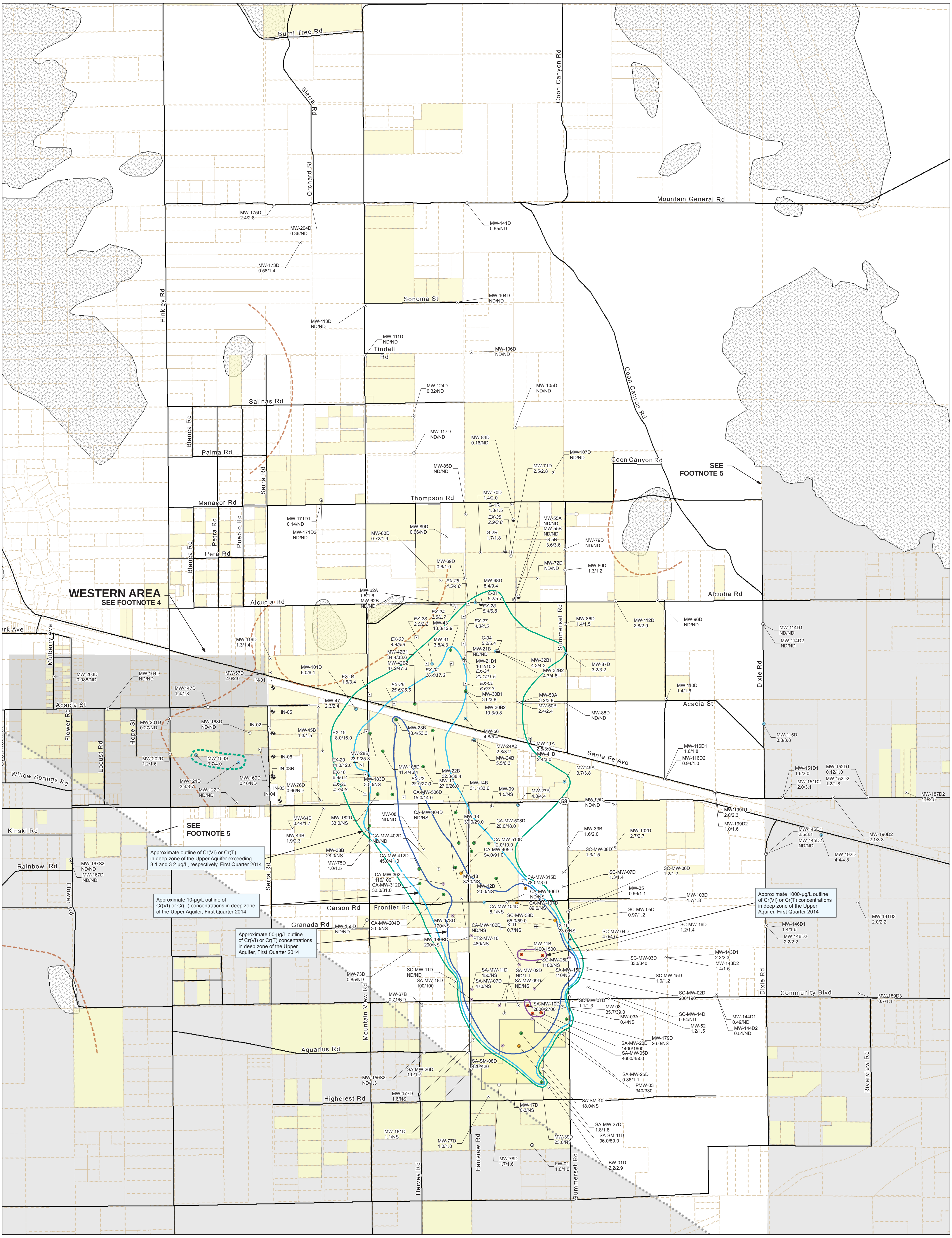
4. An evaluation of available hydrogeologic and groundwater quality data for the shaded Western Area shown on this figure was included in the January 14, 2013, document titled *Conceptual Site Model for Groundwater Flow and the Occurrence of Chromium in Groundwater of the Western Area Report* (CH2MHILL and Stantec, 2013). The findings of the January 14 report indicate that groundwater in the Western Area contains naturally occurring chromium.

5. Pursuant to the Lahontan Regional Water Quality Control Board's letter *Review of Chromium Plume Maps, Third Quarter 2013 Groundwater Monitoring Report and Agreement with Northern Investigation Concept* dated December 12, 2013, groundwater monitoring wells are not used for chromium contouring if they are located in the areas southwest of the Lockhart Fault and on or east of Dixie Road.

* Monitoring wells MW-154S1 and MW-193S3 are completed in low permeability sediments across the water table. These wells purged dry during sampling and are very slow to recharge. Groundwater samples from these wells may not be representative of the groundwater conditions in the Upper Aquifer as sampled in other wells in this area.

FIGURE 5-1
CHROMIUM RESULTS FOR GROUNDWATER MONITORING WELLS COMPLETED IN THE SHALLOW ZONE OF THE UPPER AQUIFER, FIRST QUARTER 2014
FIRST QUARTER 2014 GROUNDWATER MONITORING REPORT AND DOMESTIC WELL RESULTS
SITE-WIDE GROUNDWATER MONITORING PROGRAM
PACIFIC GAS AND ELECTRIC COMPANY
HINKLEY COMPRESSOR STATION
HINKLEY, CALIFORNIA

CH2MHILL



LEGEND:

- Groundwater monitoring well
- Agricultural supply well
- Other supply well
- Groundwater extraction well (active)
- Multiuse test well, or inactive extraction/injection well
- Freshwater injection well
- PG&E-owned property
- PG&E Compressor Station
- County parcels
- Transmission lines
- Approximate limit of saturated alluvium upper aquifer
- Approximate location of Lockhart Fault; fault trace is inferred, and there is no surface expression (Stamos et al., 2001)
- Bedrock exposed at ground surface

MW-77D — Well ID
1.0/1.4 — Cr(VI)/Cr(T) concentrations in µg/L; maximum of primary and duplicate samples during First Quarter 2014 sampling.

ABBREVIATIONS:

µg/L	micrograms per liter
Cr(VI)	hexavalent chromium
Cr(T)	total dissolved chromium
ND	not detected
NS	not sampled
PG&E	Pacific Gas and Electric Company

Groundwater Cr(VI) concentrations in monitoring wells:

- More than 1,000 µg/L
- 100 to 1,000 µg/L
- 50 to 100 µg/L
- 10 to 50 µg/L
- 3.1 to 10 µg/L
- Less than 3.1 µg/L or ND

NOTES:

1. The concentration contours shown on this map are based on First Quarter 2014 chromium results for the groundwater monitoring wells, extraction wells, and agricultural supply wells (with the exception of active wells G-2R and G-5R) completed in the deep zone of the Upper Aquifer. Active agricultural supply wells G-2R and G-5R are not included in contouring. These wells draw water from the shallow zone of the Upper Aquifer and do not represent chromium concentrations in the deep zone at these locations.

2. Concentration contours represent the maximum extent of either Cr(VI) or Cr(T) in the deep zone of the Upper Aquifer. Some chromium results for wells within the 50-, 10-, and 3.1/3.2- µg/L chromium contours are less than the contoured concentrations.

3. Based on well screen depth and hydraulic data, well MW-167S2 is assigned to the deep zone monitoring well network.

4. An evaluation of available hydrogeologic and groundwater quality data for the shaded Western Area shown on this figure was included in the January 14, 2013, document titled *Conceptual Site Model for Groundwater Flow and the Occurrence of Chromium in Groundwater of the Western Area Report* (CH2MHILL and Stantec, 2013). The findings of the January 14 report indicate that groundwater in the Western Area contains naturally occurring chromium.

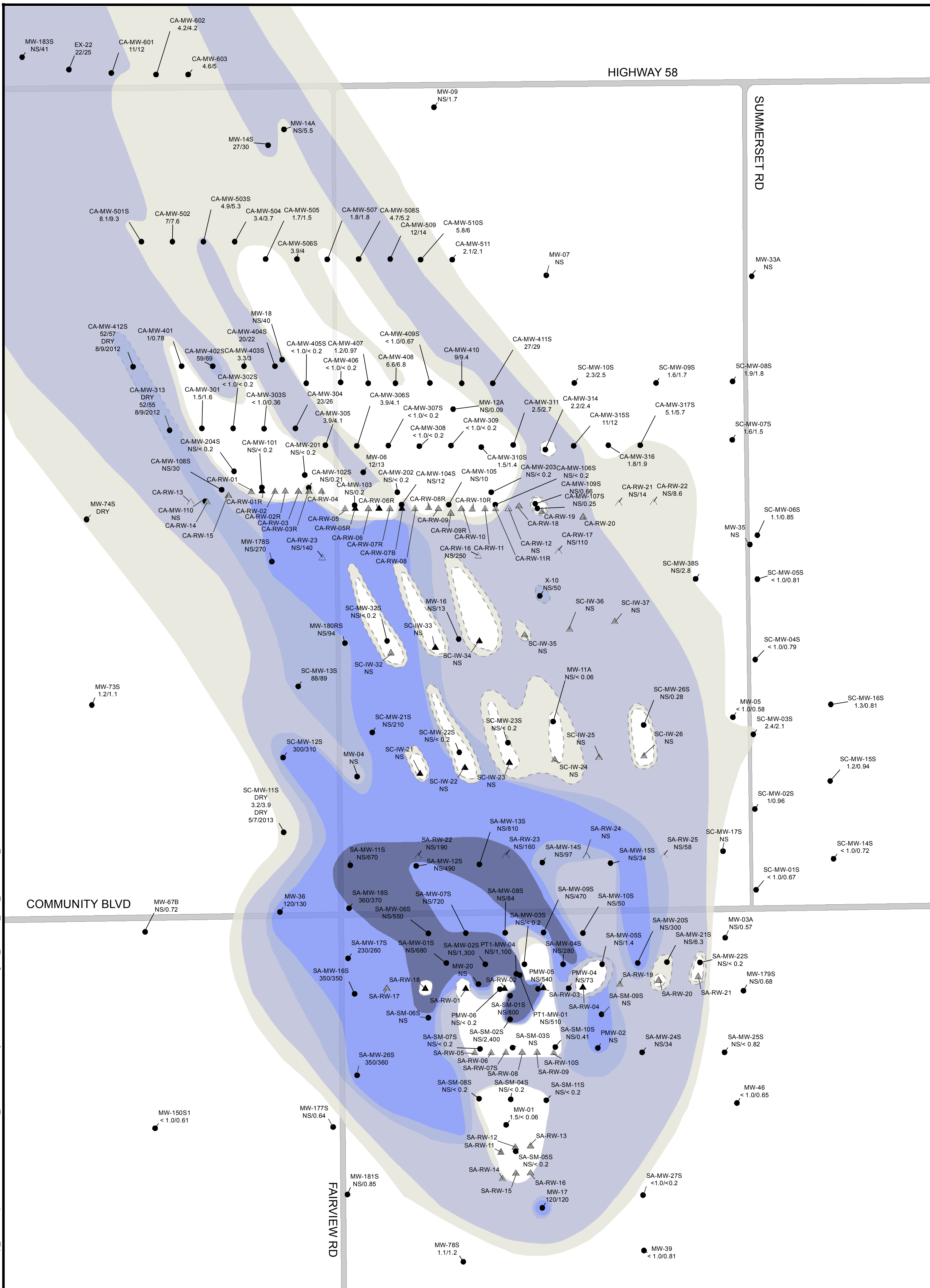
5. Pursuant to the Lahontan Regional Water Quality Control Board's letter *Review of Chromium Plume Maps, Third Quarter 2013 Groundwater Monitoring Report and Agreement with Northern Investigation Concept* dated December 12, 2013, groundwater monitoring wells are not used for chromium contouring if they are located in the areas southwest of the Lockhart Fault and on or east of Dixie Road.

N

0 1,000 2,000
Feet

FIGURE 5-2
CHROMIUM RESULTS FOR GROUNDWATER MONITORING WELLS COMPLETED IN THE DEEP ZONE OF THE UPPER AQUIFER, FIRST QUARTER 2014
FIRST QUARTER 2014 GROUNDWATER MONITORING REPORT AND DOMESTIC WELL RESULTS
SITE-WIDE GROUNDWATER MONITORING PROGRAM
PACIFIC GAS AND ELECTRIC COMPANY
HINKLEY COMPRESSOR STATION
HINKLEY, CALIFORNIA

CH2MHILL



Legend

- ● Monitoring Wells
- △ Active IRZ Extraction Well
- ▲ Active IRZ Injection Well
- △ Inactive IRZ Extraction Well
- ▲ Inactive IRZ Injection Well

Chromium Concentrations Less Than 3.1 µg/L
Chromium Concentrations Between 3.1 and 10 µg/L
Chromium Concentrations Between 10 and 50 µg/L
Chromium Concentrations Between 50 and 100 µg/L
Chromium Concentrations Between 100 and 500 µg/L
Chromium Concentrations Greater Than 500 µg/L

CA-MW-104S NS/12 — Well; Total Dissolved Chromium/Hexavalent Chromium Concentrations October and November 2013

DRY 52/57 8/9/2012 — Denotes location with insufficient water for sampling. Data and date posted are for the most recent data available from the location

Notes:
µg/L - Micrograms per liter
NS - Not Sampled
*Not used in contouring
[1]Not contoured extraction well screened across the shallow and deep zone of the upper aquifer.

N
0 300 600 Feet

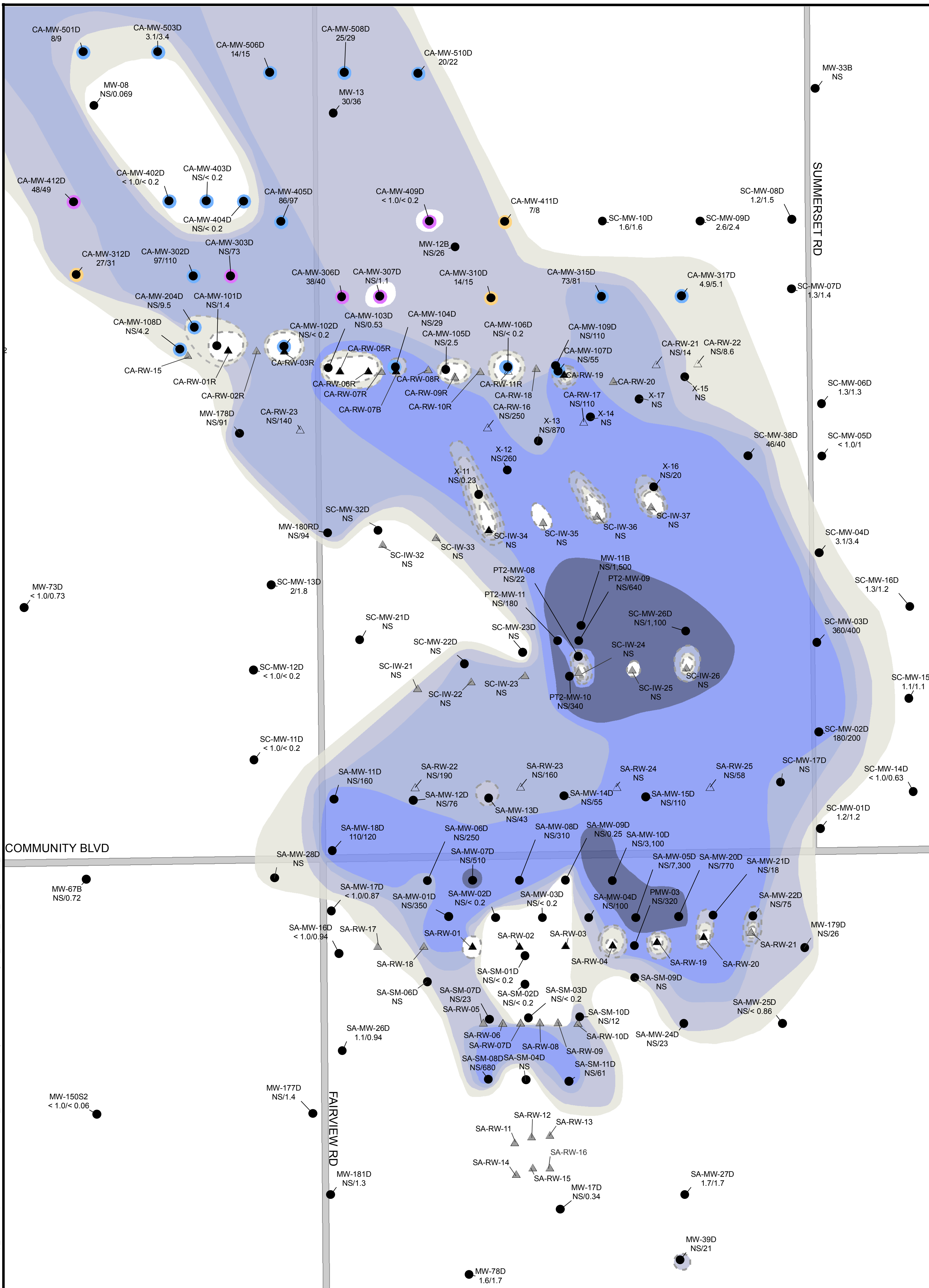
FIGURE 4-6
IRZ AREA TOTAL DISSOLVED CHROMIUM AND HEXAVALENT CHROMIUM CONCENTRATIONS (SHALLOW ZONE OF THE UPPER AQUIFER) FOURTH QUARTER 2013

FOURTH QUARTER 2013 MONITORING REPORT FOR THE IN-SITU REACTIVE ZONE AND NORTHWEST FRESHWATER INJECTION PROJECTS

PACIFIC GAS AND ELECTRIC COMPANY
HINKLEY, CALIFORNIA

ARCADIS

Drafter: BCG Path: I:\RC000699.0001_PGE_Hinkley\GIS\ArcMap_MXD\Reports\In-SituReactiveZone_NWFreshwaterInjection\4QTR2013\Fig4-6_Shallow_Hex_TotalChrom_4QTR13.mxd Date: 1/9/2014 Time: 5:05:20 PM



Legend

- Monitoring Wells
- Active IRZ Extraction Well
- Active IRZ Injection Well
- Inactive IRZ Extraction Well
- Inactive IRZ Injection Well
- Screen interval below 120 ft bgs
- Screen interval above 120 ft bgs
- Screen interval above and below 120 ft bgs

- Chromium Concentrations Less Than 3.1 µg/L
- Chromium Concentrations Between 3.1 and 10 µg/L
- Chromium Concentrations Between 10 and 50 µg/L
- Chromium Concentrations Between 50 and 100 µg/L
- Chromium Concentrations Between 100 and 500 µg/L
- Chromium Concentrations Greater Than 500 µg/L

SA-MW-22D Well
NS/75 Total Dissolved Chromium/Hexavalent Chromium Concentrations October and November 2013

Notes:
µg/L - Micrograms per liter
NS - Not Sampled

*Not used in contouring
[1]Not contoured extraction well screened across the shallow and deep zone of the upper aquifer.

N
0 250 500
Feet

FIGURE 4-7
IRZ AREA TOTAL DISSOLVED CHROMIUM AND HEXAVALENT CHROMIUM CONCENTRATIONS (DEEP ZONE OF THE UPPER AQUIFER) FOURTH QUARTER 2013

FOURTH QUARTER 2013 MONITORING REPORT FOR THE IN-SITU REACTIVE ZONE AND NORTHWEST FRESHWATER INJECTION PROJECTS

PACIFIC GAS AND ELECTRIC COMPANY
HINKLEY, CALIFORNIA

ARCADIS

Drafter: BCG Path: I:\RC000699.0001_PGE_Hinkley\GIS\ArcMap_MXD\Reports\In-SituReactiveZone_NWFreshwaterInjection\4QTR2013\Fig4-7_Deep_Hex_TotalChrom_4QTR13.mxd Date: 12/19/2013 Time: 9:06:22 AM