Revised

Contaminant Attenuation Conceptual Model Summary Report, Potrero Canyon Unit (Lockheed Beaumont Site 1) and Laborde Canyon (Lockheed Beaumont Site 2) Beaumont, California

Prepared for:

LOCKHEED MARTIN

Prepared by:

TETRA TECH
301 E. Vanderbilt Way, Suite 450
San Bernardino, California 92408

TC# 26205-01 / May 2012

Lockheed Martin Enterprise Business Services
Energy, Environment, Safety and Health
2950 North Hollywood Way, Suite 125 Burbank, CA 91505
Telephone 818•847•0197 Facsimile 818•847•0256

LOCKHEED MARTIN

May 16, 2012

Mr. Daniel Zogaib
Southern California Cleanup Operations
Department of Toxic Substances Control
5796 Corporate Avenue
Cypress, CA 90630

Subject: Submittal of the Revised *Contaminant Attenuation Conceptual Model Summary Report, Potrero Canyon Unit (Lockheed Beaumont Site 1) and Laborde Canyon (Lockheed Beaumont Site 2), Beaumont, California*

Dear Mr. Zogaib:

Please find enclosed one hard copy of the body of the report and two compact disks with the report body and appendices of the Revised *Contaminant Attenuation Conceptual Model Summary Report, Potrero Canyon Unit (Lockheed Beaumont Site 1) and Laborde Canyon (Lockheed Beaumont Site 2), Beaumont, California*, revised in compliance with responses to DTSC comments approved on April 17, 2012. The comments and responses are attached to this letter.

In the meantime, if you have any questions regarding this submittal, please contact me at 818-847-9901 or brian.thorne@lmco.com.

Sincerely,

Brian T. Thorne
Project Lead

Attachment: DTSC comments and approved responses

Enclosure: Revised *Contaminant Attenuation Conceptual Model Summary Report, Potrero Canyon Unit (Lockheed Beaumont Site 1) and Laborde Canyon (Lockheed Beaumont Site 2), Beaumont, California*

Copy: Gene Matsushita, LMC (electronic and hard copy)
Sally Drinkard, CDM (electronic copy)
Tom Villeneuve, Tetra Tech (electronic copy)
Hans Kernkamp, Riverside County Waste Management (electronic copy)
Alan Bick, Gibson Dunn (electronic copy)

BUR121 Trans-Bmt1_2 final cont att rpt.doc

Department of Toxic Substances Control

Matthew Rodriquez
Secretary for
Environmental Protection

Deborah 0. Raphael, Director
5796 Corporate Avenue
Cypress, California 90630

Edmund G. Brown Jr.
Governor

February 15, 2012

Mr. Brian T. Thorne
Remediation Analyst Senior Staff
Lockheed Martin Corporation
Energy, Environment, Safety & Health
2950 North Hollywood Way, Suite 125
Burbank, California 91505-1072

CONTAMINANT ATTENUATION CONCEPTUAL MODEL SUMMARY REPORT, LOCKHEED MARTIN CORPORATION, BEAUMONT SITES 1 AND 2, BEAUMONT, CALIFORNIA (Site Code: 400200 and 400261)

Dear Mr. Thorne:

The Department of Toxic Substances Control (DTSC) has reviewed the subject Report. DTSC's Engineering Services Unit (ESU) and my comments are as follows:

1. The current proposed conceptual model seems to be missing the overall perchlorate "cycle" through evapotranspiration. Even though salt filtration and rhizodegradation have been mentioned in the document, these mechanisms have not been tested and verified. Instead, those mechanisms have been lumped into the evapotranspiration process. However, perchlorate, as a salt, would likely accumulate through the plant's life as part of the uptake, unlike volatile organic compounds (VOCs) which may be reduced or evaporated through the plant life (although some studies did find VOC residuals in the plant leaves and trunks). Accumulated perchlorate in the plants would eventually be leached back into the site soils through the plant's lifecycle. Thus, the remaining questions to be answered are is there any salt filtration and rhizodegradation occurring near the root area and what are the residual effects (i.e. uptake by the plant, persistence in soil near the root, or complete degradation or degraded with by-products (perchlorite));

2. The anaerobic degradation of perchlorate has been well understood. However, in considering the total degradation capacity, only the "bio-available" dissolved organic carbon (DOC) for "perchlorate degradation" in the riparian area with

proper perchlorate reductive bacteria (PRB) should be considered, instead of using a simple fraction of the overall total organic carbon (TOC) at the site;

3. To address potential by-products and mass-balance, chlorite may be added to the contaminant attenuation parameter list.

The following comments are from DTSC's Geological Services Unit (GSU):

1. In this Report, the prevailing fundamental underlying conclusion that Tetra Tech emphasizes is the natural attenuation capacity in Potrero Canyon Unit (Site 1) aquifer appears to be equal to or greater than the overall plume contamination mass flux, both now and for the foreseeable future. Tetra Tech's argument is mainly based on the modeled prediction of contaminant mass reduction through two primary mechanisms including 40 pounds of annual mass discharge by evapotranspiration and an additional 135 pounds yearly mass reduction from degradation due to reducing condition in the riparian area.

   In GSU's opinion, any result from the modeling predictions of the mass fate and transport estimation must be calibrated against and compared with the site field data. Based on the absence of the data comparisons and direct support from the field groundwater data, the theoretic results and estimations can't be considered reliable to draw any substantiated conclusion;

2. Tetra Tech had presented a trending analysis for the primary contaminants including perchlorate, 1,1-DCE, TCE and 1,4-dioxane of their spatial distribution of the temporal trends for the 10 year period from 2002 to 2011 in Figures 4-4 through 4-7. These figures were estimated using the statistical summary analysis results from subsurface layers the in alluvium and the shallow Mount Eden Formation. GSU used these figures as the preliminary basis for a data comparison to evaluate if the asserted natural attenuation mechanisms are effectively removing the contaminant mass as claimed by Tetra Tech. GSU then combined both the increasing and probably increasing trend results as increasing mass, while grouping the decreasing and probably decreasing quantities as decreasing mass as shown in Table 1.

Table 1
Annual Contaminant Mass Change in ug/L/yr

Contaminant	BPA	RMPA	Riparian Area
Perchlorate	-154.76	1,918.65	212.28
1,1-DCE	-467.97	9.22	0.00
TCE	15.28	7.55	-4.47
1,4-dioxane	31.62	-1.06	11.97
Total	-575.83	1,934.36	219.78

In this Table, the perchlorate mass increased by 1,918.65 ug/l/yr in the Rocket Motor Production Area (RMPA) and decreased by 575.83 ug/l/yr in the Burn Pit Area (BPA) based on the source area mass estimations on a per year basis. It creates a significant inconsistency and deviation from the analytical results in the field. As indicated in the Report, the dominant perchlorate contaminant mass was attributed to the one-acre aquifer source area in the BPA (page 5-5, Section 5.1.1) where the area was believed to be the main source area for perchlorate contamination. The secondary source area, the RMPA, has contributed a much smaller amount of perchlorate to the groundwater (i.e. an order of magnitude less in concentration). Based on the recent soil and groundwater contamination data compiled for the 2nd quarter 2011 in Figure 2-4, a soil source area within the BPA at groundwater monitoring well MW-61B detected a groundwater concentration perchlorate concentration of 81,000 ug/l. That contrasts with the other perchlorate source area in the RMPA where the perchlorate concentration detected in groundwater monitoring well MW-98B was 1,600 ug/l. These analytical results suggest that the perchlorate contribution from the BPA is of greatest significance.

Therefore, the results tabulated in Table 1 indicating the annual total net mass change in the Burn Pit Area decreases by 575.83 ug/l/yr are completely contradictory with the field data and on-site contamination distribution originating from historical operations at the Site. That coupled with the prediction that the perchlorate mass only increases in the Rocket Motor Production Area leads GSU to consider these statistical results as skewed and misleading and that they do not reflect the actual trends. They need to be reevaluated as they are not suitable for this purpose;

3. GSU recommends that Tetra Tech focus on presenting the compiled data for the 10-year period from 2002-2011 in the temporal and spatial domains to illustrate their distribution patterns in each area (BRA, RMPA and Riparian Area respectively). For each year an estimated total mass accumulation interpolated from the groundwater monitoring data in each area should be tallied and tabulated. Then by treating the mass accumulated in the areas of BPA and RMPA as the influx mass and comparing it to the out flux mass measured in the Riparian Area, one can demonstrate if the net mass change for each contaminant will show any systematic trends. Additionally, these data can be compared with those from the distinctive subsurface layers such as the high permeable alluvium and weathered Mount Eden formation (MEF) versus the less permeable shallow alluvium layer in order to identify the maximum mass discharge [ayer for future remediation.

   GSU can only accept the final results through this vigorous exercise and data comparison as a creditable approach to prove whether the natural attenuation mechanism in the riparian area can function as described by Tetra Tech;

4 Section 5.1 - Potrero Canyon Unit Contaminant Attenuation CSM, page 5-6, Tetra Tech stated that current COPC annual mass flux released from all sources is estimated as: 19 lb/yr for 1,1-DCE, 9 lb/yr for TCE, 156 lb/yr for perchlorate and 4 lb/yr for 1,4-dioxane, and a total contaminant mass in the groundwater plume and the soil. These mass estimations appear to be based on the modeled .predictions. Tetra Tech should discuss the correlation between the conjectured mass amounts shown in Table 5.1-1 based on the modeled COPC mass and mass flux with those directly estimated from the field data and present those findings for further discussion in the cases where there are significant deviations.

5. Based on the data presented, GSU can not concur with Tetra Tech's assertion that "Generally, the plume at the site appears to be in a quasi-steady state condition where COPCs are added to the plume in the BPA and RMPA source areas at rates approximately equal to the COPC removal rates from the plume in the riparian area." As discussed in the above comments, the only way to demonstrate the influx mass from source areas in the BPA and RMPA being completely removed in the riparian area is to present groundwater data evidence showing the remaining out flux mass supports these mass removal rates. Using the model's calculation of the fate and transport for contaminants to solely argue the removal rates attain the removal objective is inadequate as well as inconclusive.

GSU does not dispute that the perchlorate will undergo biodegradation under site specific reducing conditions to become innocuous by-products. But in order to reach to the mass removal rate claimed at 175 pounds per year for on-site contaminants including perchlorate and CVOCs, Tetra Tech should provide additional concrete data to substantiate and solidify the underlying arguments.

Furthermore, GSU does not object to using the modeling predictions and numerical simulations as supplemental methods to assess the subsurface conditions to promote mass reduction. However, these calculated results should be calibrated with field data to validate them. Modeling results alone can not be used exclusively to infer contaminant mass degradation rates at Site 1 unless they are supplemented with the support of actual field data. This is a significant data gap that needs to be filled.

Please address the aforementioned comments on or before March 15, 2012.

Should you have any questions or comments, please contact me at (714) 484-5483.

Sincerely,

Daniel K. Zogaib

Daniel K. Zogaib
Project Manager
Brownfields and Environmental Restoration Program

cc: Mr. Gene Matsushita
Senior Manager
Environmental Remediation
Lockheed Martin Corporation
Energy, Environment, Safety & Health
2950 North Hollywood Way, Suite 125
Burbank, California 91505

RESPONSES TO DTSC COMMENTS ON THE CONTAMINANT ATTENUATION CONCEPTUAL MODEL SUMMARY REPORT
POTRERO CANYON UNIT (LOCKHEED BEAUMONT SITE 1) AND LABORDE CANYON (LOCKHEED BEAUMONT SITE 2)
BEAUMONT, CALIFORNIA
TETRA TECH, INC.
MARCH 2012

Environmental Services Unit Comments

Comment	Response	Proposed Action
1. The current proposed conceptual model seems to be missing the overall perchlorate "cycle" through evapotranspiration. Even though salt filtration and rhizodegradation have been mentioned in the document, these mechanisms have not been tested and verified. Instead, those mechanisms have been lumped into the evapotranspiration process. However, perchlorate, as a salt, would likely accumulate through the plant's life as part of the uptake, unlike volatile organic compounds (VOCs) which may be reduced or evaporated through the plant life (although some studies did find VOC residuals in the plant leaves and trunks). Accumulated perchlorate in the plants would eventually be leached back into the site soils through the plant's lifecycle. Thus, the remaining questions to be answered are: is there any salt filtration and rhizodegradation occurring near the root area? and what are the residual effects (i.e. uptake by the plant, persistence in soil near the root, or complete degradation or degraded with by-products (perchlorite))?	This report deals only with the soil/groundwater CSM, and does not address plant accumulation, which is addressed in the Groundwater to Plant Uptake Study submitted as part of the Human Health and Predictive Ecological Risk Assessments. The objective of this study does not include testing the numerous degradation and mass transfer processes involved in the perchlorate cycle through evapotranspiration. The Groundwater to Plant Uptake has shown that perchlorate is present in the leaf litter and shallow soils beneath the leaf litter. However, the concentrations detected are much lower than those detected in the plant tissue and do not present a risk to ecological receptors. In addition, the empirical evidence (the difference between the perchlorate and 1,4-dioxane plumes) indicates that there is significant perchlorate degradation occurring in the riparian area even if a small amount may be being recycled back into the groundwater.	The report will be revised to include a summary of the plant uptake study findings and conclusions (see Section 5.1.2). In addition, text will be added regarding the empirical evidence that shows that there is significant perchlorate degradation occurring in the riparian area (see Section 5.1.1-Page 5-11).
2. The anaerobic degradation of perchlorate has been well understood. However, in considering the total degradation capacity, only the "bio-available" dissolved organic carbon (DOC) for "perchlorate degradation" in the riparian area with proper perchlorate reductive	Tetra Tech agrees that only the bioavailable fraction of dissolved organic carbon should be used to assess the perchlorate degradation capacity,	Text revised as follows on Pages 5-24 and 5-40: “Note that the Ex-Situ

Environmental Services Unit Comments		
Comment	**Response**	**Proposed Action**
bacteria (PRB) should be considered, instead of using a simple fraction of the overall total organic carbon (TOC) at the site;	which is why Tetra Tech assumed that only a very small fraction of the TOC would be bioavailable, using literature reported values. Since the Ex-Situ Perchlorate Biodegradation Test Results indicate that a significant fraction of organic carbon appears to be biodegradable, the literature reported values showing a small fraction of organic carbon as biodegradable seems reasonable and were used for this report. Note, also, that the site TOC mass is so large relative to TOC demand, that a more conservative estimate of the bioavailable fraction of dissolved organic carbon would still be sufficient to support TOC demand at the site. Future work as the site moves into the FS and remediation phases may refine the estimates of the bioavailable fraction of dissolved organic carbon. To clarify this point, the text was revised to note that the Ex-Situ Perchlorate Biodegradation Test Results indicate that a significant fraction of organic carbon appears to be biodegradable, supporting the use of the literature-reported values.	Perchlorate Biodegradation Test Results indicate that a significant fraction of organic carbon appears to be biodegradable, supporting the use of these literature-reported values.

Environmental Services Unit Comments

Comment	Response	Proposed Action
3. To address potential by-products and mass-balance, chlorite may be added to the contaminant attenuation parameter list.	Chlorite and hypochlorite were analyzed on 14 samples collected during the focused natural attenuation monitoring event in Second Quarter 2011. However, since neither analyte was detected, the results were not included in the summary tables in Section 4 but are included in the validated analytical data tables provided in Appendix D.	The tables in Section 4 will be revised to show that these analytes were tested for but not detected. Section 3 will also be revised to more clearly indicate which parameters were tested for during each of the sampling events (Fourth Quarter 2010 and Second Quarter 2011).

Geological Services Unit Comments

Comment	Response	Proposed Action
1. In this Report, the prevailing fundamental underlying conclusion that Tetra Tech emphasizes is the natural attenuation capacity in Potrero Canyon Unit (Site 1) aquifer appears to be equal to or greater than the overall plume contamination mass flux, both now and for the foreseeable future. Tetra Tech's argument is mainly based on the modeled prediction of contaminant mass reduction through two primary mechanisms including 40 pounds of annual mass discharge by evapotranspiration and an additional 135 pounds yearly mass reduction from degradation due to reducing condition in the riparian area. In GSU's opinion, any result from the modeling predictions of the mass fate and transport estimation must be calibrated against and compared with the site field data. Based on the absence of the data comparisons and direct support from the field groundwater data, the theoretic results	GSU requests that the flow and transport model predictions be calibrated against and compared with site field data: this has already been done. Please see the flow model reports and transport model reports for the sites, where the model results are calibrated against and compared with up to 20 years of site field data, including water level measurements and water quality data. GSU also requests data comparisons between the model and field data: this	The report will be revised to include a summary of the flow and transport model results regarding mass flux and contaminant attenuation processes. The revised text will also include a summary of the model calibration process which utilized site field data from a 20 year period (see Section 5.1.1- Pages 5-5, 5-6, and 5-7).

Geological Services Unit Comments

Comment	Response	Proposed Action
and estimations can't be considered reliable to draw any substantiated conclusion;	has already been done. Please see the comparisons of the site water budgets and mass flux budgets derived in the site CSM based upon the site monitoring and field data, which are independent of the numerical model (see for example Table 5.1.1 giving both CSM mass budgets and the MT3D mass budgets). Also, please see how the ET water budget was also estimated independently of both the groundwater monitoring data and the groundwater model, by performing a survey of the vegetation in the area to independently verify a key component of the site Contaminant Attenuation CSM- the ET flux.	
2. Tetra Tech had presented a trending analysis for the primary contaminants including perchlorate, 1,1-DCE, TCE and 1,4-dioxane of their spatial distribution of the temporal trends for the 10 year period from 2002 to 2011 in Figures 4-4 through 4-7. These figures were estimated using the statistical summary analysis results from subsurface layers the in alluvium and the shallow Mount Eden Formation. GSU used these figures as the preliminary basis for a data comparison to evaluate if the asserted natural attenuation mechanisms are effectively removing the contaminant mass as claimed by Tetra Tech. GSU then combined both the increasing and probably increasing trend results as increasing mass, while grouping the decreasing and probably decreasing quantities as decreasing mass as shown in Table 1.	The presented analysis of time trends uses industry standard methods to assess the concentration trends over time at individual wells. Analysis of the mass present in an area requires integration of concentrations over a spatial domain (i.e., mass has units of grams, while concentration has units of grams/liter, so in order to make any conclusions about mass, the concentrations must be integrated over some spatial domain), which was not done in the report, and does not appear	No report revisions required.

<table>
<tr><th colspan="3">Geological Services Unit Comments</th></tr>
<tr><th>Comment</th><th>Response</th><th>Proposed Action</th></tr>
<tr>
<td>
<table>
<tr><th colspan="4">Table 1
Annual Contaminant Mass Change in ug/L/yr</th></tr>
<tr><td>Contaminant</td><td>BPA</td><td>RMPA</td><td>Riparian Area</td></tr>
<tr><td>Perchlorate</td><td>-154.76</td><td>1,918.65</td><td>212.28</td></tr>
<tr><td>1,1-DCE</td><td>-467.97</td><td>9.22</td><td>0.00</td></tr>
<tr><td>TCE</td><td>15.28</td><td>7.55</td><td>-4.47</td></tr>
<tr><td>1,4-dioxane</td><td>31.62</td><td>-1.06</td><td>11.97</td></tr>
<tr><td>Total</td><td>-575.83</td><td>1,934.36</td><td>219.78</td></tr>
</table>
In this Table, the perchlorate mass increased by 1,918.65 ug/l/yr in the Rocket Motor Production Area (RMPA) and decreased by 575.83 ug/l/yr in the Burn Pit Area (BPA) based on the source area mass estimations on a per year basis. It creates a significant inconsistency and deviation from the analytical results in the field. As indicated in the Report, the dominant perchlorate contaminant mass was attributed to the one-acre aquifer source area in the BPA (page 5-5, Section 5.1.1) where the area was believed to be the main source area for perchlorate contamination. The secondary source area, the RMPA, has contributed a much smaller amount of perchlorate to the groundwater (i.e. an order of magnitude less in concentration). Based on the recent soil and groundwater contamination data compiled for the 2nd quarter 2011 in Figure 2-4, a soil source area within the BPA at groundwater monitoring well MW-61B detected a groundwater concentration perchlorate concentration of 81,000 ug/l. That contrasts with the other perchlorate source area in the RMPA where the perchlorate concentration detected in groundwater monitoring well MW-98B was 1,600 ug/l. These analytical results suggest that the perchlorate contribution from the BPA is of greatest significance.
</td>
<td>to have been done by DTSC in their comment.
Since DTSC did not integrate the concentration data over a spatial domain, no conclusions about mass can be drawn from this concentration time trend analysis (i.e., conclusions about mass are typically derived from spatial trend analysis, not time trend analysis).
Thus, this analysis conducted by DTSC does not appear to be appropriate for evaluating mass.</td>
<td></td>
</tr>
</table>

Geological Services Unit Comments		
Comment	**Response**	**Proposed Action**
Therefore, the results tabulated in Table 1 indicating the annual total net mass change in the Burn Pit Area decreases by 575.83 ug/l/yr are completely contradictory with the field data and on-site contamination distribution originating from historical operations at the Site. That coupled with the prediction that the perchlorate mass only increases in the Rocket Motor Production Area leads GSU to consider these statistical results as skewed and misleading and that they do not reflect the actual trends. They need to be reevaluated as they are not suitable for this purpose;		
3. GSU recommends that Tetra Tech focus on presenting the compiled data for the 10-year period from 2002-2011 in the temporal and spatial domains to illustrate their distribution patterns in each area (BPA, RMPA and Riparian Area respectively). For each year an estimated total mass accumulation interpolated from the groundwater monitoring data in each area should be tallied and tabulated. Then by treating the mass accumulated in the areas of BPA and RMPA as the influx mass and comparing it to the out flux mass measured in the Riparian Area, one can demonstrate if the net mass change for each contaminant will show any systematic trends. Additionally, these data can be compared with those from the distinctive subsurface layers such as the high permeable alluvium and weathered Mount Eden formation (MEF) versus the less permeable shallow alluvium layer in order to identify the maximum mass discharge layer for future remediation. GSU can only accept the final results through this vigorous exercise and data comparison as a creditable approach to prove whether the natural attenuation mechanism in the riparian area can function as described by Tetra Tech;	DTSC requests a mass flux budget be prepared from site monitoring data: this has already been done. Please see the text in Section 3 of the Transport model report, particularly Figures 3-11 and 3-12, and Tables 3-2 through 3-4. Note the mass budgets are based upon site monitoring data, not the numerical model (a comparison of the mass budgets based upon site monitoring data with the numerical model budgets is given in Table 4-1 of that report).	The report will be revised to include a summary of the mass budgets presented in the transport model report and the source of the data used to estimate the masses (see Section 5.1.1-Page 5-7).
4. Section 5.1 - Potrero Canyon Unit Contaminant Attenuation CSM, page 5-6, Tetra Tech stated that current COPC annual mass flux released from all sources is estimated as: 19 lb/yr for 1,1-DCE, 9 lb/yr	The correlation between the mass budgets based upon site monitoring data with the numerical model budgets	The report will be revised to include text from the transport model report regarding the

Geological Services Unit Comments		
Comment	**Response**	**Proposed Action**
for TCE, 156 lb/yr for perchlorate and 4 lb/yr for 1,4-dioxane, and a total contaminant mass in the groundwater plume and the soil. These mass estimations appear to be based on the modeled .predictions. Tetra Tech should discuss the correlation between the conjectured mass amounts shown in Table 5.1-1 based on the modeled COPC mass and mass flux with those directly estimated from the field data and present those findings for further discussion in the cases where there are significant deviations.	is given on Page 4-8 and 4-9 of the transport model report, which states as follows: "*COC Mass and Mass Flux Budget The groundwater COC mass and mass flux budget for the calibrated transport model is summarized in Table 4-1. The components of the COC mass and mass flux budget generally matches the conceptual model COC mass and mass flux budget given in Section 3-3, Figure 3-12,Table 3-4, and as summarized in Table 4-1. Notable components of the transient mass flux budget include the following:* • *Total COC plume mass predicted for 2009 is within 6 percent of 2009 observed mass for perchlorate; 19 percent of 2009 observed mass for 1,4-dioxane; 36 percent of 2009 observed mass for 1,1-DCE, and 13 percent of observed 2009 mass for TCE;* • *COC mass and mass flux into the aquifer is within 14 percent of the mass and mass flux out of the aquifer due to loss to evapotranspiration, wells, streams, and biodegradation (perchlorate only). This suggests the*	correlation between the mass budgets based upon site monitoring data and the numerical model budgets (see Section 5.1.1-Page 5-7).

Geological Services Unit Comments		
Comment	**Response**	**Proposed Action**
	plume is nearly at steady-state conditions, which also is reflected in the plume mass being relatively constant over the 1992 through 2009 simulation period. While is it noted that there are some discrepancies between certain elements of the mass and mass flux, these discrepancies are attributed to the inherent uncertainty of transport model predictions rather than any true significant deviation from the aforementioned plume steady-state conditions; • *There is generally good comparison between the transport model mass and mass flux values estimated at the extraction well locations for TCE and 1,1,-DCE;* • *There is generally fair comparison between the MT3D transport model mass and mass flux values and those estimated in the conceptual model;* • *The perchlorate mass flux values from sources in the RMPA reasonably match estimated using vadose zone transport methodology in Section 3, suggesting there are no groundwater perchlorate sources in*	

Geological Services Unit Comments		
Comment	**Response**	**Proposed Action**
	the RMPA. This is consistent with all the other COCs that do not show a groundwater source in the RMPA; and • *The perchlorate mass flux values from sources in the BPA are about twice those estimated using vadose zone transport methodology in Section 3, suggesting there is a groundwater perchlorate sources in the RMPA. This is consistent with all the other COCs that show a groundwater source in the BPA.* *Thus, the transport model COC mass and mass flux budget is reasonably close to the site conceptual model COC mass and mass flux budget. Given that the model parameters, concentrations, spatial and temporal concentrations trends, and COC mass and mass flux budget agree reasonably well with the site conceptual model, the groundwater transport model appears to be adequately calibrated*." Note that this comment, which suggests that the comparison of mass budgets from the model and monitoring data given in Table 5.1.1 were not discussed sufficiently, appears to be in direct	

Geological Services Unit Comments

Comment	Response	Proposed Action
	conflict with comment 1 above, which states we did not do any calculations of mass budgets from monitoring data.	
5. Based on the data presented, GSU cannot concur with Tetra Tech's assertion that "Generally, the plume at the site appears to be in a quasi-steady state condition where COPCs are added to the plume in the BPA and RMPA source areas at rates approximately equal to the COPC removal rates from the plume in the riparian area." As discussed in the above comments, the only way to demonstrate the influx mass from source areas in the BPA and RMPA being completely removed in the riparian area is to present groundwater data evidence showing the remaining out flux mass supports these mass removal rates. Using the model's calculation of the fate and transport for contaminants to solely argue the removal rates attain the removal objective is inadequate as well as inconclusive. GSU does not dispute that the perchlorate will undergo biodegradation under site specific reducing conditions to become innocuous by-products. But in order to reach to the mass removal rate claimed at 175 pounds per year for on-site contaminants including perchlorate and CVOCs, Tetra Tech should provide additional concrete data to substantiate and solidify the underlying arguments. Furthermore, GSU does not object to using the modeling predictions and numerical simulations as supplemental methods to assess the subsurface conditions to promote mass reduction. However, these calculated results should be calibrated with field data to validate them. Modeling results alone cannot be used exclusively to infer contaminant mass degradation rates at Site 1 unless they are supplemented with the support of actual field data. This is a significant data gap that needs to be filled.	GSU requests that the flow and transport model predictions be calibrated against and compared with site field data: this has already been done. Please see the flow model report and transport model report, where the model results are calibrated against and compared with almost 20 years of site field data, including water level measurements and water quality data. GSU also requests data comparisons between the model and field data: this has already been done. Please see the comparisons of the site water budgets and mass flux budgets derived in the site CSM based upon the site monitoring and field data, which are independent of the numerical model (see for example Table 5.1.1 giving both CSM mass budgets and the MT3D mass budgets).	The report will be revised to include a summary of the flow and transport model results regarding mass flux and contaminant attenuation processes. The revised text will also include a summary of the model calibration process which utilized site field data from a 20 year period (see Section 5.1.1-Pages 5-5, 5-6, and 5-7).

Human and Ecological Risk Office Comments		
Comment	**Response**	**Proposed Action**
1. As indicated in the March 25, 2011 Memorandum by Tetra Tech, the responses to DTSC comments regarding the two prior Technical Memorandums should be included as an appendix to this report;	These will be added to the report.	As indicated in the March 25, 2011 Memorandum by Tetra Tech, the responses to DTSC comments regarding the two prior Technical Memorandums will be included as an appendix to this report
2. Page 3-2: Please explain why only three soil borings were advanced at Laborde Canyon (Site 2), as opposed to four borings (two in the riparian area near the property boundary) proposed in the January 2011 Technical Memorandum;	Four borings were attempted but only three borings were installed due to refusal at the fourth location just below the surface. Therefore, no samples were collected for TOC analysis at the fourth boring location.	Section 3 of the report will be revised explaining why the fourth boring was not installed.
3. Page 3-6: Please explain why seven of the monitoring wells at Potrero Canyon (Site 1) were not sampled for perchlorate, 1,4-dioxane, and VOCs, which appears to deviate from the groundwater analyses proposed in the December 2010 Technical Memorandum;	All wells evaluated as part of this study were analyzed for perchlorate, 1,4-dioxane, and VOCs. In the technical memorandum, 7 of the 25 wells were also selected for perchlorate reductase and dehalococcoides spp analyses. Please refer to Tables 4.1-3 and 4.1-4.	No report revisions required.
4. Page 4-6: According to the January 2011 Responses to DTSC Comments for Site 1, qPCR assays for perchlorate and TCE at EW-15 would be added to the list for future contaminant attenuation sampling. However, this well was not sampled in the second quarter 2011 sampling event (Table 4.1-6). Please explain why this work was not performed;	It was determined that qPCR assays for perchlorate and TCE would be added to any future contaminant attenuation sampling at EW-15 as indicated in the Response to DTSC comments dated January 12, 2011. DTSC deemed the responses acceptable in a letter dated	No report revisions required.

Human and Ecological Risk Office Comments		
Comment	**Response**	**Proposed Action**
	March 24, 2011. However, EW-15 was not identified for the focused data collection in Second Quarter 2011 as the objective was to identify other wells and areas of the Site to supplement the Q2 2010 and Q4 2010 data.	
5. Page 4-14: HERO notes that the "MNASOIL" sample has a higher total organic carbon (TOC) concentration than most of the soil samples on Table 4.1-1, especially those in deeper soil samples. Please discuss the anticipated effect of soil TOC content on perchlorate degradation and its implication on remediation strategy;	It should be noted that this soil sample was collected from the riparian area where it appears most of the perchlorate degradation is occurring. However, this concentration is consistent with other shallow samples collected in the riparian area as well as SB-5 located further upgradient in the main valley. As stated in Section 6.1 of the report, the TOC data collected in this investigation indicates that there is enough organic carbon in the riparian area to support continued contaminant degradation for several hundreds of years into the future, with the potential to degrade tens of thousands of pounds of contaminants, far in excess of the amount of contaminants that may potentially be released from the site in the future. Thus, the aquifer conditions appear capable of sustaining contaminant degradation for the	No report revisions required.

Human and Ecological Risk Office Comments

Comment	Response	Proposed Action
	foreseeable future.	
6. Page 4-20: The concentrations of some chemicals (e.g., methane, DOC, nitrate, and perchlorate) cited in the text do not match those on Table 4.1-6. Please resolve these discrepancies;	The text will be revised to reflect this comment.	Text revised on Page 4-20: …methane concentrations (“620 to 120 ppb” and “32 to 110 ppb” …DOC concentration of “2.1 to 1.4 mg/L” and “2.7 to 8.3 mg/L”… “11 to 9.1 mg/L” ….perchlorate in these vicinities (“62 to 20 ppb”) very little organic carbon (“0.51 to 3.2 mg/L”….. Text revised to “Well MW-109 also has a somewhat hindered geochemical situation with persistent perchlorate due to competitive inhibition due to the presence of nitrate (3.1 mg/L in July, 2011). Despite the slightly higher DOC of 3.2 mg/L at this location, very little fermentation of the organic carbon organic carbon may be occurring to critical VFAs such as lactate (as evidenced by the negligible concentration of this VFA at 0.0060 mg/L in this well) which are often critical to microbial

Human and Ecological Risk Office Comments		
Comment	**Response**	**Proposed Action**
		activity, particularly PRBs.”
7. Page 4-21: HERO could not find the results of PRBs for the August 2011 sample in Appendix E. Please clearly identify or include the laboratory report that contains the PCR test results for this sample;	The laboratory results will be added to the report appendices.	The laboratory package will be included in Appendix E.
8. Page 4-40: Please elaborate on the discussion of groundwater discharge to the cattle ponds at Site 1. If significant contaminant mass flux could be added to these ponds, the cattle grazing scenario in the HHRA may need to be revised to account for cattle uptake of COCs via ingesting contaminated pond water;	The HHRA evaluated potential health effects from the consumption of beef resulting from assumed cattle exposures via soil ingestion and plant consumption at the Riparian AOC, where the groundwater discharge ponds are located. Cattle could theoretically be exposed to perchlorate in the discharged groundwater, assuming that they obtain their drinking water from the ponds. However, there is no biotransfer factor for perchlorate for estimating beef tissue concentrations from the soil, food, or water ingestion pathways for cattle. Perchlorate is not included among the diet-to-beef uptake models (biotransfer factors) presented in Baes et al. (1984), which includes only metals, or USEPA (2005), which applies only to organic compounds. Thus, since no biotransfer models are presently available, the potential health effects for human consumers relative to beef consumption of pond water cannot be evaluated. Consequently, use of the	No report revisions required.

Human and Ecological Risk Office Comments

Comment	Response	Proposed Action
	beef consumption pathway to evaluate perchlorate levels in the groundwater discharge ponds would not be possible.	
9. Page 4-61: Table 4.6-2 appears incomplete, as the information in the table does not support the discussion of organic carbon mass in the text ("...2 million pounds in the soil solid phase of the aquifer");	There was a typographical error in the text; the 2 million should have been 14 million. The typographical error will be corrected.	Text revised on Page 4-61 from “2 million pounds” to “14 million pounds.
10. Page 5-41 and Page 6-2: The total mass flux (185 or 180 pounds per year) and the mass flux discharging to Potrero Creek (4 pounds per year) do not agree with the values listed on Table 5.1-1. Please clarify these discrepancies to avoid confusion.	The text values were rounded from those in Table 5.1.1, but the text values will be changed as requested to precisely match the average values from the model budget and CSM budget given in Table 5.1.1.	Text revised on Pages 5-41 and 6-2 to “187.9 to 189 pounds per year” and “1.7 to 4.4 pounds per year”.

Department of Toxic Substances Control

Deborah O. Raphael, Director
5796 Corporate Avenue
Cypress, California 90630

Matthew Rodriquez
Secretary for
Environmental Protection

Edmund G. Brown Jr.
Governor

E. E. S. H.
APR 19 2012
DEPT/SITE: 40/41
COPIES TO:

April 17, 2012

Mr. Brian T. Thorne
Remediation Analyst Senior Staff
Lockheed Martin Corporation
Energy, Environment, Safety & Health
2950 North Hollywood Way, Suite 125
Burbank, California 91505-1072

CONTAMINANT ATTENUATION CONCEPTUAL MODEL SUMMARY REPORT, LOCKHEED MARTIN CORPORATION, BEAUMONT SITES 1 AND 2, BEAUMONT, CALIFORNIA (Site Code: 400200 and 400261)

Dear Mr. Thorne:

The Department of Toxic Substances Control (DTSC) has reviewed your responses to our comments regarding the subject Report and has no further comments.

Please submit the revised Report on or before May 17, 2012.

Should you have any questions or comments, please contact me at (714) 484-5483.

Sincerely,

Daniel K. Zogaib
Project Manager
Brownfields and Environmental Restoration Program

cc: Mr. Gene Matsushita
Senior Manager
Environmental Remediation
Lockheed Martin Corporation
Energy, Environment, Safety & Health
2950 North Hollywood Way, Suite 125
Burbank, California 91505

REVISED

CONTAMINANT ATTENUATION EVALUATION, POTRERO CANYON UNIT (LOCKHEED MARTIN BEAUMONT SITE 1) AND LABORDE CANYON (LOCKHEED MARTIN BEAUMONT SITE 2), BEAUMONT, CALIFORNIA

Prepared for:

Lockheed Martin Corporation

Prepared by:

Tetra Tech, Inc.

May 2012

Bob Johns

Bob Johns, PhD
Principal Hydrogeologist

Ben Weink, P.G. (8037)
Potrero Canyon Unit Project Manager

Mark Feldman, CHG, CEG
Laborde Canyon Project Manager

BMW
BENJAMIN MICHAEL WEINK
No. 8037
Exp. 3-31-13

MARK FELDMAN
No. HG 747
CERTIFIED HYDROGEOLOGIST
Exp 1/13

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

APPENDIX A	**LITHOLOGICAL LOGS**
APPENDIX B	**MONITORING WELL TRANSDUCER CHARTS AND EVAPOTRANSPIRATION ANALYSES**
APPENDIX C	**INVESTIGATION-DERIVED WASTE MANIFESTS**
APPENDIX D	**VALIDATED ANALYTICAL RESULTS BY METHOD**
APPENDIX E	**LABORATORY DATA PACKAGES**
APPENDIX F	**RESPONSES TO DTSC COMMENTS ON PRELIMINARY CONTAMINANT ATTENUATION CONCEPTUAL MODEL TECHNICAL MEMORANDUMS FOR POTRERO CANYON UNIT AND LABORDE CANYON**

ACRONYMS

1,1 DCA	1,1-dichloroethane
1,1 DCE	1,1-dichloroethene
1,1,1 TCA	1,1,1-trichloroethane
bgs	below ground surface
BPA	Burn Pit Area
COPC	chemicals of potential concern
CSM	conceptual site model
DO	dissolved oxygen
DOC	dissolved organic carbon
DTSC	Department of Toxic Substances Control
EC	electrical conductivity
EPA	United States Environmental Protection Agency
ft/day	feet per day
ft/ft	feet per foot
HSUs	hydrostratigraphic units
K	hydraulic conductivity
LAC	Lockheed Aircraft Corporation
LMC	Lockheed Martin Corporation
LPC	Lockheed Propulsion Company
MCLs	maximum contaminant levels
MEF	Mount Eden Formation
µg/L	micrograms/liter
mg/L	milligrams per liter
msl	mean sea level
MW	Monitoring well
MWD	Metropolitan Water District

QAL	Quaternary alluvium
RMPA	Rocket Motor Production Area
SKR	Stephens’ Kangaroo rat
SVOCs	semi-volatile organic compounds
TCE	trichloroethene
TOC	total organic carbon
USFWS	United States Fish and Wildlife Service
VOCs	volatile organic compounds
WDA	waste discharge area

EXECUTIVE SUMMARY

Field investigations were conducted at LMC Beaumont Sites 1 and 2 to evaluate contaminant attenuation mechanisms and rates identified in recent preliminary conceptual site models. The conceptual site models and contaminant attenuation mass budgets are then updated based upon the new data.

For Potrero Canyon Unit (Lockheed Martin Beaumont Site 1), the new field data includes a riparian area plant survey; additional groundwater sampling for analysis of key contaminant attenuation parameters and quantitative perchlorate reductase assays; drilling and sampling soil borings for analysis of organic carbon and other key soil parameters; and conducting bench-scale perchlorate biodegradation tests. For Laborde Canyon (Lockheed Martin Beaumont Site 2), the new field data includes a riparian area plant survey; groundwater sampling for quantitative perchlorate reductase assays; and drilling and sampling soil borings for analysis of organic carbon and other key soil parameters.

Potrero Canyon Unit Results

Two primary mechanisms are identified by which contaminants are attenuated in the Potrero Canyon Unit groundwater plume: (1) discharge by evapotranspiration, and (2) degradation due to reducing conditions in the riparian area. Evapotranspiration in the riparian area is estimated to discharge approximately 130 acre-feet per year of groundwater, or 70 percent of the Potrero Canyon Unit groundwater plume volumetric flow rate. This finding is supported by several independent lines of evidence, including the recent riparian area plant survey and groundwater plant uptake study which showed significant concentrations of perchlorate in leaf tissue samples collected from riparian plants and trees. Evapotranspiration also removes approximately 40 pounds per year of all site groundwater contaminants (perchlorate, chlorinated volatile organic compounds, and 1,4-dioxane) from the plume, or approximately 22 percent of the Potrero Canyon Unit groundwater plume mass flux rate. The percent of plume mass flux removed by evapotranspiration (22 percent) is smaller than the percent of plume volumetric flow removed by evapotranspiration (70 percent) due to the removal of perchlorate and chlorinated volatile organic compounds by degradation prior to groundwater withdrawal by evapotranspiration.

Contaminant degradation in the riparian area is estimated to remove 135 pounds per year of perchlorate and chlorinated volatile organic compounds from the Potrero Canyon Unit plume, or 72 percent of the Potrero Canyon Unit groundwater plume mass flux rate. This finding is supported by several independent lines of evidence, including a perchlorate biodegradation bench scale test using a bioreactor constructed from site groundwater and site sediments. Data collected in this investigation also indicates that there is enough organic carbon in the riparian area aquifer sediments to support continued contaminant degradation for several hundreds of years into the future. Thus, the natural attenuation capacity Potrero Canyon Unit aquifer appears to be equal to or greater than the plume contaminant mass flux, both now and for the foreseeable future.

The combined plume contaminant mass flux removal rate due to both evapotranspiration and degradation is 175 pounds per year, or 95 percent of the plume contaminant mass flux. Since natural contaminant attenuation processes appear to currently remove a substantial portion of the current plume contaminant mass flux, natural contaminant attenuation processes will play a significant role in the overall cleanup strategy for the site. This topic will be addressed further in the upcoming site feasibility study.

Laborde Canyon Results

The Laborde Canyon investigation could not identify any significant mechanisms by which contaminants are currently being attenuated within the Site groundwater plume. Thus, if any attenuation currently exists within the plume, it must be at a very small rate relative to the plume mass flux rate.

Within the overall Laborde Canyon area, there are two potential attenuation mechanisms that may be possible in the Offsite riparian area south of the site boundary: discharge by evapotranspiration and degradation. However, since the plume has not yet migrated into the Offsite riparian area, it is difficult to assess with confidence the roles these processes may play on the future plume fate.

Since natural contaminant attenuation processes do not currently appear to remove a substantial portion of the current plume contaminant mass flux, natural contaminant attenuation processes may play a limited role in the overall cleanup strategy for the sites. This topic will be addressed further in the upcoming site feasibility study.

SECTION 1 INTRODUCTION

This Contaminant Attenuation Evaluation Report (Report) was prepared by Tetra Tech, Inc. (Tetra Tech) on behalf of Lockheed Martin Corporation (LMC) for Potrero Canyon Unit (Lockheed Martin Beaumont Site 1), located in the south and south western portions of the City of Beaumont, and Laborde Canyon (Lockheed Martin Beaumont Site 2), located in an unincorporated area of the county southwest of the City of Beaumont, in Riverside County, California (Figure 1-1). The Report presents the results of the activities performed for the contaminant attenuation evaluation which is being conducted to determine the dominant contaminant attenuation processes for each site and how contaminant attenuation may fit into the overall cleanup strategy for the sites.

1.1 STUDY OBJECTIVES AND APPROACH

The objectives of this study are to:

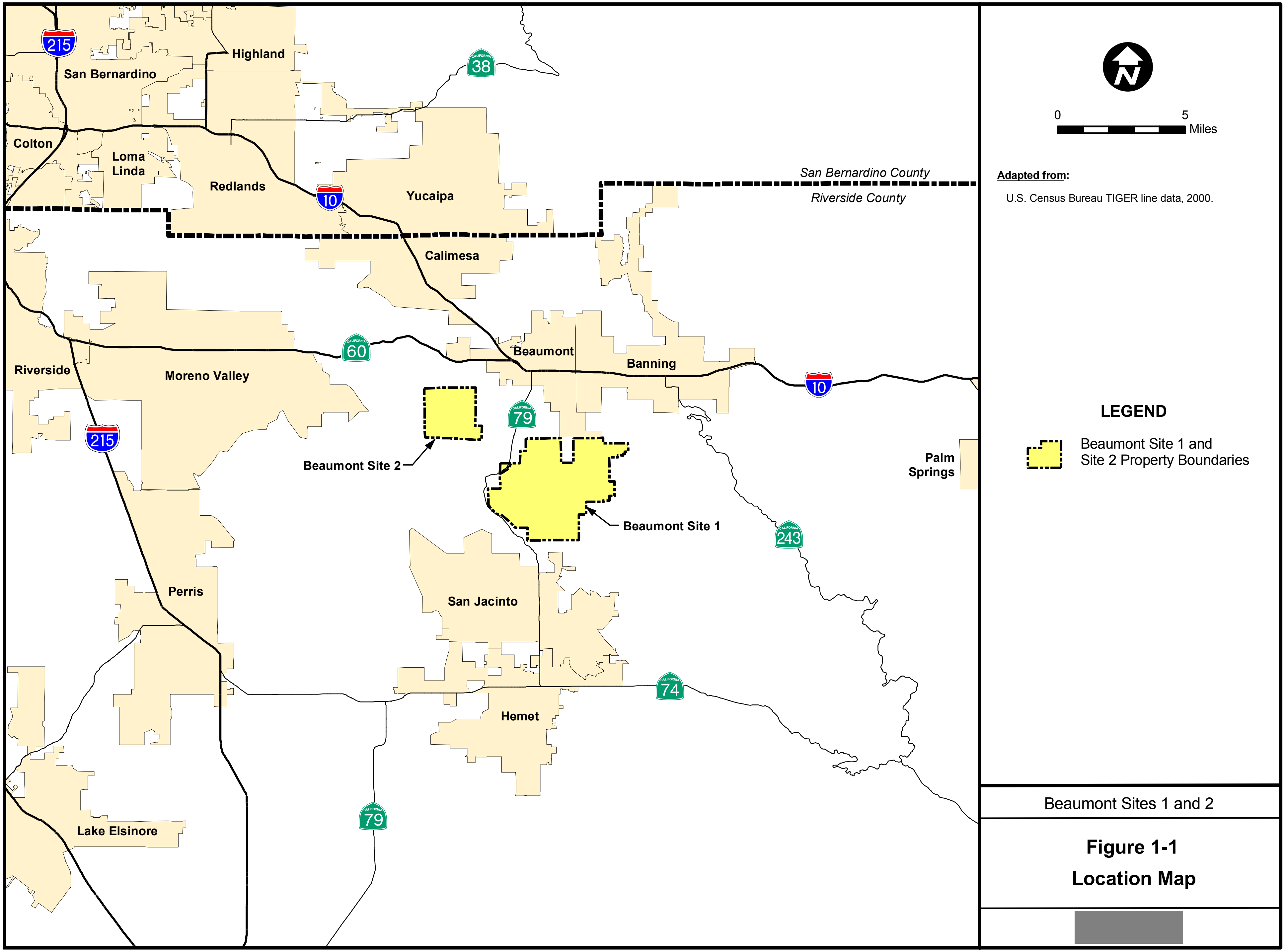
- Evaluate the naturally occurring contaminant attenuation processes at the sites at a level that is sufficient to support the assessment of this process in the feasibility studies; and
- Assess what role contaminant attenuation processes may play in the overall cleanup strategy for the sites.

Specific issues addressed include estimating the Potrero Canyon Unit and Laborde Canyon aquifer water budget and geochemical species mass and mass flux budget, and estimating the impact of the riparian areas on the respective groundwater plumes.

The approach for the study includes the following:

- Develop a preliminary contaminant attenuation conceptual site model (CSM) for Potrero Canyon Unit and Laborde Canyon;
- Evaluate the preliminary CSM for data gaps, and conduct a contaminant attenuation focused data collection effort at Potrero Canyon Unit and Laborde Canyon to fill these data gaps;

X:\GIS\Lockheed 23521-0601\Region_2 Sites.mxd



Adapted from:

U.S. Census Bureau TIGER line data, 2000.

Beaumont Sites 1 and 2

Figure 1-1
Location Map

- Prepare refined contaminant attenuation CSMs for Sites 1 and 2 based on the results of the focused data collection; and

- Estimate the natural attenuation capacity of the aquifers for the Potrero Canyon Unit and Laborde Canyon COPCs.

Development of the preliminary contaminant attenuation CSM and the recommended contaminant attenuation focused data collection were previously reported in two prior site Technical Memorandums (Tetra Tech, 2010f and 2011a).

The preliminary contaminant attenuation CSM builds on the CSM presented in three prior site groundwater modeling reports (Tetra Tech, 2010b; 2010e; and 2011b).

Based on the data gaps identified in the contaminant attenuation CSM Technical Memorandums referenced above, a plant density survey to further evaluate evapotranspiration and additional soil/groundwater data collection were recommended for the focused data collection effort. The focused data collection was conducted in late 2010 and early 2011. In addition to the data gaps identified in the technical memorandums, the Department of Toxic Substances Control (DTSC) requested that a bench scale microcosm study utilizing groundwater and sediments from the riparian areas from Potrero Canyon Unit be conducted in order to verify whether or not perchlorate biodegradation is naturally occurring as the empirical evidence suggests.

1.2 REPORT ORGANIZATION

This report presents the results of these focused data collection efforts, and an update of the Potrero Canyon Unit and Laborde Canyon contaminant attenuation CSMs along with estimates of the COPCs natural attenuation capacity of the respective aquifers. Section 1 presents the study introduction, objectives, and approach; Section 2 summarizes the site CSMs; Section 3 summarizes the field investigation activities; Section 4 presents the contaminant attenuation sampling results and discussion; Section 5 presents updated contaminant attenuation CSMs for Potrero Canyon Unit and 2; and Section 6 presents the conclusions and recommendations.

SECTION 2 CONCEPTUAL SITE MODEL SUMMARIES

A brief summary of the conceptual site models for Sites 1 and 2 are included in this section to present an overall understanding of each site with respect to the site history, setting, and nature and extent of contamination. The CSM summaries focus on the hydrogeology and nature and extent of contamination for each site as those aspects of the CSM are more relevant to the evaluation of contaminant attenuation within the aquifer.

2.1 POTRERO CANYON UNIT CSM

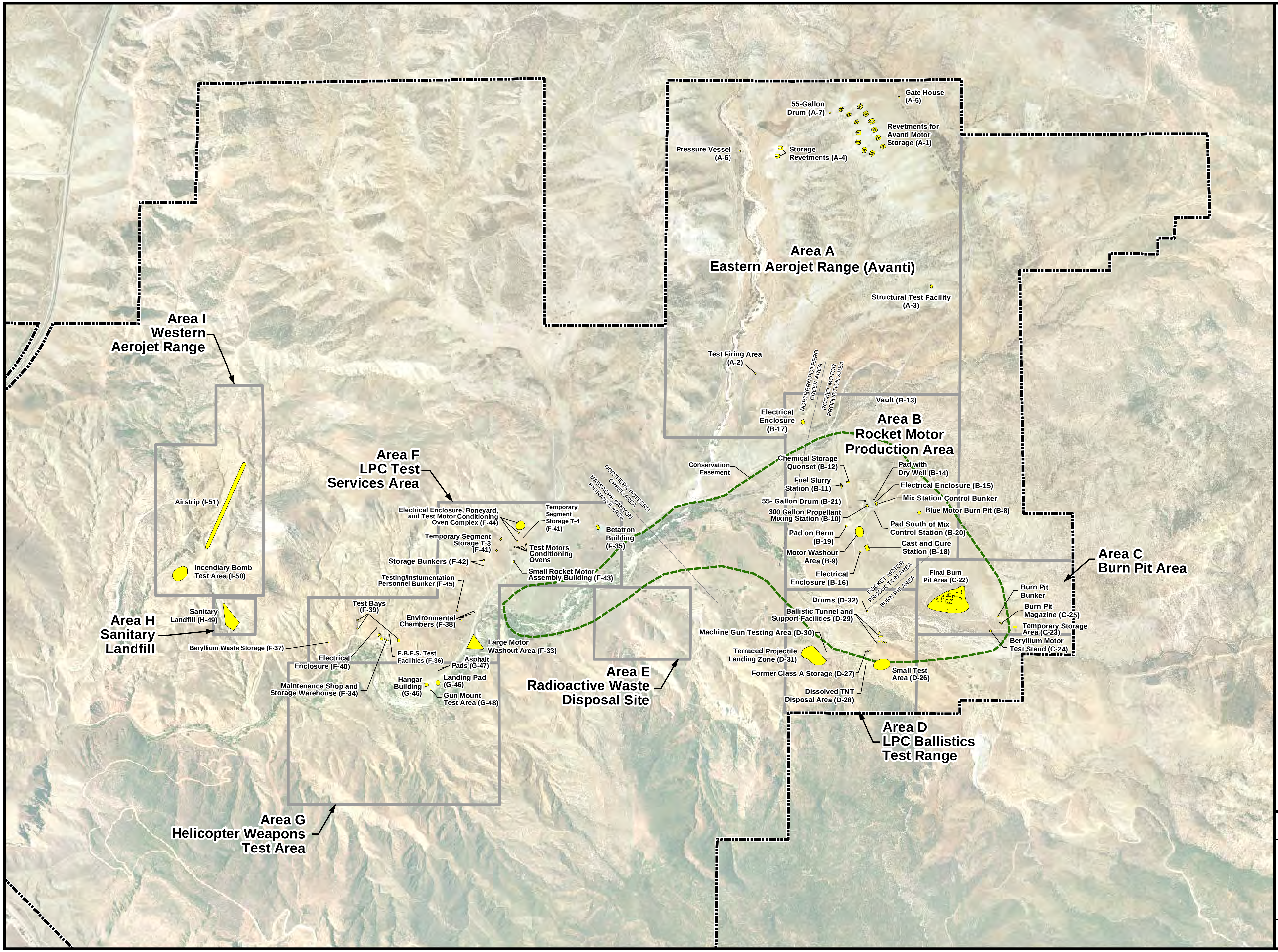
2.1.1 Background

Potrero Canyon Unit is a 9,117-acre parcel located in the southern portion of Beaumont, California (Figure 1-1). The Site was primarily used for ranching prior to 1960. From 1960 to 1974, the Site was used by Lockheed Propulsion Company (LPC) for solid rocket motor and ballistics testing. Activities at the Site also included the disposal and burning of process chemicals and waste rocket propellants in an area commonly referred to as the burn pit area (BPA).

Nine (9) primary historical operational areas have been identified at the Site. Potrero Canyon Unit historical operational areas and features are presented in Figure 2-1. Each historical operational area was used for various activities associated with ballistics testing, rocket motor assembly, testing, and propellant disposal. Significant groundwater contamination was found in Site investigations in the Rocket Motor Production Area (RMPA) and the BPA. Details on the historical operations at the site and previous environmental investigations are provided in the Summary Remedial Investigation Report (Tetra Tech, 2010c).

Two groundwater remediation systems were historically installed and operated at Potrero Canyon Unit: the RMPA Groundwater Extraction and Injection System and a combined dual-phase groundwater/SVE remedial system in the BPA. The RMPA Groundwater Extraction and Injection System operated from August 1994 through December 2002. Groundwater was extracted from wells EW-1 and EW-2, treated, and re-injected into wells IW-1 to IW-5. A total of 124 million gallons of groundwater was extracted and re-injected from the Bedsprings Creek alluvium during this period at an average rate of about 30 to 55 gpm. Upon shutdown, the RMPA system had extracted a cumulative total equal to three-quarters of a pore volume of the 400 µg/L Total VOCs

X:\GIS\Lockheed 25421-01-0603\Site.mxd



Adapted from: March 2007 aerial photograph.

LEGEND

- Historic Feature Location
- Conservation Easement Boundary
- Historical Operational Area Boundary
- Potrero Canyon Unit Property Boundary (Lockheed Martin Beaumont Site 1)

Note: Beaumont Site 1 property boundary is approximate.

Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 2-1
Historical Operational Areas, Site Features, and Conservation Easement

TETRA TECH

plume targeted for cleanup, or about one-quarter of a pore volume of the entire plume. The combined dual-phase groundwater/SVE remedial system was operated at the BPA from August 1994 through July 1998 to treat soils and very shallow groundwater in low permeability bedrock of the Mount Eden formation (MEF), extracting groundwater at a total system flowrate of 2 gpm and soil vapors at a total system flowrate of approximately 200 SCFM. Upon shut-down, the BPA two-phase system had reduced soil vapor concentrations from 147,800 ppbv to 1,370 ppbv.

Groundwater level and water quality monitoring has been conducted on a routine basis from 1990 to monitor the Potrero Canyon Unit groundwater plume and the progress of the BPA and RMPA remedial operations. The results of groundwater monitoring activities are summarized twice per year along with a presentation of the most current site conceptual model in the site groundwater monitoring semi-annual reports.

2.1.2 Physical Setting

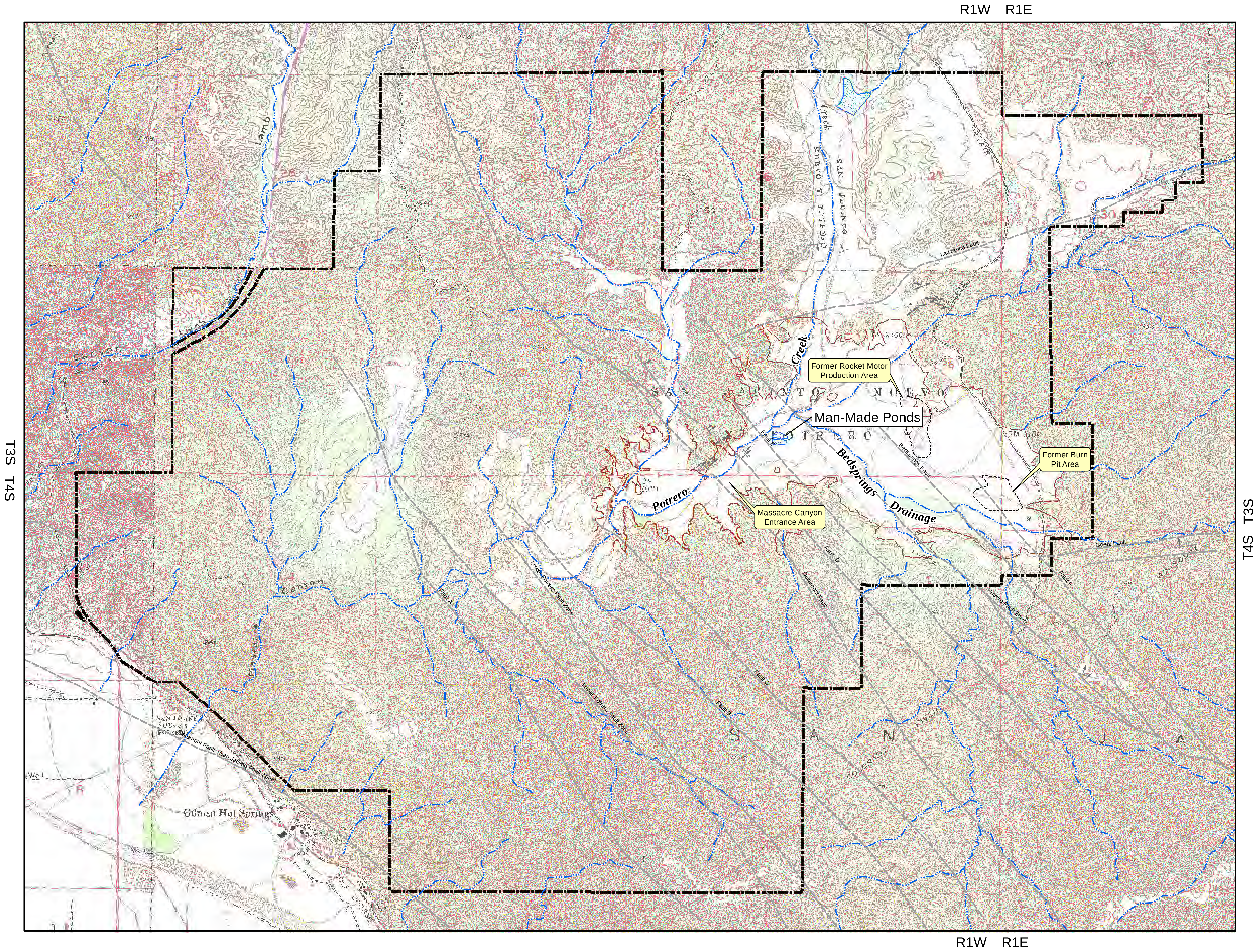
The Site is located in the southern portion of the city of Beaumont, in a semi-arid region of southern California, at the northern end of the Peninsular Ranges Geomorphic Province (Harden, 1998). Locally, the Site is situated in a small valley (which was part of the San Jacinto Nuevo y Potrero Ranchero) in the northwestern foothills of the San Jacinto Mountains (Figure 2-2). The area is referred to as the Potrero Valley. Southwest of Potrero valley, the topographic gradient of the valley steepens toward Massacre Canyon and flattens out when it opens up into the San Jacinto Valley past the mountain range present on the south side of the property.

2.1.3 Geology

Based on seismic reflection studies and detailed geologic mapping conducted during the lineament study (Tetra Tech, December 2009, Appendix L), numerous faults are present in the area, particularly in the Bedsprings and Potrero Creek areas. Faults that cross Potrero Valley are not well expressed in the younger alluvial sediments indicating that the faults are older than the most recent sediments. Borehole data and geophysical surveys conducted throughout Bedsprings drainage and the upper part of Potrero Creek supports the presence of numerous faults; however, their influence on groundwater flow is still not completely understood.

Three lithologic units have been identified at the Site: the Granitic/Metasedimentary rocks, the MEF, and the younger QAL. The STF is present along the northern part of Potrero Canyon Unit (Dibblee, 2003); however, soil impacts, affected groundwater, and related hydrogeology is not influenced by this unit because it is not present in Potrero Valley where soil and groundwater has been affected by site activities.

X:\GIS\Lockheed 25421-01-0603\TOPO.mxd



Adapted from:

USGS 7.5' Topographic Quadrangles, El Casco, Lakeview, San Jacinto, and Beaumont.

Faults from structural analysis of Potrero Valley, *Lineament and Geologic Mapping Study, Tetra Tech, 2009.*

LEGEND

- Potrero Canyon Unit 1 Property Boundary (Lockheed Martin Beaumont Site 1)
- Intermittent Creek/Drainage
- Mt. Eden/Alluvium Surface Contact
- Fault, Accurately Located Showing Dip
- Fault, Approximately Located

Note: Beaumont Site 1 property boundary is approximate.

Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 2-2
Physical Setting

TETRA TECH

2.1.4 Hydrogeology

Several previous reports discuss in detail the occurrence and movement of groundwater at the Site (Leighton and Associates, 1983; Radian, 1990; Radian, 1992b). A summary of general findings from these reports is provided in this section along with an update on the current understanding of aquifer properties and groundwater flow based on recent site investigations

Hydrostratigraphy

Groundwater occurs in each of the major geologic units encountered beneath the Site; the QAL, the MEF, and the Granitic/Metasedimentary rock. Groundwater is present in the QAL in the majority of the valley except in areas where the underlying MEF rises above the surrounding water table (the BPA in particular). In general, groundwater is present in weathered and more competent portions of the MEF, either where QAL is not present at the water table (the water table is deeper) or at depth below the saturated QAL. Based on a limited number of monitoring wells drilled into the Granitic/Metasedimentary rock, groundwater is also present in the basement rock, however, the degree to which water is present appears largely dependent on the fractured nature of the basement rock itself. Wells installed into the basement rock to date have been installed near known fault zones and the water is likely the result of highly fractured basement material related to tectonic activity in the area.

Although the QAL and weathered MEF are 2 different lithologic units, potentiometric heads, water level responses to seasonal recharge, and water quality data, indicate that the 2 units are hydraulically connected. Previous reports indicate that the 2 units, while having varying hydraulic conductivities, are in hydraulic communication (Radian, 1992b). Based on a limited number of wells that have been installed within the deeper, more competent MEF, there appears to be some hydraulic separation between the deeper, more competent MEF and the shallower, highly to moderately weathered portion of the MEF and overlying QAL. The thickness of this weathered MEF appears to be variable depending on its proximity to faults and possibly the fractured nature of the sandstone at depth. The weathered MEF wells tend to respond to rainfall events rather rapidly while the wells screened in the deeper MEF respond more slowly both to recharge and discharge and have peak water levels that tend to be significantly lower than the shallower screened wells (Figure 5-11).

Groundwater Flow

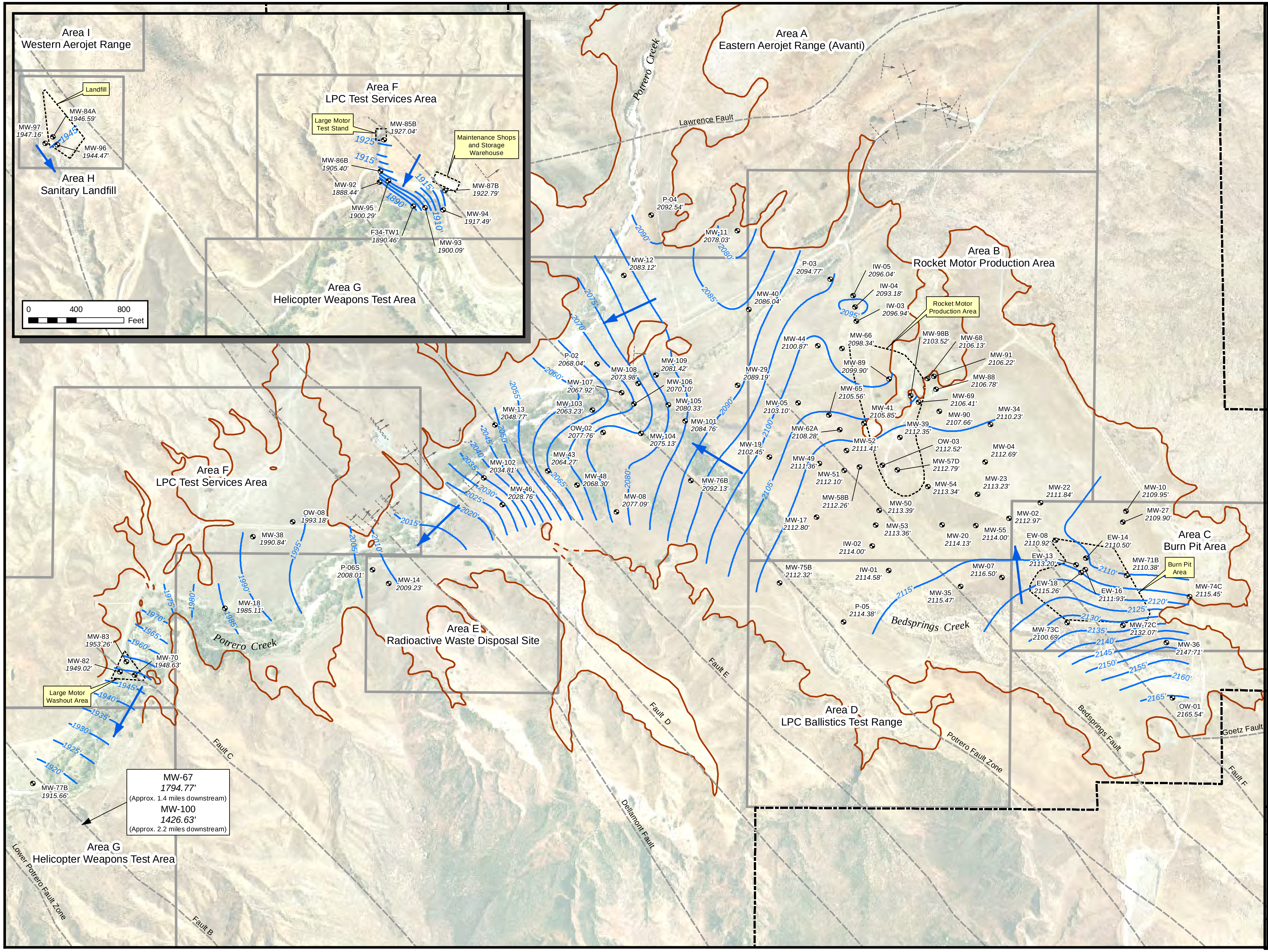
Groundwater flow through the Site mainly occurs in the QAL and weathered MEF. To a lesser extent groundwater also flows through the deeper, more competent MEF and the fractured Granitic/Metasedimentary rock. Generally, groundwater flow through the Site begins just south of the BPA where major drainages channel runoff from the foothills of the San Jacinto Mountains into Potrero Valley. Groundwater flow is directed northwest through the BPA toward the RMPA. North of the RMPA, groundwater flow turns west southwest to parallel surface water flow along Potrero Creek. Figure 2-3 presents the groundwater contours from shallow wells across the Site to depict the general groundwater flow direction and gradient. Based upon the very low gradients and aquifer thickening between the RMPA and BPA, aquifer transmissivity is likely higher to some degree in this area.

Groundwater flow direction from the former BPA downgradient through the former RMPA appears to change between periods of low precipitation (dry periods) and periods of high precipitation (wet periods). During wet periods, groundwater flow from the former BPA has both westerly and north northwesterly components. However, during dry periods the groundwater flow direction from the former BPA is more westerly. This seasonal change in flow direction likely is caused by increased recharge in the Bedsprings Creek area during wet periods and subsequent decrease in recharge during dry periods.

Based on the current understanding, the MEF outcrop that extends from the east to the west at the RMPA is thought to be a bedrock barrier to the downgradient flow of groundwater to the north. Based on groundwater data from monitoring wells located around this bedrock high, groundwater flow appears to wrap around the bedrock exposure and continue northwest toward the confluence of the Bedsprings Creek and Potrero Creek.

Downgradient of the RMPA, water levels from shallow groundwater monitoring wells show that the groundwater flow direction turns southwest and parallels the flow of surface water in Potrero Creek. Surface water flow enters from the south along the Bedsprings drainage and merges with surface water flow from Potrero Creek to the north and from an unnamed drainage that enters from the east near piezometer P-03. In this area of the Site, groundwater movement appears to be influenced by either; parallel to subparallel faults that possibly created a filled graben or, constriction of groundwater flow due to the presence of more competent MEF near the surface west of the Potrero Fault, or both.

X:\GIS\Lockheed 25421-01-0603\GW_Cont_Q211.mxd



0 500 1,000 Feet

Adapted from: March 2007 aerial photograph.

Faults from structural analysis of Potrero Valley, *Lineament and Geologic Mapping Study, Tetra Tech, 2009.*

LEGEND

MW-10 2107.31' ●	Monitoring Well Location with Groundwater Elevation (June 2011)
↗	Fault, Accurately Located Showing Dip
⟋	Fault, Approximately Located
⌒	Groundwater Elevation Contour
⌒	Bedrock/Alluvium Surface Contact Dashed where inferred
←	Groundwater Flow Direction
◌	Source Areas
⊏	Potrero Canyon Unit Property Boundary (Lockheed Martin Beaumont Site 1)
⊏	Historical Operational Area Boundary

Notes: Beaumont Site 1 property boundary is approximate.

5-foot contour interval.

MW-73C was not used for groundwater contours.

Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 2-3
Second Quarter (June) 2011 Groundwater Contours for Alluvium and Weathered Mount Eden Formation

TETRA TECH

Further west down Potrero Creek, groundwater flow is west–southwest coincident with Potrero Creek. Alluvial sediments in this area of the Site are typified as being rather fine grained for the first 20 to 35 feet and are then dominated by coarse grained sediments at depth. The hydraulic conductivities also suggest that the deeper part of the alluvial aquifer in this area of the Site is more permeable.

Further downgradient, the more competent MEF is near the surface and appears to force the groundwater to the surface. Mapping of the QAL/bedrock interface in the area of Potrero Creek indicates that Potrero Creek has no more than 15 feet of QAL in the active channel. Mapping of the QAL/bedrock contact from this area to the southwestern property boundary suggests that bedrock is shallow and the QAL is thin to nonexistent. Only in major bends of Potrero Creek are significant deposits of QAL present. Depth to water in this area is also very shallow (on the order of 5 to 20 feet bgs).

Based on the limited number of wells, nature of fracture flow, and the presence of numerous faults at the Site, the groundwater flow directions in the deeper Mount Eden Formation and Granitic/Metasedimentary Rock are uncertain. In general, the groundwater flow direction in the deeper MEF follows the same trend as the shallow QAL/weathered MEF groundwater flows. However, based on the groundwater contours a saddle shaped groundwater divide is present for the Granitic/Metasedimentary rock wells along the northern portion of the BPA. A northwesterly component of flow may be present in the northern part of the BPA, which is similar to groundwater flow represented by wells screened in the alluvium; however, this interpretation is based on very limited water level data. The apparent reversal of groundwater flow may be related to faults that pass through the area, or could be related to extensive fractures within the basement rock that is associated with the tectonic setting of the area.

Hydraulic Conductivity

Hydraulic conductivity (K) values were calculated using various methods including traditional long-term pumping tests, the modified specific capacity test method, and slug tests. K values in the QAL ranged from 0.16 to 137 ft/day with the highest conductivities found in the deeper coarse-grained sediments northeast of the BPA and in the area west of the confluence of Potrero Creek and Bedsprings Creek. K values from wells screened within the MEF were much lower ranging from 0.13 to 2.3 ft/day. Published K values for competent sandstone are on the order of 0.01 ft/day (Heath, 1987). Even lower K values were calculated from wells screened within the Granitic/Metasedimentary rock which ranged from 0.0096 to 0.54 ft/day. Based on published hydraulic conductivities, competent granite has conductivity values of 0.001 ft/day (assuming that the fracturing is not intense but does exist). Areas near fault zones are likely to have higher conductivities and areas away from faults (and thus fewer fractures) would have lower conductivities (Heath, 1987).

2.1.5 Nature and Extent of Contamination

An overall sitewide description of the nature and extent of soil, groundwater, and surface water contamination is presented in this section. Detailed descriptions of the nature and extent of contamination by feature can be found in the Summary Remedial Investigation Report (Tetra Tech, 2010c).

2.1.5.1 Nature and Extent of Soil Contamination

This section summarizes the site wide nature, magnitude, and extent of affected soil based on all existing sampling data collected since 2002. An overall site wide description of the soil source areas and extent of impacts is provided in this section for the three primary soil COPCs at the Site (perchlorate, TCE, and PCBs). Although 1,4 dioxane is also a primary site COPC with respect to groundwater, it has not been detected in soil other than a couple of locations outside the BPA at concentrations near the MDL (0.005-0.031 mg/kg) and therefore is not considered a primary soil COPC for the Site.

Perchlorate

The highest concentrations of perchlorate in soil have been detected at the BPA (Feature C-22 at 171,000 µg/kg), the primary source area located in the southeastern portion of the Site in Operational Area C, and the Large Motor Washout Area (at 302,000 µg/kg) located in the western portion of the Site in Operational Area F. Relatively high concentrations (up to 20,400 µg/kg) have also been detected in the RMPA which is considered a secondary source area for perchlorate in soil in comparison to the BPA. In general, the perchlorate concentrations at the RMPA are an order of magnitude less than the BPA but have a much larger areal extent, possibly due to the transport mechanism resulting from the historical operations (processing and mixing of rocket motor solid propellants and motor washouts) which may have governed the distribution of perchlorate on the surface and eventually into the subsurface. In addition, the operations at the RMPA used the largest quantities of perchlorate at the Site since it is here where the processing and mixing of rocket motor solid propellants was conducted.

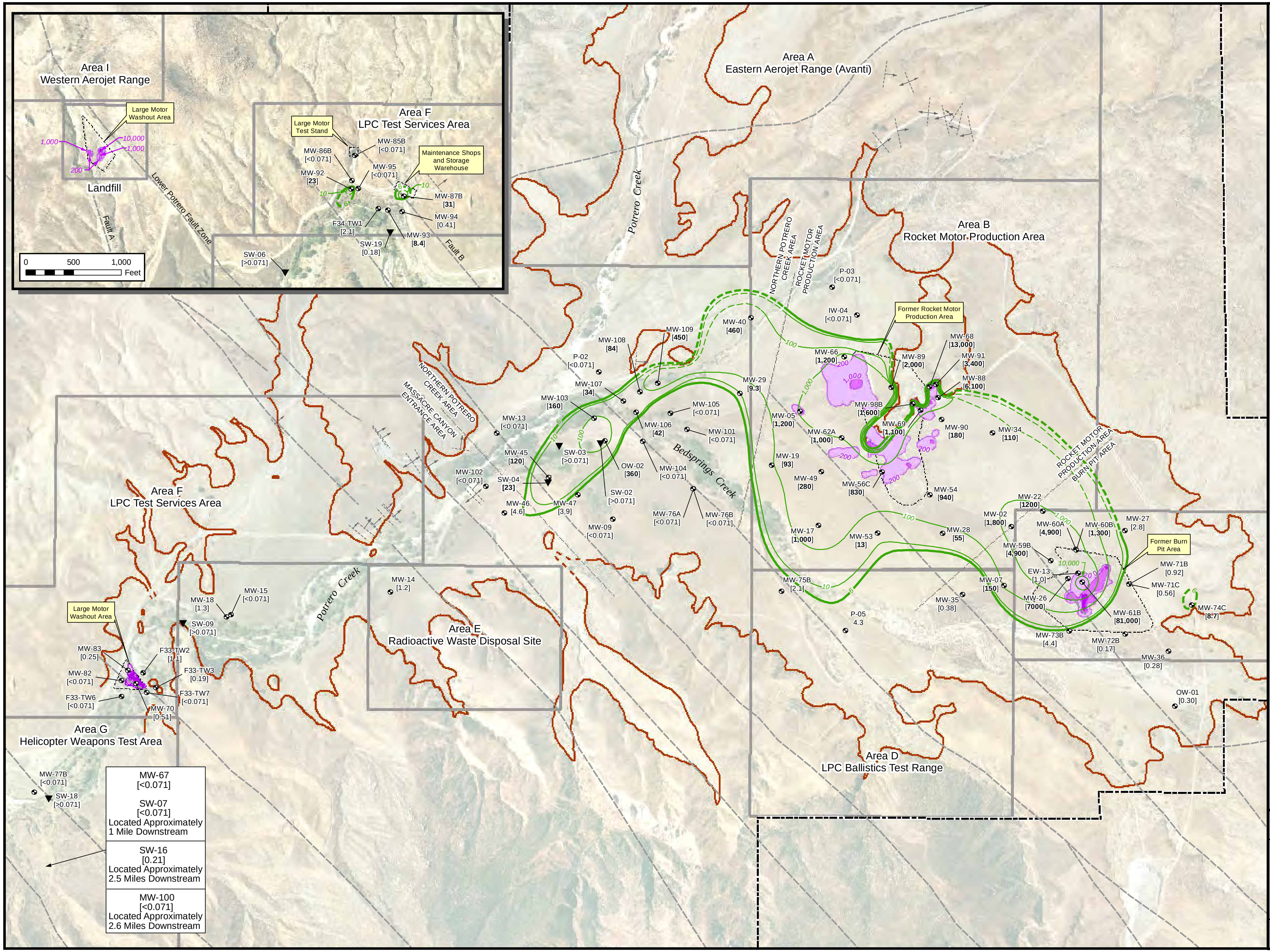
Also, motor washout areas traditionally use significant amounts of water as part of their operation. This coupled with the high solubility of perchlorate could explain the wide distribution of low level perchlorate in this area.

Figure 2-4 shows the site-wide distribution of perchlorate in soil and groundwater. As shown in this Figure, the high soil concentration areas (Features C-22, B-10, B-14, and B-11) also have a shadow of perchlorate impacts in groundwater above 1,000 µg/L immediately below or downgradient of the soil source areas. This trend observed in the eastern portion of the Site is not present in the western portion at the Large Motor Washout Area, the Maintenance Shop and Storage Warehouse Area, Test Bays (Feature F-39), and Sanitary Landfill (Feature H-49) (Figure 2-4). At the Large Motor Washout Area, only low concentrations (<10 µg/L) are detected in groundwater below the soil source area that has the highest reported perchlorate soil concentrations at the Site. Groundwater monitoring data indicates that in addition to other natural attenuation processes, the anaerobic conditions in this riparian area are biodegrading the perchlorate that has migrated into groundwater. Further south at Features F-34 and F-39, perchlorate has been detected at relatively low concentrations (<50 µg/L) in groundwater but only sporadic detections have been found within the surface water downgradient of these features. At the Sanitary Landfill, perchlorate has been detected up to 67,300 µg/kg in shallow soils (0.5-foot bgs) and up to 5,000 µg/kg at 40 feet bgs. However, groundwater samples collected at a depth of approximately 90 feet bgs reported only low level detections during the initial sampling event in February 2009. Perchlorate was not detected above the MDL in any of the wells during the later sampling events in 2009 and the most recent sampling event in June 2010.

TCE

The only TCE soil source identified at the Site is the BPA which was remediated through excavation and SVE in the mid to late 1990s with the system being shutdown in 1998 after VOC concentrations had decreased by 99.6%. Elevated concentrations of TCE in soil gas still remain at the BPA which is attributed to off gassing of affected groundwater beneath this feature and/or possibly residual contamination in the vadose zone. Although TCE impacted groundwater was also detected at Features F-34 and F-39, no soil source was identified at either feature. The soil gas concentrations and trends at these features indicate off gassing of the TCE impacted groundwater and therefore soil source areas may no longer be present. Figure 2-5 shows the TCE soil source at the BPA along with extent of TCE impacts in groundwater.

Path: X:\GIS\Lockheed 25421-01-0603\Perc_Sources_2.mxd



MW-67
[<0.071]

SW-07
[<0.071]
Located Approximately
1 Mile Downstream

SW-16
[0.21]
Located Approximately
2.5 Miles Downstream

MW-100
[<0.071]
Located Approximately
2.6 Miles Downstream

0 500 1,000 Feet

Adapted from: March 2007 aerial photograph.

Faults from structural analysis of Potrero Valley, *Lineament and Geologic Mapping Study, Tetra Tech, 2009.*

LEGEND

MW-22 [340] ●	Well ID Perchlorate Concentration
SW-07 [23] ▼	Surface Water Sample Location Perchlorate Concentration
	Perchlorate in Groundwater Concentration Contour (µg/L) - Dashed where inferred
	MCL Contour (6.0 µg/L) - Dashed where inferred
	Bedrock/Alluvium Surface Contact Dashed where inferred
	Fault, Accurately Located Showing Dip
	Fault, Approximately Located
	Source Areas
	Historical Operational Area Boundary
	Potrero Canyon Unit Property Boundary (Lockheed Martin Beaumont Site 1)

Perchlorate Concentration in Soil

- >200 µg/kg
- >1,000 µg/kg
- >10,000 µg/kg
- >100,000 µg/kg

Notes:

MCL - Maximum Contaminant Level.
Concentrations shown are in microgram per liter (µg/L)

Highest concentration shown is contoured for clustered or nested well locations.

Bold indicates MCL value exceeded.

Beaumont Site 1 property boundary is approximate.

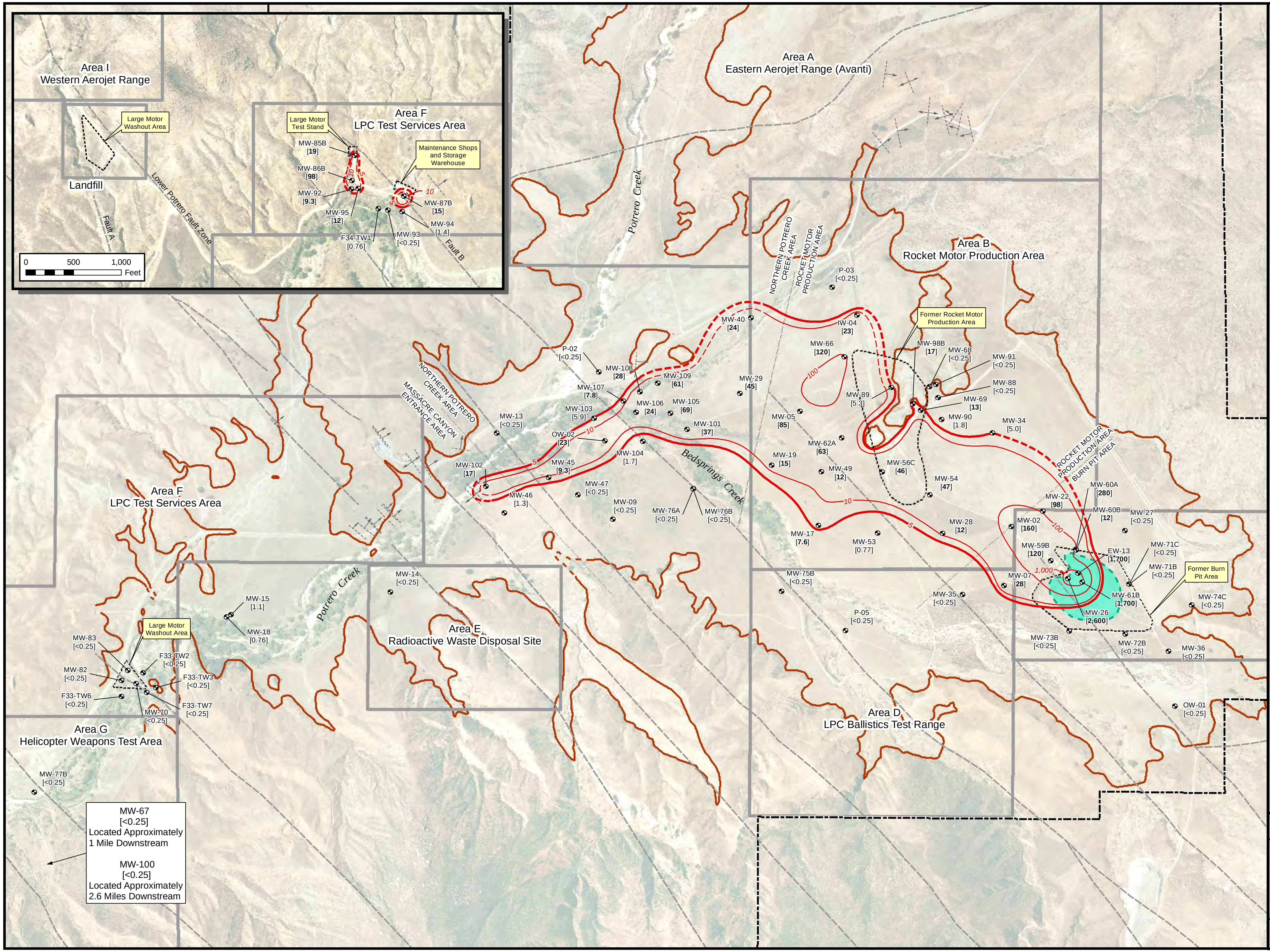
Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 2-4

Perchlorate Soil Source Areas and Groundwater Impacts Second Quarter 2011

TETRA TECH

X:\GIS\Lockheed 25421-01-06\03TCE.mxd



MW-67
[<0.25]
Located Approximately
1 Mile Downstream

MW-100
[<0.25]
Located Approximately
2.6 Miles Downstream

N

0 500 1,000 Feet

Adapted from: March 2007 aerial photograph.

Faults from structural analysis of Potrero Valley, *Lineament and Geologic Mapping Study, Tetra Tech, 2009.*

LEGEND

MW-22 [340] ⊕	Well ID TCE Concentration
	TCE in Groundwater Concentration Contour (µg/L) - Dashed where inferred
	MCL Contour (5.0 µg/L) - Dashed where inferred
	Bedrock/Alluvium Surface Contact Dashed where inferred
	Fault, Accurately Located Showing Dip
	Fault, Approximately Located
	Source Areas
	Historical Operational Area Boundary
	Potrero Canyon Unit Property Boundary (Lockheed Martin Beaumont Site 1)

Trichloroethene (TCE) in Soil

🟩	VOC Soil Source Area

Notes:

MCL - Maximum Contaminant Level.
Concentrations shown are in microgram per liter (µg/L)

TCE - Trichloroethene.

Highest concentration shown is contoured for clustered or nested well locations.

Bold indicates MCL value exceeded.

Beaumont Site 1 property boundary is approximate.

Portero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 2-5
TCE Soil Source Area and Groundwater Impacts Second Quarter 2011

TETRA TECH

PCBs

PCBs were detected at four features with very localized shallow impacts at three of the four features [Betatron Building (F-35), E.B.E.S. Testing Area (F-36), and Electrical Enclosure (F-40)]. At the Sanitary Landfill, PCBs were detected in several areas and appear to be fairly localized and limited to shallow soils except on the east side where PCBs were detected at 20 feet bgs in two locations. Figure 2-6 shows the lateral extent of PCB impacts at Betatron Building, E.B.E.S. Testing Area, and Electrical Enclosure.

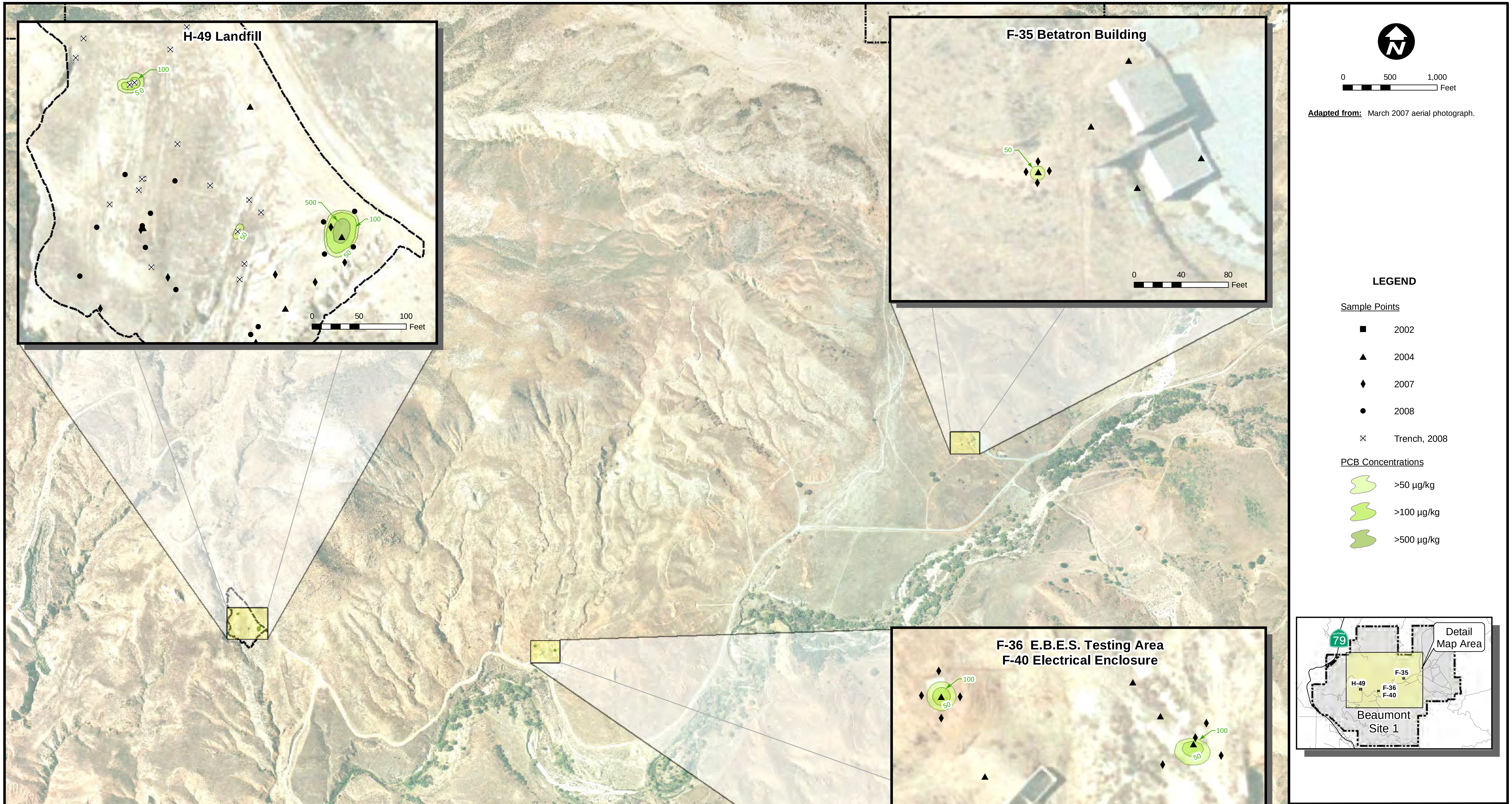
2.1.5.2 Nature and Extent of Groundwater Contamination

Based on Site history and the results of the groundwater monitoring performed at the Site, a list of primary COPCs was identified. Additional chlorinated compounds, which have also been routinely detected in groundwater samples, are considered secondary COPCs. The groundwater COPCs identified for the Site based on past site activities and groundwater monitoring results include perchlorate, 1,1-DCE, TCE, 1,4-dioxane, 1,1-DCA, 1,2-DCA, cis-1,2-DCE, and 1,1,1-TCA. The primary groundwater COPCs which are detected most frequently and at the highest concentrations are perchlorate, 1,1-DCE, TCE, and 1,4-dioxane. The primary COPCs are considered representative of the overall Site; therefore, the following subsections are limited to describing the distribution of primary COPCs affecting groundwater at the Site.

In general the Potrero Canyon Unit groundwater plume has remained relatively stable over time. Slight modifications to the definition of the plume over time are generally the result of newly installed wells better defining the lateral extent of the plume.

Perchlorate

The highest concentrations of perchlorate (up to 141,000 µg/L) have been reported in groundwater samples collected from the uppermost bedrock zone located in the BPA (Feature C-22) and concentrations appear to rapidly decrease outside, and downgradient, of the former BPA. The rapid decrease in concentrations is due to the fact that the high concentrations within the primary source area are tied up in the low permeability sandstone and slowly diffuse out into the alluvial valley where there is a much larger volume of water present thus resulting in a rapid decline in concentrations. However, secondary perchlorate source areas are also present at the RMPA including the Motor Washout Area (Feature B-9), the Propellant Mixing Station (Feature B-10), the Fuel Slurry Station (Feature B-11), and the Pad with Dry Well (Feature B-14). Perchlorate was detected in groundwater samples collected from wells within the RMPA source areas ranging from 1,600 to 14,000 µg/L. These perchlorate concentrations are elevated in comparison to concentrations in nearby wells that represent migration of perchlorate from the BPA plume (TCE, 1,1-DCE, 1,4-dioxane, perchlorate). Based on the presence of low concentrations of TCE,



X:\GIS\Lockheed 25421-01-0603\PCBs.mxd

Potero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 2-6

Lateral Extent of PCB in Soil Impacts, F-35, F-36, F-40 and H-49

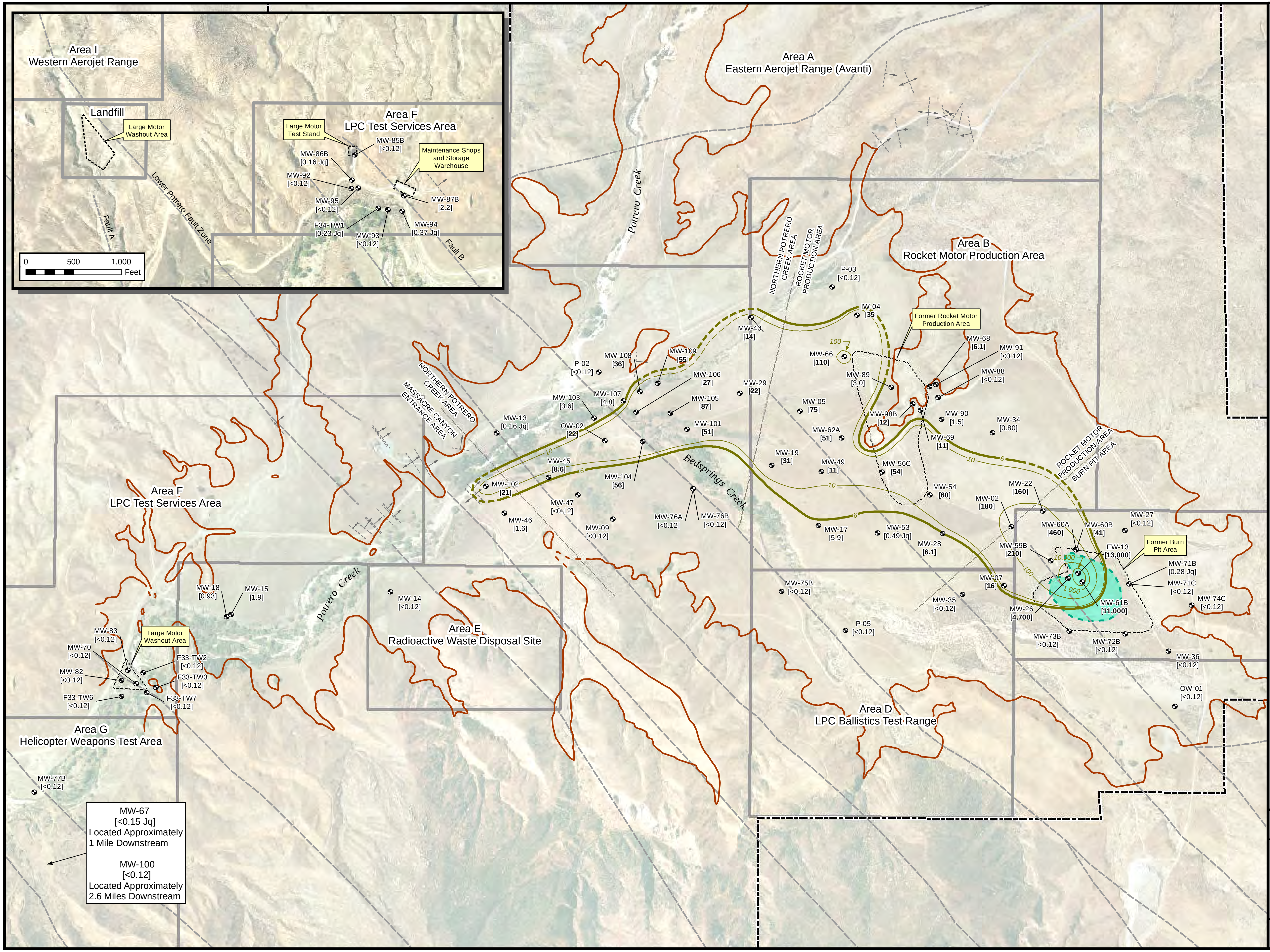
TETRA TECH

1,1-DCE, and 1,4-dioxane in the RMPA, it is thought that the BPA plume migrates into this area after significant storm events when the groundwater flow directions change from northwest to northeast within the main alluvial valley. The vertical extent of perchlorate in groundwater at the RMPA has been characterized with perchlorate concentrations decreasing rapidly with depth. Low concentrations of perchlorate on the order of 10 to 50 µg/L have also been detected at the Large Motor Washout Area, the Maintenance Shop and Storage Warehouse Area (Feature F-34), and the Test Bays (Feature F-39). The highest concentrations of perchlorate have been detected in the alluvium and the shallow weathered Mount Eden formation. However, low concentrations of perchlorate have also been detected in groundwater within the deeper Mount Eden formation and the granitic/metasedimentary basement complex at the BPA. The primary source of perchlorate affected groundwater appears to be the BPA with secondary sources located within the former RMPA and at the Large Motor Washout Area, the Maintenance Shop and Warehouse Area, and Test Bays in Historical Operational Area F.

1,1 Dichloroethene (1,1 DCE)

The highest concentrations of 1,1-DCE (around 10,000 µg/L) have been reported in groundwater samples collected from the uppermost bedrock zone located in the western portion of the former BPA and have also been the highest VOC concentrations reported in groundwater samples collected since 2002, see Figure 2-7. Similar to perchlorate, groundwater concentrations rapidly decrease outside, and downgradient, of the footprint of the former BPA. 1,1-DCE was reported in groundwater samples collected from wells screened in the alluvium, shallow Mount Eden formation and deeper Mount Eden formation. The concentrations of 1,1-DCE show a decreasing trend with depth. Low level concentrations of 1,1-DCE have been detected in groundwater samples collected from all four of the deeper Mount Eden formation wells with the highest concentrations detected in the BPA. 1,1-DCE has been detected in groundwater samples collected within the RMPA, however, based on the vertical distribution of 1,1-DCE in soil gas (increasing with depth), the 1,1-DCE groundwater concentrations, and the groundwater flow direction during wet periods, the 1,1-DCE detected in the RMPA in groundwater and soil gas appears to be originating from the BPA groundwater plume. In addition, the magnitude of the VOC concentrations detected in soil gas is consistent with offgassing of the groundwater using equilibrium partitioning via Henry's Law. The data does not support that a separate source of 1,1-DCE is present in the RMPA. The source of 1,1-DCE affected groundwater appears to be the former BPA.

X:\GIS\Lockheed 25421-01-0603\DCE.mxd



N

0 500 1,000 Feet

Adapted from: March 2007 aerial photograph.

Faults from structural analysis of Potrero Valley, *Lineament and Geologic Mapping Study, Tetra Tech, 2009.*

LEGEND

MW-22 [340] ●	Well ID 1,1-DCE Concentration
∼	1,1-DCE in Groundwater Concentration Contour (µg/L) - Dashed where inferred
∼	MCL Contour (6.0 µg/L) - Dashed where inferred
∼	Bedrock/Alluvium Surface Contact Dashed where inferred
↗	Fault, Approximately Located
⋯	Fault, Accurately Located Showing Dip
⬚	Source Areas
⬚	Potrero Canyon Unit Property Boundary (Lockheed Martin Beaumont Site 1)
▭	Historical Operational Area Boundary

1,1-Dichloroethene in Soil

🟩	Soil Source Area

Notes:

MCL - Maximum Contaminant Level.
Concentrations shown are in microgram per liter (µg/L)

DCE - 1,1-Dichloroethene.

Highest concentration shown is contoured for clustered or nested well locations.

Bold indicates MCL value exceeded.

Beaumont Site 1 property boundary is approximate.

Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 2-7
1,1-DCE Soil Source Areas and Groundwater Impacts Second Quarter 2011

TETRA TECH

Trichloroethene (TCE)

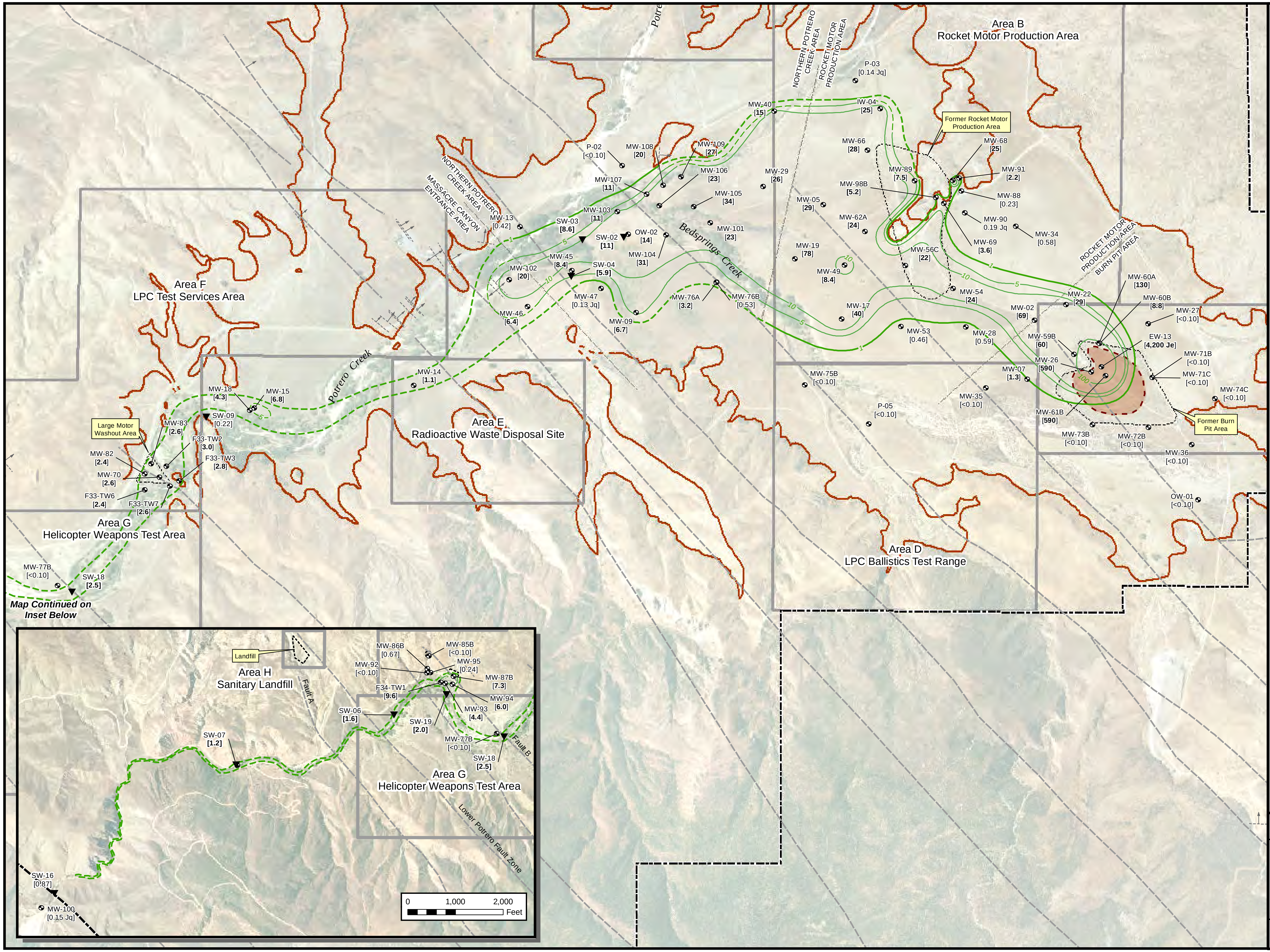
The highest concentrations of TCE (2,000 to 8,000 µg/L) have been reported in groundwater samples collected from the uppermost bedrock zone located in the former BPA (Feature C-22). Similar to perchlorate and 1,1-DCE, TCE concentrations appear to rapidly decrease outside, and downgradient, of the former BPA. No sources of TCE have been identified in the RMPA or elsewhere in the main alluvial valley. However, further to the west outside of the main valley, two other TCE sources in groundwater have been identified at the Site, the Maintenance Shop and Storage Warehouse Area and the Test Bays located in the western portion of Operational Area F. Relatively small localized TCE groundwater plumes are present at Features F-34 and F-39 with maximum TCE concentrations around 100 µg/L and decreasing with depth. The vertical extent of TCE in groundwater at these features has been characterized and monitoring wells have been installed to monitor the plumes over time.

Similar to 1,1-DCE, TCE has been detected in groundwater samples collected within the RMPA, however, based on the vertical distribution of TCE in soil gas (increasing with depth), the TCE groundwater concentrations, and the groundwater flow direction during wet periods, the TCE detected in the RMPA in groundwater and soil gas appears to be originating from the BPA groundwater plume. In addition, the magnitude of the VOC concentrations detected in soil gas are consistent with offgassing of the groundwater using equilibrium partitioning via Henry's Law. The data does not support that a separate source of TCE is present in the RMPA. The former BPA is the primary source of TCE affected groundwater at the Site. Features F-34 and F-39 represent secondary sources that are fairly localized based on the topographical setting and low permeability/hydraulic conductivity of the aquifer within the sandstone of the Mount Eden formation.

1,4 Dioxane

Although 1,4-dioxane represents one of the primary COPCs in groundwater at the Site, 1,4-dioxane has not been detected in soil at the BPA (Feature C-22) which is thought to be the primary source for 1,4-dioxane at the Site, see Figure 2-8. 1,4-Dioxane was a common stabilizer in 1,1,1-TCA and to a lesser degree in TCE and therefore is usually associated with a 1,1,1-TCA or TCE spill or source area such as the BPA. The highest concentration of 1,4-dioxane detected in soil at the Site was only 4 µg/kg and was detected at Feature B-11 located approximately 3,000 feet downgradient of the BPA. The highest concentrations of 1,4-dioxane in groundwater on the order of 1,000 to 4,000 µg/L have been reported in samples collected from the uppermost bedrock

Path: X:\GIS\Lockheed 25421-01-0603\Diox_Source.mxd



N

0 500 1,000 Feet

Adapted from: March 2007 aerial photograph.

Faults from structural analysis of Potrero Valley, *Lineament and Geologic Mapping Study, Tetra Tech, 2009.*

LEGEND

MW-22 [340]	Well ID 1,4-Dioxane Concentration
SW-07 [23] ▼	Surface Water Sample Location 1,4-Dioxane Concentration
	1,4-Dioxane in Groundwater Concentration Contour (µg/L) - Dashed where inferred
	DWNL Contour (1.0 µg/L) - Dashed where inferred
	Bedrock/Alluvium Surface Contact Dashed where inferred
	Fault, Accurately Located Showing Dip
	Fault, Approximately Located
	Source Areas
	Historical Operational Area Boundary
	Potrero Canyon Unit 1 Property Boundary (Lockheed Martin Beaumont Site 1)

1,4-Dioxane in Soil

🟫	1,4-Dioxane Soil Source Area

Notes:

DWNL - Drinking water notification level.
Concentrations shown are in microgram per liter (µg/L)

Highest concentration shown is contoured for clustered or nested well locations.

Bold indicates DWNL value exceeded.

Beaumont Site 1 property boundary is approximate.

Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 2-8

1,4-Dioxane Source Area and Groundwater Impacts Second Quarter 2011

TETRA TECH

zone located in the BPA, the primary source of 1,4-dioxane at the Site. Similar to the other groundwater contaminants, 1,4-dioxane concentrations rapidly decrease outside, and downgradient of the BPA. Two other sources of 1,4-dioxane in groundwater have been identified at the Site, the Maintenance Shop and Storage Warehouse Area and the Test Bays located in the western portion of Operational Area F. Relatively small localized 1,4-dioxane groundwater plumes are present at Features F-34 and F-39 with maximum concentrations around 75 and 13 µg/L, respectively. However, similar to the BPA, 1,4-dioxane was not detected in soil samples collected from either feature. The BPA is the primary source of 1,4-dioxane affected groundwater at the Site with Features F-34 and F-39 representing secondary sources that are fairly localized based on the topographical setting and low permeability/hydraulic conductivity of the aquifer within the sandstone of the Mount Eden formation. Based on the results from surface water sampling conducted, the 1,4-dioxane groundwater impacts at Features F-34 and F-39 do not appear to be adversely affecting the surface water in Potrero Creek near and downgradient of these features.

1,4-Dioxane has been persistent in surface water at the Site and is the only analyte that has been detected within Potrero Creek at the Site boundary. The concentrations of 1,4-dioxane detected in surface water in the western portion of the Site near the property boundary have been around 1 µg/L and have never exceeded the DWNL of 1 µg/L. 1,4-Dioxane has also been detected at concentrations of around 0.15 µg/L in the offsite guard well (MW-100) located approximately 400 feet downgradient of the property boundary.

2.1.5.3 Nature and Extent of Surface Water Impacts

All groundwater COPCs have been detected in the surface water ponds located near the west end of the alluvial valley which are directly fed by discharging groundwater. COPC concentrations within these surface water ponds, which are not directly connected to the streambed, are consistent with groundwater concentrations detected in nearby monitoring wells. In addition, several groundwater COPCs have been detected in surface water samples collected from within the streambed of Potrero Creek with the highest concentrations generally detected where surface water first daylights within the streambed from discharging groundwater. Concentrations then generally decrease in surface water samples downstream of the first surface water occurrence. As stated above, these areas of intermittent surface flow where the samples are collected represent groundwater discharge where the stream is gaining in some reaches. The highest groundwater COPC concentrations detected in surface samples collected from within the streambed are as follows; perchlorate (41.0 µg/L), 1,4-dioxane (4.5 µg/L), 1,1-DCE (1.2 µg/L), TCE (0.42 µg/L), and cis-1,2-DCE (0.46 µg/L). 1,4-Dioxane has been persistent in surface water samples collected within the streambed at the Site and is the only analyte that has been detected within Potrero Creek at the site boundary. Concentrations of 1,4-dioxane detected in surface water in the western portion of the Site at the property boundary have been about 1 µg/L and have never exceeded the DWNL of 3 µg/L.

2.2 LABORDE CANYON CSM

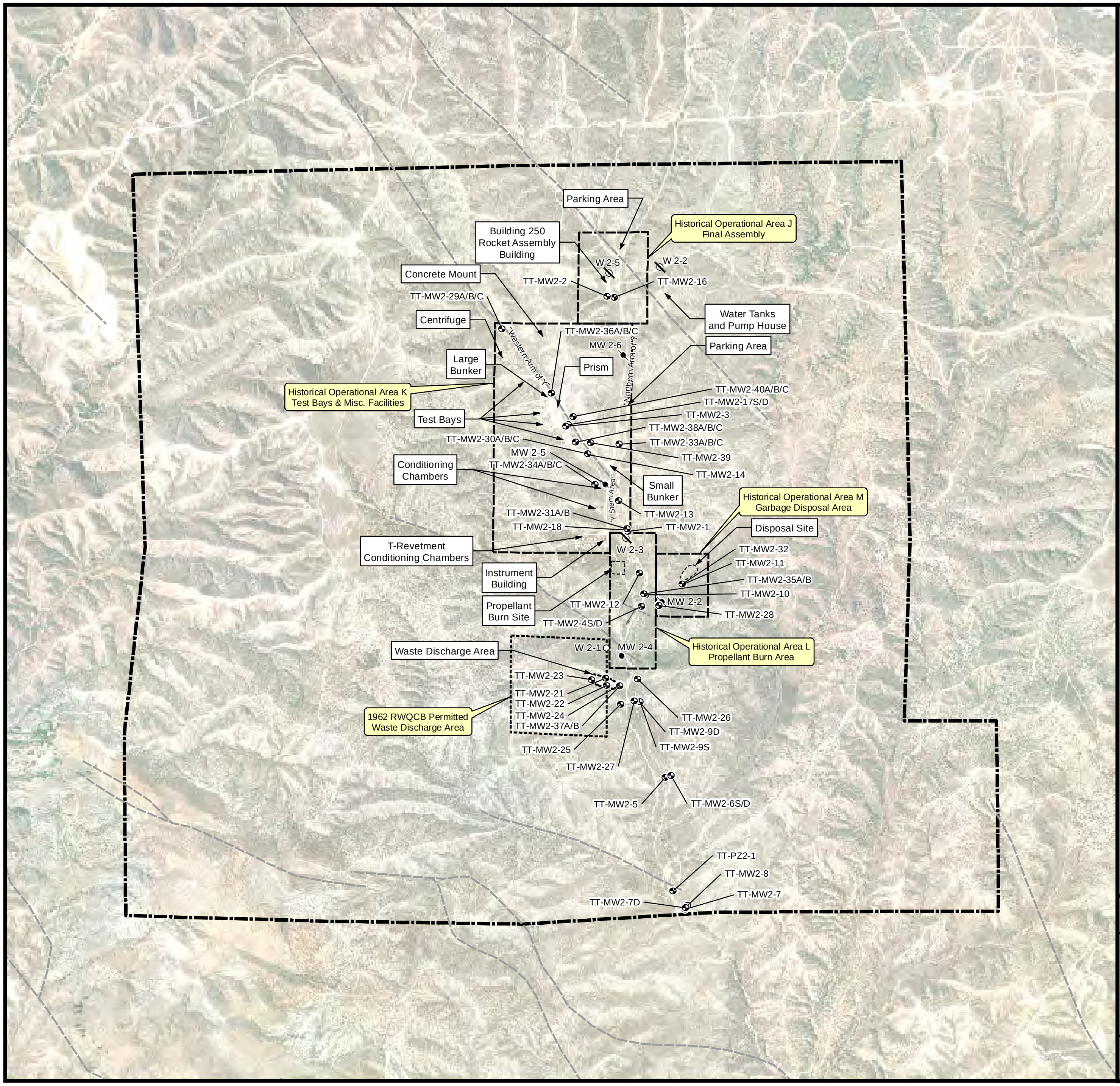
2.2.1 Background

The Laborde Canyon site consists of 2,668 acre of land located in the southwestern portion of Beaumont, California (Figure 1-1). Prior to 1958, the parcels that comprise Laborde Canyon were owned by individuals and the United States (U.S.) government, and were used for agricultural purposes. Between 1958 and 1960, portions of the Site were purchased by Grand Central Rocket Company (GCR) for use as a remote rocket motor test facility (Radian, 1986a). In 1960, Lockheed Aircraft Corporation (LAC) purchased one half interest in GCR. In 1961, GCR became a wholly owned subsidiary of LAC. The remaining parcels of land that comprise Laborde Canyon were purchased from the U.S. government between 1961 and 1964. In 1963, Lockheed Propulsion Company (LPC) became an operating division of LAC, and was responsible for the operation of the Site until its closure in 1974. In 2006, the Site was sold to the County of Riverside.

From 1958 to 1974, the Site was utilized by GCR and LPC for small rocket motor assembly, rocket motor testing operations, propellant incineration, and minor disposal activities (Radian, 1986a). Ogden Technology Laboratories, Inc. (Ogden) is known to have leased portions of the Site in the 1970s (Radian, 1986a). According to interviews with LPC personnel familiar with the Site, a portion of Laborde Canyon was also used by General Dynamics for testing remote sensing devices in the late 1980s (Tetra Tech, 2010a).

Four primary historical operational areas (Areas J, K, L, and M; Figure 2-9) were initially identified at Laborde Canyon by Radian (1986) and Tetra Tech (2003). Area J (Final Assembly Area) consisted of a former building (Building 250) and related facilities which were used for the final assembly and shipment of rocket motors. Area K (Test Bays and Miscellaneous Facilities) included a test centrifuge, 4 rocket motor test bays, 2 bunkers, a large earthen structure referred to as the “Prism,” and 3 groups of conditioning chambers. Area L (Propellant Burn Area) is located immediately south of Area K. Reportedly, large slabs of solid propellant were transported and placed on the ground surface for incineration in Area L. Area M (Garbage Disposal Area) is

X:\GIS\Lockheed 25421-01-0603\Op_Areas.mxd



N

0 1,000 2,000
Feet

Adapted from:

March 2007 aerial photograph.

Faults from the, *Site 2 Lineament Study, Tetra Tech, 2009.*

LEGEND

- ● Groundwater Monitoring Well Location
- ⊘ Destroyed Production Well Location
- ● Destroyed Monitoring Well Location
- ○ Reported Production Well Location
- Fault, Accurately Located Showing Dip
- Fault, Approximately Located
- Waste Discharge Area
- RWQCB Permitted Waste Discharge Area
- Historical Operational Area Boundary
- Laborde Canyon Property Boundary (Lockheed Martin Beaumont Site 2)

Note: Laborde Canyon property boundary (Lockheed Martin Beaumont Site 2) from Hillwig-Goodrow survey, May 2004.

Disposal and Propellent Burn Site perimeters are estimated (Radian, 1986a).

Laborde Canyon
(Lockheed Martin Beaumont Site 2)

Figure 2-9
Historical Operational Areas and Site Features

TETRA TECH

located in a side canyon; scrap metal, paper, wood, and concrete were disposed in this area. Based on information obtained in 2006, the Waste Discharge Area (WDA; Figure 2-9) was identified as a fifth area where historical operations were conducted. The WDA is located in a small canyon on the western side of Laborde Canyon, and consists of 2 shallow basins protected by berms. Details on historical operations in each of these areas are provided in the Dynamic Site Investigation and Summary Remedial Investigation Report (Tetra Tech, 2010a).

Remediation activities at the Laborde Canyon site have consisted of excavation and offsite disposal of trash from the Area M disposal area. Groundwater level and water quality monitoring has been conducted on a quarterly basis since 2004 to monitor the site groundwater plumes. The results of groundwater monitoring activities are presented in semiannual groundwater monitoring reports prepared twice per year. Each groundwater monitoring report includes a presentation the most current conceptual site model.

2.2.2 Physical Setting

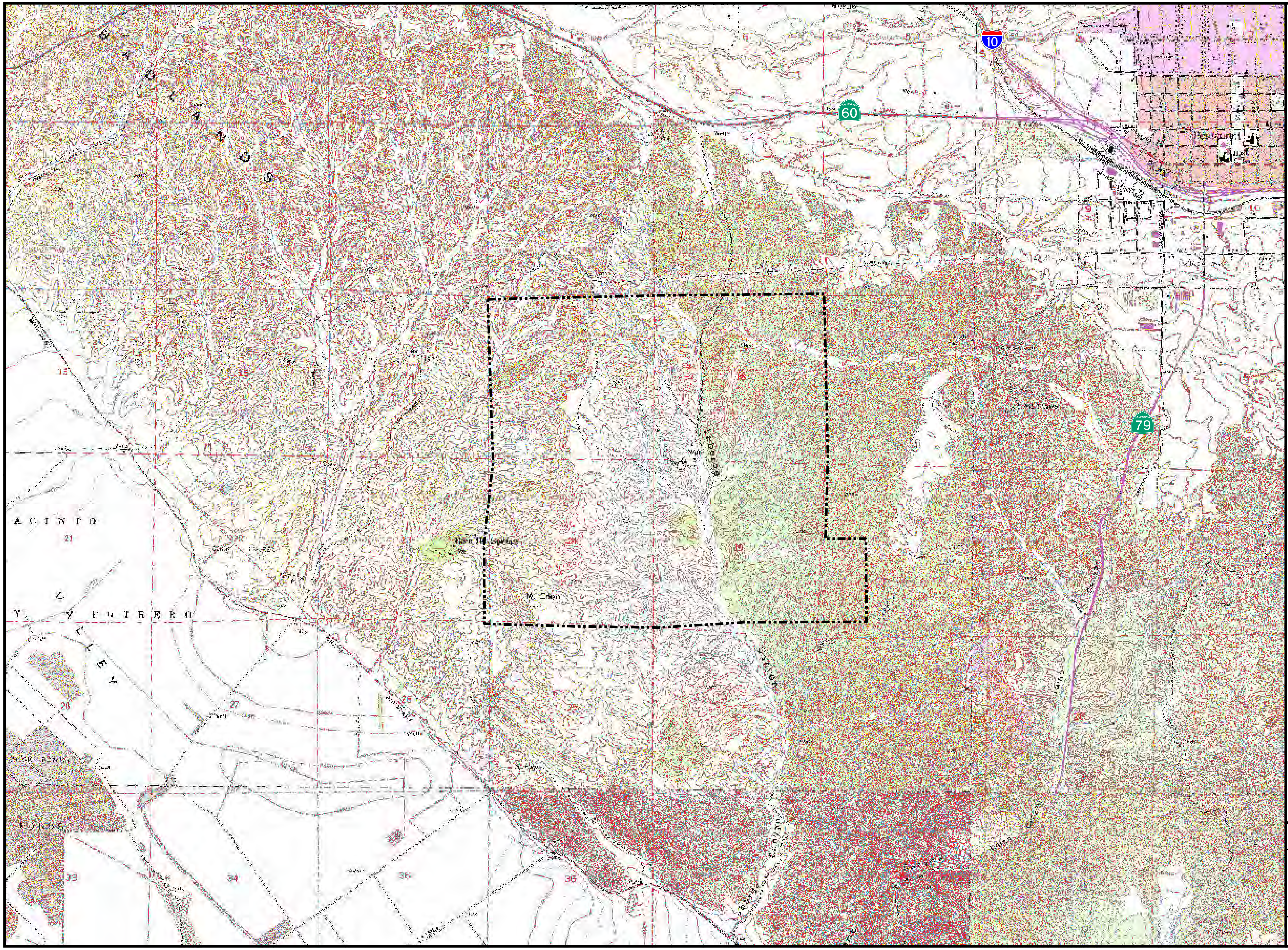
The Site is located within the San Timoteo Badlands, an area of badlands topography characterized by steep slopes, sparse vegetation, and complex drainage patterns developed primarily in poorly-indurated Pliocene- and Pleistocene-age non-marine sedimentary rocks of the San Timoteo Formation (STF), see Figure 2-10. The principal topographic feature of the Site is Laborde Canyon, a major north-south oriented canyon which is at roughly 2,380 feet above mean sea level (msl), dropping to approximately 1,550 feet msl where Laborde Canyon enters the San Jacinto Valley, a gradient of approximately 0.035 feet per foot (ft/ft). Most of the hillsides at the Site are relatively steep, with slopes often approaching 100%. There are no perennial streams, ponds, springs, or other permanent surface water bodies within the boundaries of the Site, and Laborde Canyon, which drains generally southward toward the San Jacinto Valley, is the principal drainage course for the Site.

2.2.3 Geology

The Site is located at the northern end of the Peninsular Ranges geologic province of California. The following four primary geologic units are present in the area:

Crystalline Basement: Crystalline basement rocks in the area of the Site include Cretaceous-age plutonic rocks of the Peninsular Ranges batholith, and undifferentiated metasedimentary rocks and marbles of inferred Paleozoic age. Crystalline basement is not exposed in any of the areas where historical operations took place, and has not been encountered in any soil borings drilled at the site to date.

X:\GIS\Lockheed 25421-01-0603\Topo_S2.mxd



N

0 1,500 3,000
Feet

Adapted from:
USGS 7.5' topographic quadrangle, El Casco, CA 1979.
USGS 7.5' topographic quadrangle, Lakeview, CA 1979.
USGS 7.5' topographic quadrangle, San Jacinto, CA 1979.
USGS 7.5' topographic quadrangle, Beaumont, CA 1988.

LEGEND

⬚	Laborde Canyon Property Boundary (Lockheed Martin Beaumont Site 2)

Note: Beaumont Site 2 property boundary from Hillwig-Goodrow survey, May 2004.

Laborde Canyon
(Lockheed Martin Beaumont Site 2)

Figure 2-10
Physical Setting

TETRA TECH

San Timoteo Formation (STF): The STF consists primarily of grayish brown fine grained sandstones and mudstones, with localized conglomerate lenses. Well-indurated beds of carbonate-cemented, medium- to coarse-grained sandstone are occasionally encountered at depth. The degree of induration of the STF generally tends to increase with depth, although poorly indurated beds are encountered throughout the section to a depth of at least 250 feet. The STF also appears more indurated at shallow depths in borings drilled in side canyons compared with those drilled near the midline of the major canyons, which suggests that the STF is most deeply-weathered near the center of the major canyons and less deeply-weathered toward the canyon margins.

Mount Eden Formation (MEF): The MEF consists of early Pliocene and Miocene sandstones, mudstones, conglomeritic sandstones, and sedimentary breccia, which are exposed primarily to the south of the site.

Quaternary Deposits: Quaternary deposits at the Site include alluvium and colluvium. Alluvium consists of stratified gravel, sand, silty sand, and silt deposits flooring the major canyons throughout the Site. Colluvium consists mainly of poorly to well graded sand and silty sand with minor gravel, which typically occur as aprons at the base of steep hillsides and flooring minor side canyons with small catchment areas. Colluvial deposits likely interfinger laterally with alluvium along the margins of the main canyons.

No faults are shown within the former operational areas of the Site on published geologic maps by Dibblee (2003) and Morton (2004). The most prominent faults in the area of the Site are the San Jacinto and Claremont faults, both of which are active right lateral strike slip faults related to the SAF system. The San Jacinto fault is located approximately 2 miles south of Site. Morton (2004) has mapped several west northwest trending faults in the southwestern corner of the Site, which cross Laborde Canyon approximately 3,000 feet south of the Site.

Mapping by Dibblee (2003) shows bedding near Laborde Canyon dipping generally to the north northeast, at angles ranging from horizontal to 5°; whereas Morton (2004) shows dips ranging from 12° to 25°, toward both the northeast and northwest. Field measurements by Tetra Tech support the steeper dip angles indicated by Morton (2004).

2.2.4 Hydrogeology

Hydrostratigraphy

Groundwater at the Site occurs mainly in sandstones and mudstones of the STF. The STF is deeply weathered within the major canyons, and first groundwater in the canyons is mainly unconfined and found within the weathered section of the STF. Groundwater conditions appear to be more variable in smaller side canyons, with first groundwater frequently encountered at depths greater than the water table in the main canyon, suggesting that first groundwater may be in the relatively unweathered STF. Perched groundwater may be present in the centrifuge area in the northern portion of Test Bay Canyon, where groundwater was encountered in two soil borings at elevations much higher than in nearby wells.

Deeper groundwater at the site is most commonly found in relatively unweathered but very poorly indurated fine-to medium-grained sandstone lenses within the STF. Groundwater also appears to be present in fine-grained mudstones. Fracture or bedding plane-related permeability may play a role in the occurrence of groundwater in fine-grained rocks.

Groundwater Flow

Depths to groundwater at the Site ranges from approximately 70 feet bgs in Test Bay Canyon to approximately 14.5 feet bgs in the SBA. Groundwater generally flows down the major tributary canyons to Laborde Canyon, and then to the south, consistent with the direction of surface water flow and topography. The overall groundwater gradient across the Site is roughly 0.030 ft/ft, slightly less than the local ground surface slope of approximately 0.035 ft/ft, and consistent with the decreasing depth to water noted from north to south. Little seasonal variation in groundwater levels is observed. Longer-term groundwater level variations are typically only 1 to 3 feet over the limited period of record. There is generally a downward vertical gradient of 0.1 to 0.2 ft/ft in most locations, except in the offsite riparian area where the gradient is upward.

Hydraulic Conductivity

Hydraulic conductivity values estimated from slug tests and pumping tests have a geometric mean around 0.16 feet per day for the weathered San Timoteo formation and 0.04 feet per day for the competent San Timoteo formation , with estimated aquifer transmissivity values in the range of 10 feet2 per day for the weathered San Timoteo formation, and about 1 ft2/day for individual water bearing zones within the competent San Timoteo formation.

2.2.5 Nature and Extent of Contamination

An overall sitewide description of the nature and extent of soil and groundwater contamination is presented in this section.

2.2.5.1 Nature and Extent of Soil Contamination

The primary contaminants detected in soil include perchlorate, TCE, and methylene chloride. Several other VOCs, including 1,1-DCE, 1,2-DCA, acetone, and 4-methyl-2-pentanone (MIBK), have been detected at the WDA at lower concentrations than TCE and methylene chloride, and are considered secondary contaminants. Other contaminants, including 1,4-dioxane and RDX, have been detected in groundwater but not in soil, and are not discussed in this section.

Perchlorate

The extent of perchlorate in soil and groundwater is shown in Figure 2-11. The highest perchlorate concentrations detected at the site are found in southern Test Bay Canyon (up to 130,000 µg/kg) and in the WDA (up to 114,000 µg/kg). These two source areas comprise approximately 99% of the total perchlorate mass in soil at the Laborde Canyon site. Perchlorate has also been detected in soil in Area M and in northern Test Bay Canyon at maximum concentrations of 3,100 and 690 µg/kg, respectively. These source areas are relatively small and comprise less than 1% of the total perchlorate mass in soil.

TCE

The extent of TCE in soil and groundwater is shown in Figure 2-12. The highest TCE concentrations detected in soil (up to 680 µg/kg) were found at the WDA. Although TCE has also been consistently detected at relatively low concentrations in Area M, a source of TCE in soil has not been identified in this area.

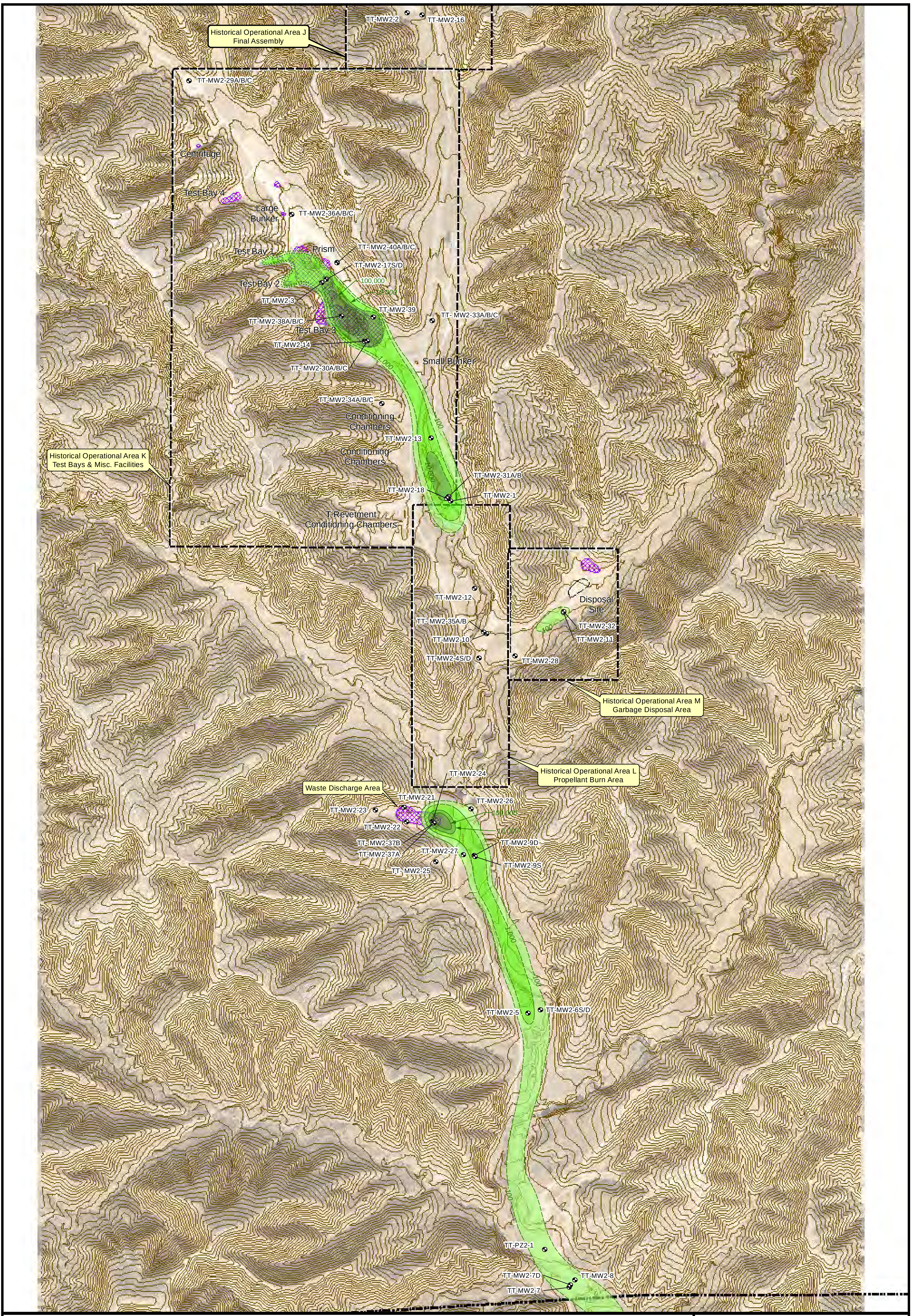
Methylene Chloride

The extent of methylene chloride in soil and groundwater is shown in Figure 2-13. The highest methylene chloride concentrations at the site were found at the WDA (up to 21,000 µg/kg).

2.2.5.2 Nature and Extent of Groundwater Contamination

Two major perchlorate groundwater plumes have been identified at the Site: one related to soil impacts in southern Test Bay Canyon (Test Bay Canyon plume), and one related to soil impacts in the WDA (WDA plume). Total perchlorate mass present in these two plume areas is approximately 4,400 pounds. Other minor groundwater plumes have been identified at the Site, containing less than one pound each of TCE, 1,4-dioxane, and RDX.

X:\GIS\Lockheed 25421-01-0603\Perch_Source_GW_S2.mxd



LEGEND

Perchlorate in Groundwater

- 🟩 100 µg/L
- 🟩 1,000 µg/L
- 🟩 10,000 µg/L
- 🟩 100,000 µg/L

Perchlorate Soil Source

- ▨ >100 µg/kg

- Perchlorate Isoconcentration Line
- Isoconcentration Segment Inferred
- Isoconcentration Segment Based on 2008 Grab Sample Data
- Monitoring Well Location
- Ground Surface Elevation Contour (10-foot interval - feet msl)
- Historic Operational Area Boundary
- Laborde Canyon Property Boundary (Lockheed Martin Beaumont Site 2)

Note:
µg/L - Micrograms per liter.

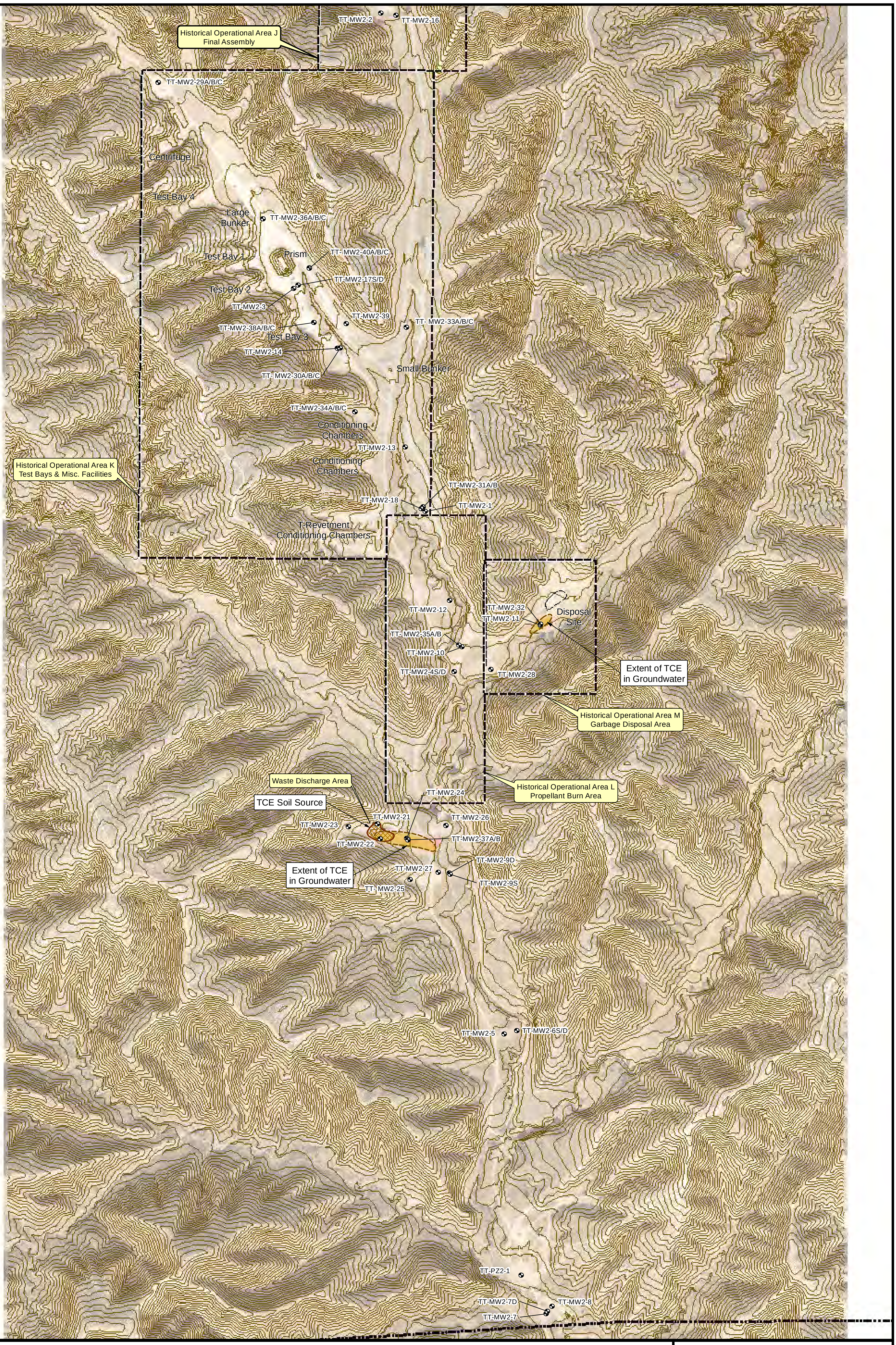
Laborde Canyon
(Lockheed Martin Beaumont Site 2)

Figure 2-11

Perchlorate Source Areas and Groundwater Impacts

TETRA TECH

X:\GIS\Lockheed 25421-01-0603\TCE_Source_S2.mxd



LEGEND

- ● Monitoring Well Location
- ▨ TCE Soil Source
- ▨ TCE in Groundwater
- ~ Ground Surface Elevation Contour (10-foot interval - feet msl)
- ⌐¬ Historic Operational Area Boundary

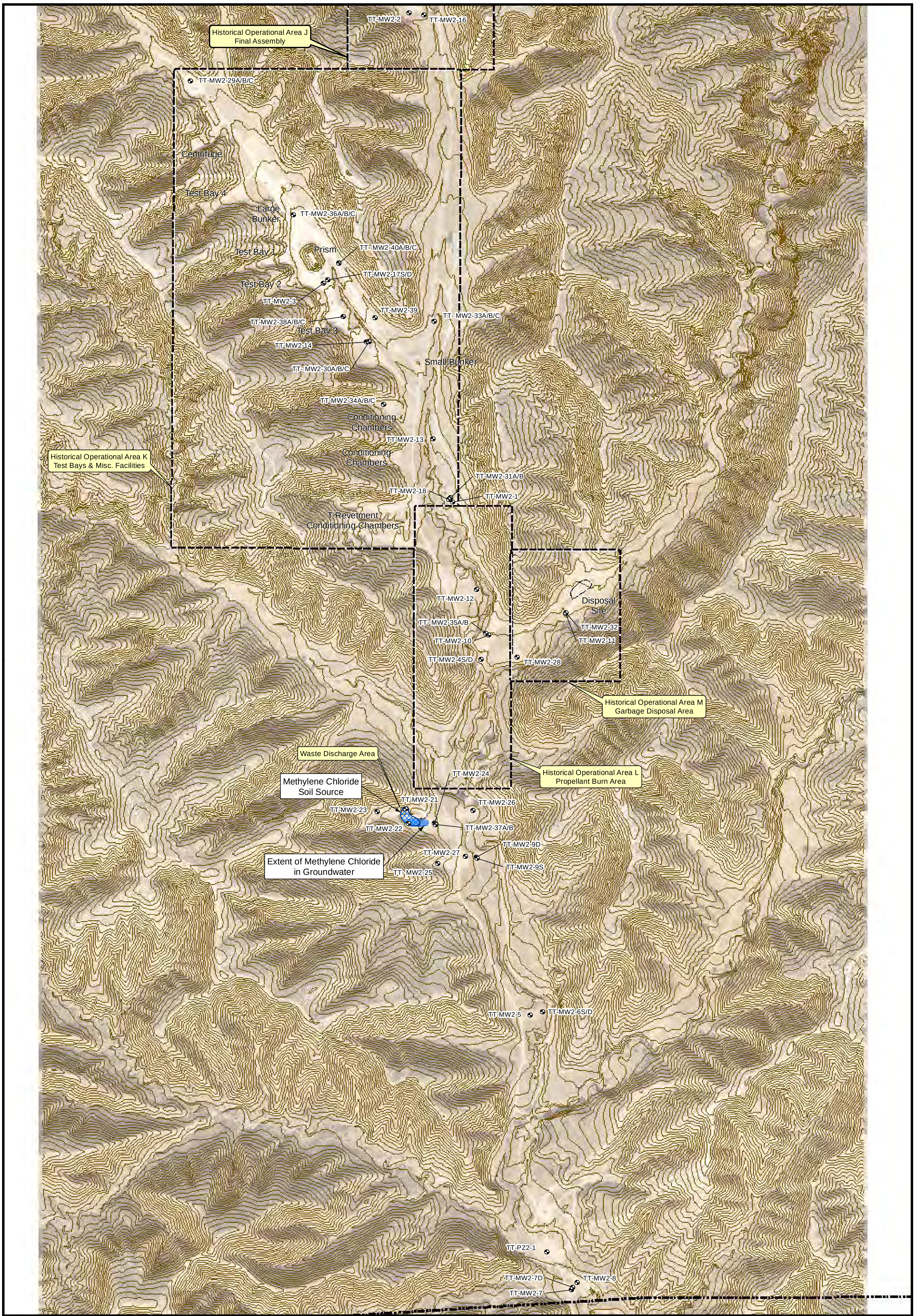
Laborde Canyon
(Lockheed Martin Beaumont Site 2)

Figure 2-12

TCE Source Areas and Groundwater Impacts

TETRA TECH

X:\GIS\Lockheed 25421-01-0603\MCL_Source_S2.mxd



LEGEND

● Monitoring Well Location

▨ Methylene Chloride Soil Source

🟦 Methylene Chloride in Groundwater

~ Ground Surface Elevation Contour
(10-foot interval - feet msl)

⌐¬ Historic Operational Area Boundary

0 300 600
Feet

Laborde Canyon
(Lockheed Martin Beaumont Site 2)

Figure 2-13

Methylene Chloride Source Areas and Groundwater Impacts

TETRA TECH

Perchlorate

The extent of perchlorate in groundwater is shown in Figure 2-11. The highest perchlorate concentrations detected in source area groundwater during the fourth quarter 2010 were in southern Test Bay Canyon (up to 210,000 µg/L) and the WDA (up to 160,000 µg/L). Large perchlorate plumes extend downgradient from both of these areas. Perchlorate concentrations in groundwater at the Garbage Disposal Area and northern Test Bay Canyon are much lower (up to 220 and 230 µg/L, respectively), and limited in lateral extent.

TCE

The extent of TCE in groundwater is shown on Figure 2-12. The highest TCE concentration detected in groundwater at the site during the fourth quarter of 2010 was in the WDA (up to 420 µg/L). Lower concentrations of TCE (6.9 µg/L) were also detected in Area M during the fourth quarter of 2010.

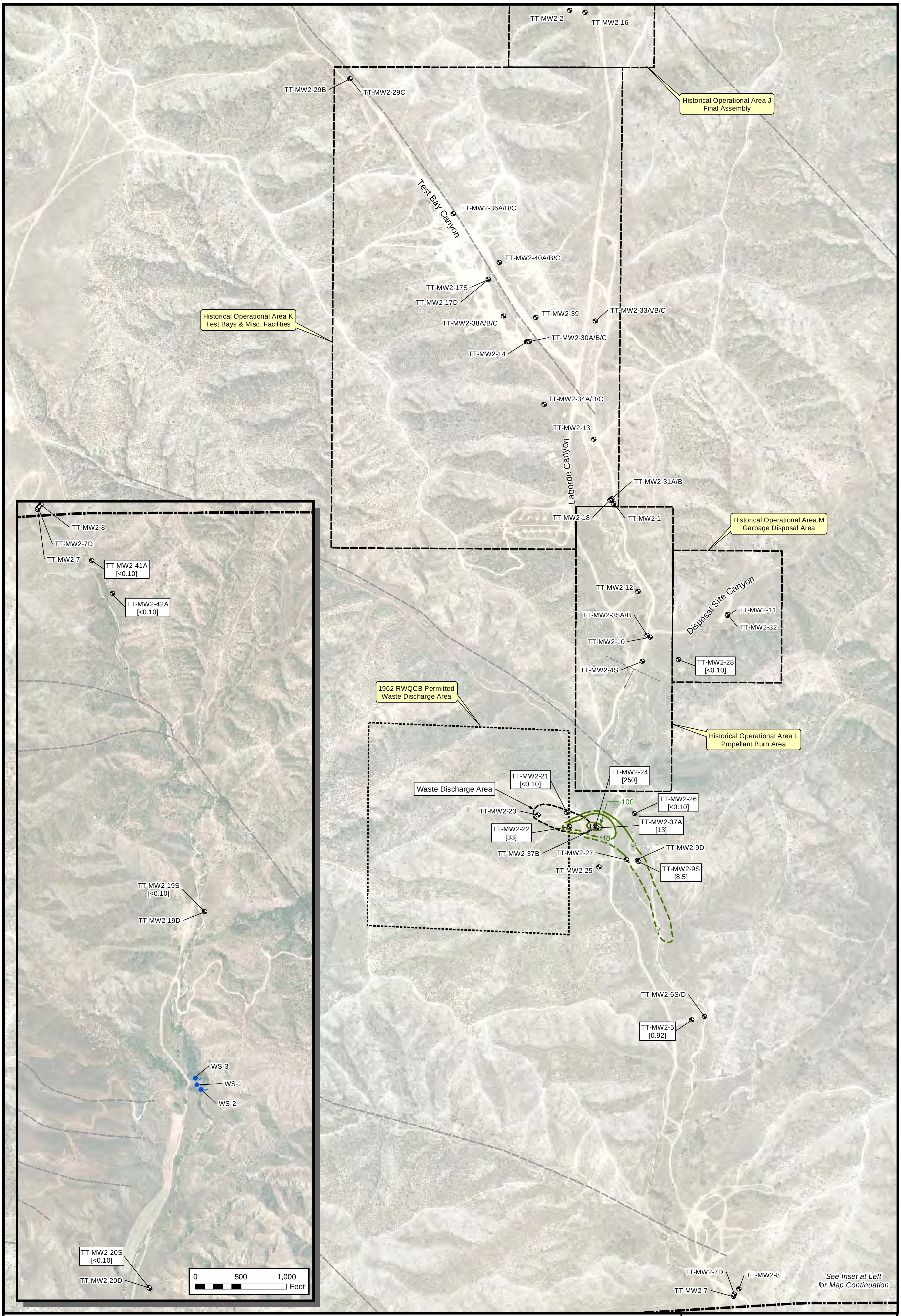
1,4-Dioxane

The extent of 1,4-dioxane in groundwater is shown in Figure 2-14. The highest 1,4-dioxane concentration in groundwater at the site during the fourth quarter of 2010 was at the WDA (up to 480 µg/L).

RDX

The extent of RDX in groundwater is shown in Figure 2-15. The highest RDX concentration in groundwater at the site during the second quarter of 2010 was 2.1 µg/L at the WDA. RDX was also detected in well TT-MW2-13 at a concentration of 0.83 µg/L during the second quarter of 2010.

X:\GIS\Lockheed 25421-01-0603\DIOX_Isocon_S2.mxd



Adapted from: April 2007 aerial photograph.

Faults from the, *Site 2 Lineament Study, Tetra Tech, 2009.*

Notes: Beaumont Site 2 property boundary from Hillwig-Goodrow survey, May 2004.

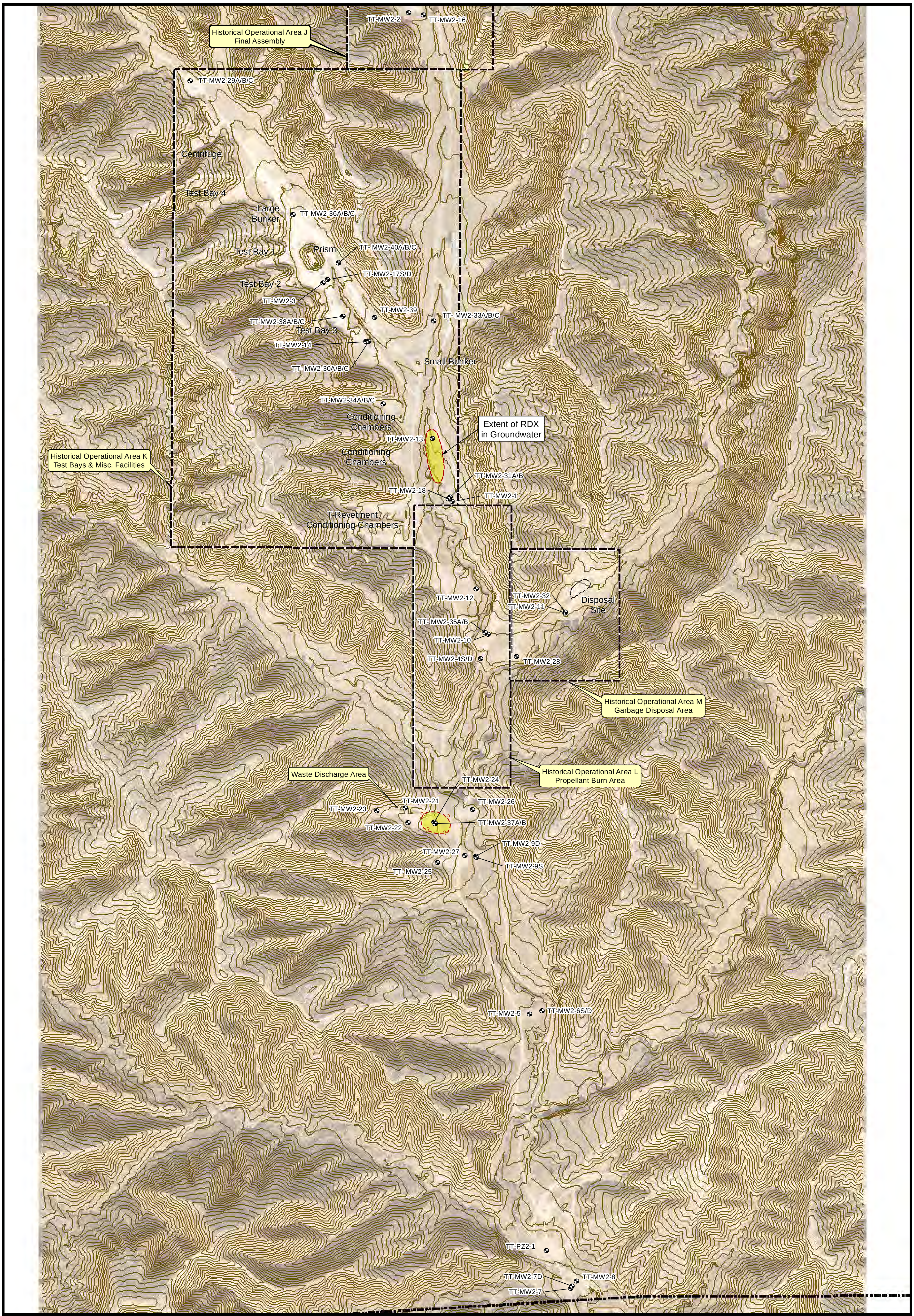
Results shown for sampled locations only.

Laborde Canyon
(Lockheed Martin Beaumont Site 2)

Figure 2-14
1,4-Dioxane Isoconcentration Map (µg/L) for Shallow Wells Second Quarter 2010

TETRA TECH

X:\GIS\Lockheed 25421-01-0603\RDX_Source.mxd



LEGEND

●	Monitoring Well Location
⬭	RDX in Groundwater
⌐┘	Historic Operational Area Boundary
~	Ground Surface Elevation Contour (10-foot interval - feet msl)

N

0 300 600
Feet

Laborde Canyon
(Lockheed Martin Beaumont Sie 2)

Figure 2-15

RDX Groundwater Impacts

TETRA TECH

SECTION 3 SUMMARY OF FIELD INVESTIGATION

This section summarizes the field activities conducted for the focused soil and groundwater data collection, plant density survey, and ex-situ perchlorate biodegradation test as part of the contaminant attenuation evaluation.

3.1.1 SITE PREPARATION ACTIVITIES

Pre drilling activities that were part of this investigation includes: underground utility clearance, biological monitoring, and health and safety.

Underground Utility Clearance

Prior to commencement of intrusive activities, drilling locations were marked for subsurface utility clearance. Underground Service Alert was contacted prior to the commencement of drilling activities in order to identify potential underground utility or service lines near the proposed drilling locations. Prior to drilling, the hollow stem auger borings were hand augered to 5 feet bgs to ensure clearance of subsurface utilities or obstructions. No underground utilities or service lines were encountered during the drilling activities.

Biological Monitoring

Prior to initiating field sampling activities, biological surveys of proposed soil borings were performed by a Section 10A permitted or sub permitted biologist to evaluate the potential for impacts to sensitive species and habitats (i.e., Stephens' kangaroo rat [SKR]). As part of the biological survey, the biologist identified and marked potential or suspected SKR burrows that were located within the vicinity of each drilling location to avoid the potential "take" of SKR and sensitive habitat. The biologist also clearly marked the ingress and egress routes at each drilling location in an effort to minimize the overall footprint of the field activities and to prevent potential "take".

Health and Safety

Selection of personal protective equipment (PPE) was made prior to the commencement of field work. Based on previous field activities at the sites and the site specific Health and Safety Plan (HASP), modified Level D was utilized at the start of field activities. As site conditions and field activities changed, the PPE level was reevaluated. Based on the site conditions and field activities encountered, the PPE level remained unchanged throughout the field program.

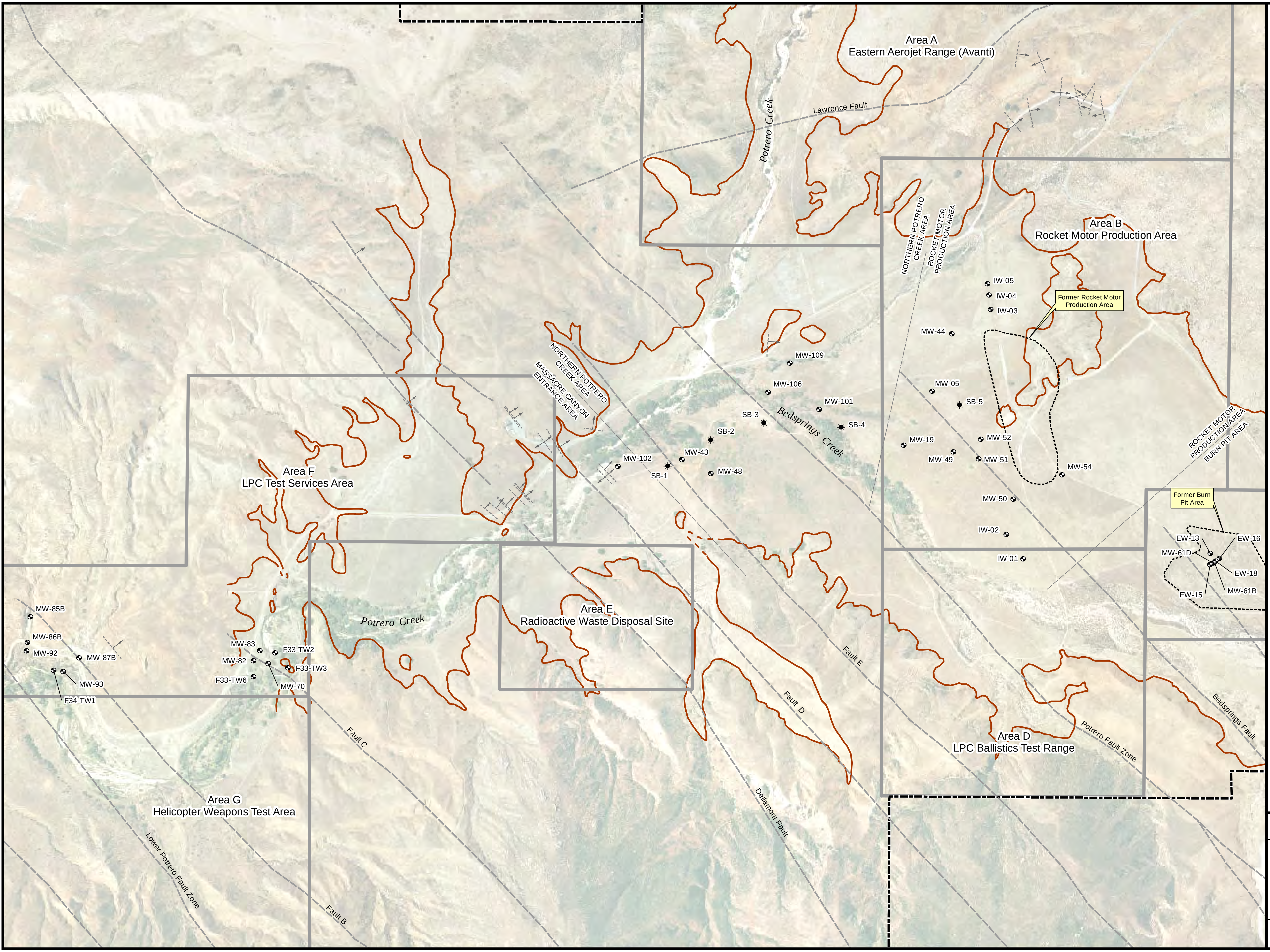
3.2 SOIL BORINGS

Soil borings were drilled at Sites 1 and 2 using a hollow stem auger (HSA) rig. As previously mentioned, all HSA boreholes were initiated by hand-augering a pilot borehole to a depth of approximately 5 feet bgs prior to drilling. Drilling activities were conducted by California-licensed drilling contractors WDC Exploration, Inc. (WDC) or Cascade Drilling, L.P. Five soil borings were advanced to depths of 50 to 60 feet bgs at Potrero Canyon Unit to total depths from 50 to 60 feet bgs, see Figure 3-1. Three soil borings (designated K-54-SB144, WDA-SB104, and SBA-SB104) were advanced to depths of 21.5 to 60 feet bgs at Laborde Canyon, see Figure 3-2. Field procedures used for drilling, lithologic logging, and borehole abandonment are described in the Programmatic Sampling and Analysis Plan (PSAP; Tetra Tech, 2010d). Copies of the soil boring logs are provided in Appendix A.

3.3 SOIL SAMPLING AND ANALYSIS

Procedures for soil sampling and analysis are described in the PSAP (Tetra Tech, 2010d), Soil samples were collected as part of the focused data collection to evaluate the distribution of total organic carbon in both the vadose and saturated zones. To provide profiles of organic carbon with depth, samples were typically collected at 5-foot intervals and submitted to E.S. Babcock Laboratory for analysis of total organic carbon by EPA Method 9060 and total solids by Method SM 2540B. Subsets of these samples (up to 10 per site) were collected based on lithology to determine the soils physical properties to support the contaminant attenuation model, the forthcoming feasibility studies, treatability studies, or remedial actions. These samples were collected using six inch stainless steel or brass sleeves and were submitted to Environmental Geotechnology Laboratory Inc. for the following analysis: including sieve analysis (ASTM D422), specific gravity (ASTM D854), total porosity (API RP40), moisture content and dry bulk density (ASTM D2937).

Continuous sampling was conducted using an 18 inch split spoon sampler and a five foot CME continuous sampler. When using split spoons, soil samples were collected from the relatively undisturbed formation by advancing the split spoon sampler, lined with the three 6 inch sleeves, ahead of the auger bit. The recovered soil within the sleeves, if chosen based on lithology, was analyzed for geotechnical parameters. Samples selected for TOC analysis were collected from the 5-foot continuous sampler.



Adapted from:

March 2007 aerial photograph.

Faults from structural analysis of Potrero Valley,
Lineament and Geologic Mapping Study, Tetra Tech, 2009.

LEGEND

- ⊕ Groundwater Sample Location
- ✱ Soil Boring Location
- ∼ Bedrock/Alluvium Surface Contact
  Dashed where inferred
- ↗ Fault, Accurately Located Showing Dip
- ╌ Fault, Approximately Located
- ⬚ Potrero Canyon Unit Property Boundary
  (Lockheed Martin Beaumont Site 1)
- ☐ Historical Operational Area Boundary

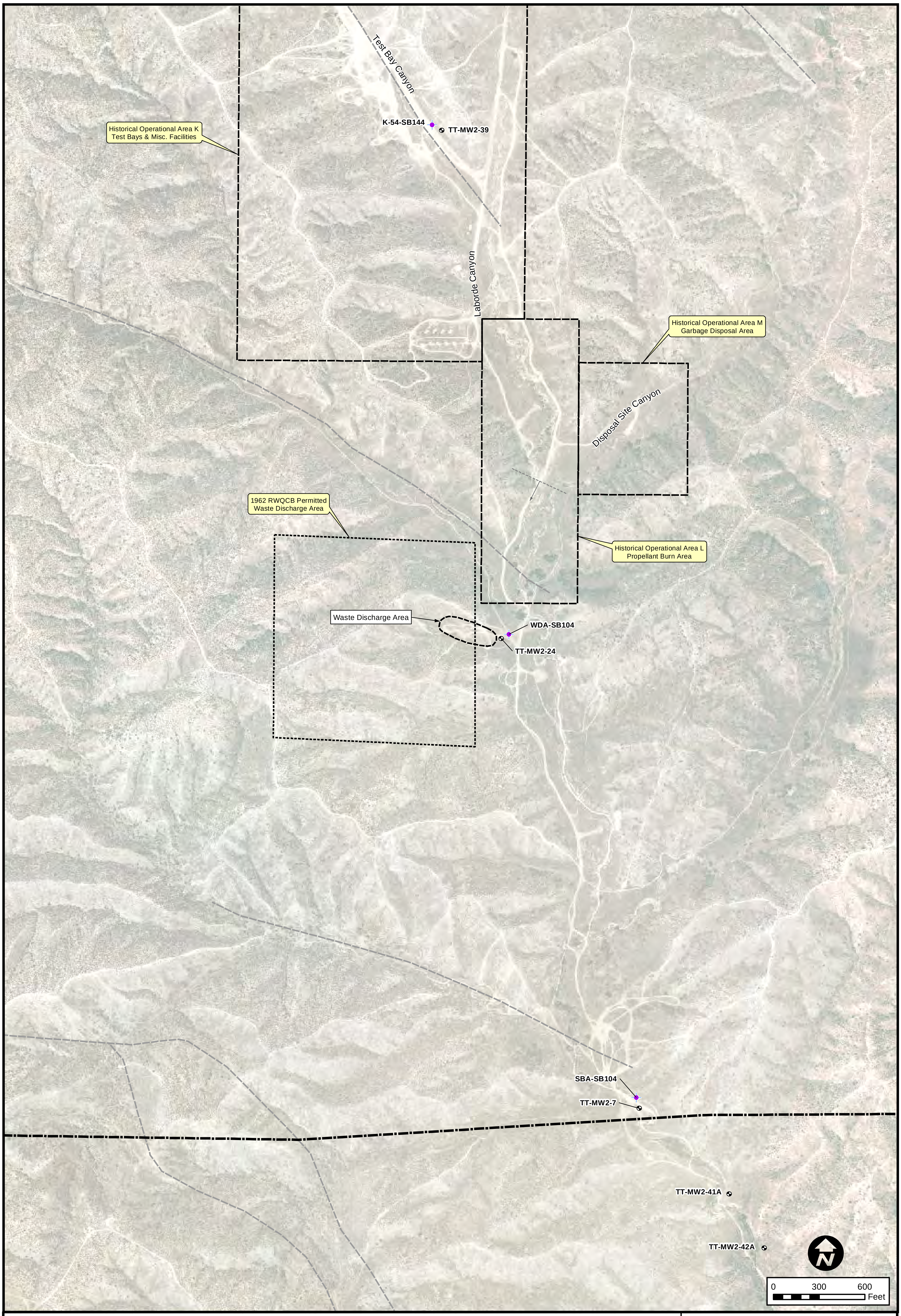
Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 3-1
Groundwater Sampling and Soil Boring Locations

TETRA TECH

X:\GIS\Lockheed 25421-01-0603\Sample_Locs.mxd

X:\GIS\Lockheed 25421-01-0603\Bore_Locs_S2.mxd



LEGEND

- Well Sample Location
- Soil Boring Location
- Fault, Accurately Located Showing Dip
- Fault, Approximately Located
- Waste Discharge Area
- RWQCB Permitted Waste Discharge Area
- Historical Operational Area Boundary
- Laborde Canyon Property Boundary (Lockheed Martin Beaumont Site 2)

Note: Beaumont Site 2 property boundary from Hillwig-Goodrow survey, May 2004.

Adapted from: April 2007 aerial photograph.

Faults from the, *Site 2 Lineament Study, Tetra Tech, 2009.*

Laborde Canyon
(Lockheed Martin Beaumont Site 2)

Figure 3-2

Groundwater Sampling and Soil Boring Locations

TETRA TECH

3.4 MONITORING WELL SAMPLING AND ANALYSIS

During the Second Quarter 2010 sampling event, site-wide samples were collected at both Sites 1 and 2 for analytes that would indicate if conditions were favorable for the natural attenuation of COPCs to occur. Sampling, analytical, and QA/QC procedures were performed in accordance with the PSAP (Tetra Tech, 2010d).

3.4.1 Potrero Canyon Unit

The results from the Second Quarter 2010 site-wide contaminant attenuation sampling showed an increased potential for the natural attenuation of site COPCs. Based on these results, an additional 25 groundwater monitoring wells were sampled as part of the Fourth Quarter 2010 groundwater monitoring event and was followed by the sampling of 12 additional groundwater monitoring wells in May 2011 to support the contaminant attenuation evaluation. In addition to perchlorate, 1,4-dioxane and VOCs, groundwater samples were also analyzed for the following contaminant attenuation parameters listed below, Table 3.4-1 and 3.4-2.

- Chlorate by Method E332.0;
- General Minerals ((chloride (Method E300.0), chlorite (Method 332-M), alkalinity (Method SM2320B), nitrate (Method E300.0), nitrite (Method E300.0), total iron (Method 200.7), dissolved manganese (Method 200.7), and sulfate (Method E300.0));Total dissolved solids by Method SM2540C;
- Hypochlorite by Method DI-MSMS;
- Dissolved Organic Carbon by Method SM5310B;
- Hydrogen by Method AM20GAX;
- Methane, ethane, and ethene by Method RSK 175; and

A subset of wells with favorable biodegradation conditions were analyzed for quantitative perchlorate reductase and Dehalococcoides spp polymerase chain reaction (qPCR) assays, genetic tests for specific microbial functions implicated in perchlorate and solvent biodegradation, respectively.

3.4.2 Laborde Canyon

The results from the second quarter site-wide sampling showed limited potential for the natural attenuation of site COPCs. Based on these results additional sampling was confined to five wells which were sampled for qPCR assays only.

Table 3.4-1 Potrero Canyon Unit Fourth Quarter 2010 Sampling Schedule – Monitored Natural Attenuation - Focused Data Collection

Monitoring Well Location	Sample Date	VOCs (1)	1,4-Dioxane (2)	Perchlorate (3)	Focused Data Collection Natural Attenuation Parameters (4)	Perchlorate reductase and/or Dehalococcoides spp polymerase chain reaction	Comments and QA / QC Samples
EW-13	01/12/11	X	X	X	X	X	Sampled with Portable Bladder Pump
EW-15	01/11/11	X	X	X	X		Sampled with Portable Bladder Pump
EW-16	01/20/11	X	X	X	X		Sampled with Portable Bladder Pump
EW-18	01/19/11	X	X	X	X		Sampled with Portable Bladder Pump
F33-TW2	01/07/11	-	-	-	X		Sampled with Peristaltic Pump
F33-TW3	01/13/11	-	-	-	X	X	Sampled with Peristaltic Pump, MS/MSD, Duplicate F33-TW3-Dup
F33-TW6	01/07/11	-	-	-	X		Sampled with Peristaltic Pump
IW-01	01/18/11	X	X	X	X		Sampled with Portable Bladder Pump
IW-02	01/18/11	X	X	X	X		Sampled with Portable Bladder Pump
IW-03	01/17/11	X	X	X	X		Sampled with Portable Bladder Pump
IW-04	01/17/11	-	-	-	X	X	Sampled with Dedicated Pump
IW-05	01/19/11	X	X	X	X		Sampled with Portable Bladder Pump
MW-19	01/11/11	X	X	X	X	X	Sampled with Dedicated Pump
MW-44	01/19/11	X	X	X	X		Sampled with Portable Bladder Pump
MW-49	01/10/11	X	X	X	X		Sampled with Dedicated Pump, Duplicate MW-49-Dup
MW-50	01/18/11	X	X	X	X		Sampled with Portable Bladder Pump
MW-51	01/18/11	X	X	X	X		Sampled with Portable Bladder Pump
MW-52	01/18/11	X	X	X	X		Sampled with Portable Bladder Pump
MW-61B	01/10/11	X	X	X	X		Sampled with Dedicated Pump
MW-61C	01/12/11	X	X	X	X		Sampled with Dedicated Pump
MW-70	01/13/11	-	-	-	X	X	Sampled with Dedicated Pump
MW-82	01/10/11	-	-	-	X		Sampled with Dedicated Pump
MW-83	01/10/11	-	-	-	X		Sampled with Dedicated Pump
MW-101	01/11/11	X	X	X	X	X	Sampled with Dedicated Pump
MW-102	01/17/11	X	X	X	X	X	Sampled with Dedicated Pump

Total Sample Locations:	25
Total Samples Collected:	25

Notes:

(1) -	Volatile organic compounds (VOCs) analyzed by EPA Method SW8260 B
(2) -	1,4 - Dioxane analyzed by EPA Method SW8270C SIM
(3) -	Perchlorate analyzed by EPA Method E332.0
(4) -	Focused data collection natural attenuation parameters by various methods (chlorate, chloride, chlorite, alkalinity, nitrate, nitrite, total iron, dissolved manganese, sulfate, total dissolved solids, hypochlorite, dissolved organic carbon, hydrogen, methane, ethane, and ethane).
"-" -	Not analyzed.
MS/MSD -	Matrix Spike/Matrix Spike Duplicate.

Table 3.4-2 Potrero Canyon Unit Second Quarter 2011 Sampling Schedule – Monitored Natural Attenuation - Focused Data Collection

Monitoring Well Location	Sample Date	VOCs (1)	1,4-Dioxane (2)	Perchlorate (3)	Focused Data Collection Natural Attenuation Parameters (4)	Perchlorate reductase and/or Dehalococcoides spp polymerase chain reaction	Comments and QA / QC Samples
F34-TW1	5/4/2011	X	X	X	X	X	Sample with Peristaltic Pump, Duplicate F34-TW1-DUP, MS/MSD
MW-05	5/5/2011	X	X	X	X		Sample with Dedicated Pump, Duplicate MW-05-DUP
MW-43	5/4/2011	X	X	X	X		Sample with Dedicated Pump
MW-48	5/4/2011	X	X	X	X		Sample with Dedicated Pump
MW-54	5/4/2011	X	X	X	X		Sample with Dedicated Pump
MW-85B	5/3/2011	X	X	X	X	X	Sample with Dedicated Pump
MW-86B	5/3/2011	X	X	X	X	X	Sample with Dedicated Pump
MW-87B	5/2/2011	X	X	X	X	X	Sample with Dedicated Pump
MW-92	5/3/2011	X	X	X	X	X	Sample with Dedicated Pump
MW-93	5/2/2011	X	X	X	X	X	Sample with Dedicated Pump
MW-106	5/5/2011	X	X	X	X	X	Sample with Peristaltic Pump
MW-109	5/5/2011	X	X	X	X	X	Sample with Peristaltic Pump

Total Sample Locations:	12
Total Samples Collected:	12

Notes:

(1) -	Volatile organic compounds (VOCs) analyzed by EPA Method SW8260 B
(2) -	1,4 - Dioxane analyzed by EPA Method SW8270C SIM
(3) -	Perchlorate analyzed by EPA Method E332.0
(4) -	Focused data collection natural attenuation parameters by various methods (chlorate, chloride, chlorite, alkalinity, nitrate, nitrite, total iron, dissolved manganese, sulfate, total dissolved solids, hypochlorite, dissolved organic carbon, hydrogen, methane, ethane, and ethane).
"-" -	Not analyzed.

Table 3.4-3 Laborde Canyon Sampling Schedule – Monitored Natural Attenuation - Focused Data Collection

Monitoring Well or Surface Water Location	Sample Date	qPCR assay (perchlorate) (1)	Comments and QA / QC Samples
TT-MW2-24	02/01/11	X	Sample with Dedicated Pump
TT-MW2-39	02/01/11	X	Sample with Dedicated Pump
TT-MW2-41A	01/27/11	X	Sample with Dedicated Pump
TT-MW2-42A	01/27/11	X	Sample with Portable Bladder Pump
TT-MW2-7	5/16/2011	X	Sample with Dedicated Pump
Total Sample Locations:		4	
Total Samples Collected:		4	

Notes:

(1) -	qPCR assay by CENSUS method
NA -	Not available.
"-"	Not analyzed
MS / MSD -	Matrix Spike / Matrix Spike Duplicate.

3.5 EX-SITU PERCHLORATE BIODEGRADATION TEST

A contaminant attenuation field biodegradation test was conducted in July 2011 to provide another line of evidence that natural biodegradation of perchlorate was occurring in the riparian area at Potrero Canyon Unit. Test preparation encompassed the collection of shallow saturated or near-saturated soil in the riparian area, where elevated levels of total organic carbon (TOC) were detected, and collection of groundwater from a shallow well in the riparian area with perchlorate concentrations representative of groundwater entering the riparian area. Soil was collected from four locations at various depths, near soil borings SB-2 and SB-3 and wells MW-80 and OW-02, in order to obtain a sample representative of the entire area and amenable to perchlorate biodegradation, see Table 3.5-1.

Table 3.5-1 Potrero Canyon Unit Soil Collection Locations

Location	Depth (feet bgs)
Near SB-2	5 - 6
Near SB-3	7.5
Near MW-80	1.5 - 2
Near OW-02	1 - 1.5

The soil was screened to remove any material greater than 1/4-inch and homogenized by mixing the soils thoroughly before filling the test containers. A soil sample was collected after the soil was thoroughly mixed and analyzed for perchlorate, nitrate, TOC, and pH to ensure the soil conditions were suitable before conducting the test. Soil was placed into 2-liter glass containers with lids that properly seal to ensure minimal oxygen intrusion into the microcosms. Soil was placed into the containers leaving enough room at the top of the container for collection of a 250-ml water sample for laboratory testing and field parameters.

Groundwater was collected from a shallow well at the upgradient edge of the riparian area (MW-109) where perchlorate concentrations are on the order of 300-500 µg/L and is representative of groundwater migrating into the riparian area. The groundwater was analyzed for perchlorate, nitrate, and TOC, along with the standard field parameters (DO, ORP, pH, temp, EC, and turbidity) to determine baseline conditions.

The test containers were filled with about 75-85% soil by volume and fill the remaining void space with groundwater to the top with minimal headspace. The test was conducted in triplicate in order to reduce the chance that perchlorate degradation in a single microcosm is inhibited due to unfavorable conditions related to heterogeneities in the soil (low microbial population, high nitrate concentrations, low TOC concentrations, low or high pH). Seven containers per test (total of 21 containers) were filled so that only a single sample was collected from each test container to minimize exposure to oxygen during the test. The microcosms were mixed by inversion three times a day to promote mixing of the solid substrate with the groundwater and stored at room temperature. Results of the ex-situ biodegradation test are presented in Section 4.1.3.

3.6 PLANT DENSITY SURVEY

Plant density surveys were conducted in October 2010 at Sites 1 and 2 and in March 2011 at Potrero Canyon Unit to evaluate whether phytoremediation could be a major natural attenuation mechanism within the riparian habitat. The plant density survey was conducted using the methodology described in the BLM publication “Measuring and Monitoring Plant Populations” (BLM Technical Reference 1730-1, Elzinga, 1998), and was limited to large (i.e., trees or large shrubs) obligate or facultative phreatophyte species (e.g., willows, cottonwood, and mulefat).

At Sites 1 and 2, transect points were randomly placed within the washes. At each transect point, a 100-foot by 100-foot (10,000 square feet) quadrat was established. Each transect point served as a corner position for a quadrat. From this point, two 100-foot lines, forming a right angle, were created to delineate the boundaries of the quadrat. One line was drawn at a right angle to the direction of the wash and the other parallel to the direction of the wash. Within the quadrat, the number of individuals of each perennial species were counted and recorded and the percent cover for each species was estimated by the surveyor.

The wash at Laborde Canyon is much narrower than the washes at Potrero Canyon Unit, therefore, the transect points were used as the center of a 100-foot line crossing the wash at a right angle to the direction of the wash. From each end of this line another line, at a right angle, was created to delineate the sides of the quadrat. Similar to Potrero Canyon Unit, the number of individuals of each perennial species was counted and recorded and the percent cover for each species was estimated by the surveyor and recorded. The point locations where the plant density surveys were conducted are shown in Figure 3-3 (Potrero Canyon Unit) and Figures 3-4 (Laborde Canyon).

X:\GIS\Lockheed 25421-01-0603\Riparian_S1.mxd

0 500 1,000
Feet

LEGEND

● Survey Location

Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 3-3
Plant Density Survey Locations

TETRA TECH

X:\GIS\Lockheed 25421-01-0603\Riparian_S2.mxd

LEGEND

- ● Survey Location
- ⊗ Monitoring Well Location
- ● Springs
- ▭ Laborde Canyon Property Boundary (Lockheed Martin Beaumont Site 2)

Notes: Laborde Canyon (Lockheed Martin Beaumont Site 2) property boundary from Hillwig-Goodrow survey, May 2004.

Laborde Canyon
(Lockheed Martin Beaumont Site 2)

Figure 3-4

Plant Density Survey Locations

3.7 EVAPOTRANSPIRATION MONITORING

In areas where plant growth is pulling water from shallow water tables, daily fluctuations of groundwater levels have been shown to correlate with the rate of evapotranspiration from the water table (White, 1932). Evapotranspiration surveys have previously been undertaken at the Potrero Canyon Unit riparian areas to record daily groundwater level variations in wells in order to help quantify the evapotranspiration mechanism and rate (Tetra Tech, 2010e). Pressure transducers were placed in seven (7) monitoring wells located in the plant uptake area to estimate evapotranspiration using the same analysis methods outlined in previous site groundwater monitoring reports (Tetra Tech, 2009a), with the results given in Appendix B. These charts also show daily measurements of precipitation from the nearby Beaumont and San Jacinto NWS stations, and daily measurements of evapotranspiration from the nearby University of California, Riverside (UCR) monitoring station maintained by the California Irrigation Management Information System (CIMIS) (CIMIS, 2011).

The water level variations and evapotranspiration values seen in the Appendix B figures correlate well with the precipitation and CIMIS evapotranspiration measurements, and this data also shows a fair correlation between evapotranspiration rate and depth to groundwater at the monitoring well locations. This data will be used along with similar measurements previously reported in other site wells to better define evapotranspiration rates in the site groundwater model and groundwater budget.

3.8 INVESTIGATION-DERIVED WASTE

Waste management activities were conducted in accordance with the Waste Management Plan, Lockheed Martin Corporation, Beaumont Sites 1 & 2, Beaumont, California (Tetra Tech 2009d). Investigation derived waste (IDW) generated from the field activities at Sites 1 and 2 included soil cuttings from drilling and decontamination water and purge water from sampling activities. Excess soil from sampling activities was temporarily stored on site in one a 20 cubic yard roll off containers prior to disposal, pending characterization. Water generated during drilling activities and subsequent sampling/purging activities was placed in 55-gallon drums. All IDW was characterized prior to final transportation and disposal to an approved waste recycling/disposal facility. Copies of the analytical data and copies of IDW manifests are included in Appendix C.

3.9 HABITAT CONSERVATION

All monitoring activities were performed in accordance with the U.S. Fish and Wildlife Service approved Habitat Conservation Plan (HCP) [USFWS, 2005] and subsequent clarifications (LMC, 2006a and 2006b) of the HCP. Groundwater sampling activities were conducted with light duty vehicles and were supervised by a United States Fish and Wildlife Service (USFWS) approved biologist as specified in the Low Effect HCP.

SECTION 4 CONTAMINANT ATTENUATION RESULTS AND DISCUSSION

4.1 POTRERO CANYON UNIT CONTAMINANT ATTENUATION RESULTS

4.1.1 Site Geology and Lithology

The drilling conducted as part of this investigation was focused on collecting samples to assess what role natural attenuation processes may play in the attenuation of COPCs and therefore additional information collected with respect to site-wide geology is limited. Two stratigraphic units that exist beneath the Site were encountered during this investigation, the Quaternary alluvium, and the weathered portion of the Mount Eden formation. General observations regarding the depths encountered and make-up of the different units observed during the drilling of the borings during this investigation are provided below.

Quaternary Alluvium

Alluvium was observed at all of the locations drilled during this investigation. The thickness of the alluvium ranged from 38 feet, in SB3, to a total depth of 50-60 feet bgs in the remaining borings (SB1, SB2, SB4 and SB5). The alluvium observed during this investigation consisted primarily of sand, silt, and a combination thereof, with interbedded clays. The exception was SB3 where there was a 12 foot thick layer of clay from 13 to 25 feet bgs.

Mount Eden formation

During this investigation, the Mount Eden formation was encountered at one boring location, SB3 located near OW-02 south of the wash and before the confluence of Potrero Creek and Bedsprings Creek. The Mount Eden formation has several members and varies from very well indurated to poorly consolidated and friable. The formation can be red to olive gray and range from mudstone to coarse thick-bedded conglomeritic sandstone. At this location the weathered formation was encountered at 38 feet bgs and was observed as being yellowish red, fine to coarse grained and at 48 feet bgs becomes moderately to well indurated.

Analytical Results

This section summarizes the focused data collection results by environmental media as part of the contaminant attenuation study.

4.1.1.1 Data Quality Review

The quality control samples were reviewed as described in the Programmatic Sampling and Analysis Plan (Tetra Tech, 2010d). The data for the groundwater sampling activities were contained in analytical data packages generated by Microseeps Laboratories Inc., Microbial Insights Inc., and E.S. Babcock and Sons Laboratories Inc. These data packages were reviewed using the latest versions of the National Functional Guidelines for Organic and Inorganic Data Review documents from the EPA.

Preservation criteria, holding times, field blanks, laboratory control samples (LCS), method blanks, duplicate environmental samples, spiked samples, and surrogate and spike recovery data were reviewed. Within each environmental sample the sample specific quality control spike recoveries were examined. These data examinations include comparing statistically calculated control limits to percent recoveries of all spiked analytes and duplicate spiked analytes. Relative Percent Difference (RPD) control limits are compared to actual spiked (MS/MSD) RPD results. Surrogate recoveries were examined for all organic compound analyses and compared to their control limits.

Environmental samples were analyzed by the following methods: Method AM23G for Volatile Fatty Acids, Method AM20GAX for Hydrogen, Method E300.0 for anions, Method E332.0 for Perchlorate, Method E332.0M for Chlorate and Chlorite, Method DI-MSMS for Hypochlorite, Method SM2320 for Alkalinity, Method CENUS for Perchlorate Reductase, Method A5310 for Total Organic Carbon, Method RSK-175 for Methane, Ethane, Ethene, Method SW8270C SIM for 1,4-Dioxane, Methods SW6010B and E200.7 for Metals, and Method SW8260B for VOCs.

Unless otherwise noted below, all data results met required criteria, are of known precision and accuracy, did not require qualification, and may be used as reported.

Method SW8270C SIM for 1,4-Dioxane had holding time errors that caused 10.5 percent (4 samples out of 38 samples) of the total SW8270C SIM data to be qualified as estimated. The sample was extracted within holding times but the sample extract vial was broken after extraction holding times were expired. Therefore the sample had to be extracted outside of holding times. The data qualified as estimated is usable for the intended purpose.

Method SM5310B for Total Organic Carbon (TOC) had field duplicate RPD errors and MS/MSD RPD errors that caused 2.7 percent (3 samples out of 111 samples) of the total SM5310B data to be qualified as estimated. The data qualified as estimated is usable for the intended purpose.

Method SM5310B also had field blank contamination that qualified 8.1 percent (9 out of 111) of the total TOC data. The blank qualified data may be considered not detected at an elevated detection level equal to the blank contamination level.

Method SW8260B for VOCs had field blank contamination that caused 1.3 percent (22 analytes of 1634 analytes) of the total SW8260B data to be qualified for field blank contamination. Method blank contamination caused 0.4 percent (6 out of 1634) of the total SW8260B data to be qualified for method blank contamination. Corrective action for the method blank contamination is being performed at the laboratory. The blank qualified results should be considered not detected at elevated detection levels equal to the blank contamination level.

Method AM23G for volatile fatty acids had field duplicate RPD errors that qualified as estimated 1.4 percent (2 analytes out of 144 analytes) of the total AM23G data. The data qualified as estimated is usable for the intended purpose. Method blank contamination caused 1.4 percent (2 out of 144) of the total AM23G data to be qualified for method blank contamination. Corrective action for the method blank contamination is being performed at the laboratory. The blank qualified results should be considered not detected at elevated detection levels equal to the blank contamination level.

Method AM20GAX for hydrogen had method blank contamination that caused 10.3 percent (4 out of 39) of the total AM20GAX data to be qualified for method blank contamination. Corrective action for the method blank contamination is being performed at the laboratory. The blank qualified results should be considered not detected at elevated detection levels equal to the blank contamination level.

Method DI-MSMS for hypochlorite had zero recovery of the MS/MSD spike. The hypochlorite ion is highly reactive and cannot be detected in water samples since it reacts completely with the native TOC in the sample. Therefore all of the hypochlorite data results are rejected and should not be used.

Method E200.7 and SW6010B for metals had field blank contamination that caused 10.7 percent (4 of 38 analytes) of the total metals data to be qualified for field blank contamination. Method blank contamination caused 5.3 percent (2 out of 38) of the total metals data to be qualified for method blank contamination. Corrective action for the method blank contamination is being performed at the laboratory. The blank qualified results should be considered not detected at elevated detection levels equal to the blank contamination level.

Method E300.0 for chloride had field blank contamination that qualified 8.1 percent (3 out of 37) of the total chloride data. The blank qualified results should be considered not detected at elevated detection levels equal to the blank contamination level.

Method E300.0 for sulfate had field blank contamination that qualified 7.9 percent (3 out of 38) of the total sulfate data. The blank qualified results should be considered not detected at elevated detection levels equal to the blank contamination level.

Method E300.0 for nitrate had LCS recoveries outside control limits that qualified as estimated 5.5 percent (3out of 55) of the total nitrate data. The estimated data is usable for the intended purpose. The laboratory is performing corrective action for the LCS failure.

Method E332.0M for chlorate and chlorite had MS/MSD recoveries below control limits that qualified as estimated 100 percent (24 out of 24) of the data. There appears to be matrix issues that have caused the analytes to be recovered at low levels. The data qualified as estimated may be used for the intended purpose.

Method RSK-175 for methane/ethane/ethane had matrix spike recoveries outside control limits that qualified as estimated 0.9 percent (1 out of 114) of the total data. The data qualified as estimated may be used for the intended purpose. Method RSK-175 had field blank contamination that caused 4.4 percent (5 out of 114) of the total data to be qualified for field blank contamination. Method blank contamination caused 7.9 percent (9 out of 114) of the total data to be qualified for method blank contamination. Corrective action for the method blank contamination is being performed at the laboratory. The blank qualified results should be considered not detected at elevated detection levels equal to the blank contamination level.

4.1.1.2 Soil Results

A total of 55 soil samples (including 7 duplicate samples) were collected from five borings and analyzed for TOC and total solids. Positive detections of TOC occurred in 41 samples at concentrations ranging from 510 mg/kg to 24,000 mg/kg. The highest TOC concentrations were detected in the upper 20 feet of the subsurface. The results of these analyses are shown in Table 4.1-1.

Table 4.1-1 Soil Sampling Results for Total Organic Carbon

Sample Name	Depth (ft bgs)	Sample Date	Total Organic Carbon (mg/kg)
SB1-7'	7	1/19/2011	1,800 Jq
SB1-12'	12	1/19/2011	1,500 Jq
SB1-18'	18	1/19/2011	14,000
SB1-23'	23	1/19/2011	2,900
SB1-28'	28	1/19/2011	510 Jq
SB1-33'	33	1/19/2011	3,700 Jf
SB1-38'	38	1/19/2011	10,000
SB1-43'	43	1/19/2011	1,900 Jq
SB1-48'	48	1/19/2011	8,700
SB1-52'	52	1/19/2011	660 Jfq
SB2-8'	8	1/19/2011	21,000
SB2-12'	12	1/19/2011	8,800
SB2-18'	18	1/19/2011	810 Jq
SB2-22'	22	1/19/2011	770 Jq
SB2-27'	27	1/19/2011	16,000
SB2-33'	33	1/19/2011	5,700
SB2-37'	37	1/19/2011	700 Jq
SB2-42'	42	1/19/2011	3,700
SB2-47'	47	1/19/2011	<510
SB3-9'	9	1/18/2011	24,000 Jf
SB3-13'	13	1/18/2011	1,800 Jq
SB3-17'	17	1/18/2011	5,700
SB3-22'	22	1/18/2011	5,200
SB3-28'	28	1/18/2011	1,600 Jq
SB3-34'	34	1/18/2011	<500
SB3-39'	39	1/18/2011	<500
SB3-44'	44	1/18/2011	<500
SB4-7'	7	1/17/2011	14,000
SB4-12'	12	1/17/2011	22,000
SB4-17'	17	1/17/2011	12,000
SB4-22'	22	1/17/2011	4,200
SB4-27'	27	1/17/2011	1,200 Jq
SB4-32'	32	1/17/2011	2,000
SB4-37'	37	1/17/2011	3,500
SB4-42'	42	1/17/2011	1,100 Jq
SB4-47'	47	1/17/2011	3,100
SB4-59'	59	1/17/2011	16,000
SB5-7'	7	1/17/2011	24,000
SB5-12'	12	1/17/2011	6,200
SB5-17'	17	1/17/2011	18,000
SB5-22'	22	1/17/2011	880 Jq
SB5-27'	27	1/17/2011	8,600
SB5-32'	32	1/18/2011	2,000
SB5-37'	37	1/18/2011	2,700
SB5-42'	42	1/18/2011	2,700
SB5-47'	47	1/18/2011	<490
SB5-52'	52	1/18/2011	<500
SB5-57'	57	1/18/2011	<500

Notes: ft bgs – feet below ground surface.

Two samples were collected from each boring to determine physical properties to support development of the contaminant attenuation model. Geotechnical test results show the soil types vary depending on the location and samples depths. The soil types determined for samples were clayey sands, silty sands, and low plasticity clays. The geotechnical laboratory testing results are summarized in Table 4.1-2.

Table 4.1-2 Soil Sampling Results for Physical Properties

Sample Name	Depth (ft bgs)	Moisture Content (%) (ASTM D2216)	Dry Density (pcf) (ASTM D2937)	Specific Gravity (ASTM D854)	Total Porosity (%) (API RP40)
SB1-11’	11.0	12.9	106.0	2.703	37.52
SB1-36’	36.0	22.2	106.2	2.725	37.5
SB2-26.5’	26.5	28.3	91.8	2.697	46.39
SB2-41.5’	41.5	17.6	114.0	2.71	31.88
SB3-16’	16.0	26.6	100.4	2.699	40.39
SB3-26’	26.0	24.4	102.1	2.719	39.47
SB4-31.5’	31.5	32.8	88.8	2.723	47.78
SB4-46.5’	46.5	21.1	107.4	2.744	36.18
SB5-16.5’	16.5	19.2	100.4	2.682	40.63
SB5-31.5’	31.5	21.9	104.8	2.699	37.77

Notes: ft bgs – feet below ground surface.

4.1.1.3 Groundwater Results

Summaries of validated analytical results for organic (VOCs and 1,4-dioxane) and inorganic (perchlorate, natural attenuation and general mineral parameters) analytes detected above their respective method detection limits (MDLs) from Fourth Quarter 2010 and Second Quarter 2011 sampling events are presented in Tables 4.1-3, 4.1-4, 4.1-5 and 4.1-6. A complete list of analytes tested, along with the validated sample results by analytical method are provided in Appendix D.

Sample results detected above the published California Department of Public Health maximum contaminant level (MCL) or the California Department of Public Health drinking water notification level (DWNL) are bolded in Tables 4.1-3, 4.1-4, 4.1-5 and 4.1-6. Laboratory analytical data packages, which include environmental, field QC, and laboratory QC results, are provided in Appendix E. Tables 4.1-7 and 4.1--8 present summary statistics of the organic and inorganic analytes detected during the Fourth Quarter 2010 and Second Quarter 2011 monitoring events.

Table 4.1-3 Summary of Detected Organic Analytes in Monitoring Wells - Fourth Quarter 2010

Area	Sample Location	Sample Date	1,4-Dioxane	Benzene	Carbon Disulfide	Chloro benzene	Chloro ethane	Carbon Tetra chloride	Chloro form	1,1-Dichloro ethane	1,2-Dichloro ethane	1,1-Dichloro ethene	c-1,2-Dichloro ethene	t-1,2-Dichloro ethene	Methylene Chloride	Toluene	1,1,1-Trichloro ethane	1,1,2-Trichloro ethane	Trichloro ethene	Tetrachloro ethene	Vinyl Chloride
All results are reported in µg/L unless otherwise stated.																					
Burn Pit Area	EW-13	1/12/2011	**450 Je**	0.89	<0.36	<0.23	<0.35	<0.15	1.1	**23**	**47**	**1,900**	**130**	0.86	0.90 BJkq	<0.22	0.13 Jq	**7.2**	**560**	2.1	**36**
	EW-15	1/11/2011	**48**	<0.14	<0.36	<0.23	<0.35	<0.15	1.4	**19**	**24**	**530**	**12**	<0.10	0.28 BJkq	<0.22	0.19 Jq	1.5	**130**	0.30 Jq	0.31 Jq
	EW-16	1/20/2011	**480 Je**	0.7	<0.36	<0.23	<0.35	**0.39 Jq**	18	**30**	**26**	**2,100**	**12**	1	0.60 BJkq	<0.22	0.71	**9.5**	**390**	0.77	0.22 Jq
	EW-18	1/19/2011	**520 Je**	**3.1**	<0.36	0.46 Jq	1.2	**1.4**	18	**190**	**210**	**6,900**	**84**	4.2	1.8 BJkq	0.22 Jq	1.9	**13**	**1,900**	**5.4**	**3.4**
	MW-61B	1/10/2011	**570 Je**	**1.9**	<0.36	0.49 Jq	<0.35	**7.2**	27	**170**	**95**	**7,500**	**41**	3.7	0.39 BJakq	<0.22	5.6	**15**	**1,700**	**7.9**	0.47 Jq
	MW-61C	1/12/2011	**8.9**	<0.14	0.42 Jq	<0.23	<0.35	<0.15	1.2	4.2	**3.3**	**170**	0.97	<0.10	0.19 BJkq	<0.22	0.13 Jq	0.35 Jq	**43**	<0.23	<0.13
Injection Area	IW-01	1/18/2011	<0.10	<0.14	<0.36	<0.23	<0.35	<0.15	<0.46	<0.098	<0.21	<0.12	<0.18	<0.10	0.17 BJkq	<0.22	<0.12	<0.31	<0.25	<0.23	<0.13
	IW-02	1/18/2011	1.0	<0.14	<0.36	<0.23	<0.35	<0.15	<0.46	<0.098	<0.21	0.51 Bk	<0.18	<0.10	<0.15	<0.22	<0.12	<0.31	1.2 Bk	<0.23	<0.13
	IW-03	1/17/2011	**24**	0.21 Jq	<0.36	<0.23	<0.35	<0.15	<0.46	1.8	0.38 Jq	**47**	1.5	<0.10	0.15 BJkq	<0.22	<0.12	<0.31	**43**	<0.23	<0.13
	IW-04	1/17/2011	**23**	0.25 Jq	<0.36	<0.23	0.67	<0.15	<0.46	0.33 Jq	0.33 Jq	**25**	1.8	0.40 Jq	0.40 BJkq	0.32 Jq	<0.12	<0.31	**18**	<0.23	**0.83**
	IW-05	1/19/2011	**26**	<0.14	<0.36	<0.23	<0.35	<0.16	0.47 Jq	1.1	0.42 Jq	**28**	0.65	<0.10	0.22 BJkq	<0.22	<0.12	<0.31	**42**	<0.23	<0.13
Large Motor Washout Area	F33-TW2	1/7/2011	**4.0**	<0.14	<0.36	<0.23	<0.35	<0.17	<0.46	<0.098	<0.21	<0.12	<0.18	<0.10	0.41 BJakq	<0.22	<0.12	<0.31	<0.25	<0.23	<0.13
	F33-TW3	1/13/2011	**3.0**	<0.14	<0.36	<0.23	<0.35	<0.18	<0.46	<0.098	<0.21	<0.12	<0.18	<0.10	0.23 BJkq	<0.22	<0.12	<0.31	<0.25	<0.23	<0.13
	F33-TW6	1/7/2011	**3.4**	<0.14	<0.36	<0.23	<0.35	<0.20	<0.46	<0.098	<0.21	<0.12	<0.18	<0.10	0.22 BJakq	<0.22	<0.12	<0.31	<0.25	<0.23	<0.13
	MW-70	1/13/2011	**2.5**	<0.14	<0.36	<0.23	<0.35	<0.22	<0.46	<0.098	<0.21	<0.12	<0.18	<0.10	0.22 BJkq	<0.22	<0.12	<0.31	<0.25	<0.23	<0.13
	MW-82	1/10/2011	**3.2**	<0.14	<0.36	<0.23	<0.35	<0.23	<0.46	<0.098	<0.21	<0.12	<0.18	<0.10	<0.15	<0.22	<0.12	<0.31	<0.25	<0.23	<0.13
	MW-83	1/10/2011	**2.4**	<0.14	<0.36	<0.23	<0.35	<0.24	<0.46	<0.098	<0.21	<0.12	<0.18	<0.10	2.2 BJaq	<0.22	<0.12	<0.31	<0.25	<0.23	<0.13
Riparian Area	MW-101	1/11/2011	**24**	<0.14	<0.36	<0.23	<0.35	<0.25	<0.46	1.5	0.48 Jq	**49**	**41**	1.5	0.19 BJkq	<0.22	<0.12	<0.31	**41**	<0.23	**2.2**
	MW-102	1/17/2011	**20**	<0.14	<0.36	<0.23	<0.35	<0.26	<0.46	1.5	0.25 Jq	**19**	**29**	1.9	0.15 BJkq	<0.22	<0.12	<0.31	**14**	<0.23	**3.2**
RMPA	MW-19	1/11/2011	**62**	<0.14	<0.36	<0.23	<0.35	<0.27	<0.46	2.7	0.44 Jq	**34**	0.53	<0.10	0.15 BJkq	<0.22	0.31 Jq	<0.31	**17**	<0.23	**2.2**
	MW-44	1/19/2011	**25**	<0.14	<0.36	<0.23	<0.35	<0.28	1.5	2.3	**0.79**	**88**	0.40 Jq	<0.10	0.26 BJkq	<0.22	0.34 Jq	0.36 Jq	**100**	<0.23	<0.13
	MW-49	1/10/2011	**11**	<0.14	<0.36	<0.23	<0.35	<0.29	<0.46	0.23 Jq	<0.21	**13**	<0.18	<0.10	<0.15	<0.22	0.27 Jq	<0.31	**16**	<0.23	<0.13
	MW-50	1/18/2011	**13**	<0.14	<0.36	<0.23	<0.35	<0.31	<0.46	0.75	0.49 Jq	**28**	<0.18	<0.10	<0.15	<0.22	0.31 Jq	<0.31	**29**	<0.23	<0.13
	MW-51	1/18/2011	**19**	<0.14	<0.36	<0.23	<0.35	<0.32	0.53	0.49 Jq	0.21 Jq	**25**	<0.18	<0.10	<0.15	<0.22	0.44 Jq	<0.31	**28**	<0.23	<0.13
	MW-52	1/18/2011	**22**	<0.14	<0.36	<0.23	<0.35	<0.33	0.52	0.78	0.41 Jq	**43**	0.20 Jq	<0.10	0.29 BJkq	<0.22	0.26 Jq	<0.31	**43**	<0.23	<0.13
MDL			<0.10	<0.14	<0.36	<0.23	<0.35	<0.34	<0.46	<0.098	<0.21	<0.12	<0.18	<0.10	<0.15	<0.22	<0.12	<0.31	<0.25	<0.23	<0.13
MCL/DWNL			1 (1)	1	160 (1)	-	-	0.5	-	5	0.5	6	6	10	-	150	200	5	5	5	0.5

Notes: Only analytes positively detected are presented in this table. For a complete list, refer to the laboratory data package.

µg/L - micrograms per liter.

MDL - Method detection limit

DWNL - California Department of Public Health drinking water notification level.

MCL - California Department of Public Health Maximum Contaminant Level

(1) DWNL

"-" - MCL or DWNL not available.

Bold - MCL or DWNL exceeded.

<# - Analyte not detected, method detection limit concentration is shown.

B - The result is < 5 times the blank contamination. Cross contamination is suspected and the data is considered unusable

a - The analyte was found in the method blank.

e - a holding time violation occurred.

k - The analyte was found in a field blank.

q - The analyte detection was below the Practical Quantitation Limit (PQL).

J - The analyte was positively identified, but the analyte concentration is an estimated value.

Table 4.1-4 Summary of Detected Inorganic Analytes in Monitoring Wells - Fourth Quarter 2010

Area	Sample Location	Sample Date	Per-chlorate µg/L	Chloride mg/L	Ethene µg/L	Ethane µg/L	Methane µg/L	Total Alkalinity (as CaCO3) mg/L	Bicarbonate (as CaCO3) mg/L	Dissolved Organic Carbon mg/L	Dis-solved Solids mg/L	Hyd-rogen nM	Acetic Acid mg/L	Lactic Acid and HIBA mg/L	Pyruvic Acid mg/L	Prop-ionic Acid mg/L	Nitrite as N mg/L	Nitrate as N mg/L	Sulfate mg/L	Iron - µg/L	Dissolved Man-ganese µg/L	Functional Genes Perchorate Reductase (pcrA) cells/mL	Dechlorinating Bacteria Dehalococcoides spp. (DHC) cells/mL
Burn Pit Area	EW-13	1/12/2011	0.92	18	14	11	23	61	74	1.3 Bk	98	5.5	0.056 BJkq	0.230 Bak	<0.033	<0.007	<0.017	<0.11	2.6	**1,100**	6.2 Jq	<1.00	8.60
	EW-15	1/11/2011	**4,300**	11	7.5	9.3	10	98	120	13	160	2.0	0.120 Bk	0.160 Bak	<0.033	0.080	<0.017	1.2	5.8	**2,300**	**120**		
	EW-16	1/20/2011	**17,000**	34	3.2	14	4.4	61	74	3.0 Bk	180	11	0.071 Bk	0.200 Bk	<0.033	0.074 Bk	<0.017	1.7	7.7	**4,500**	**78**		
	EW-18	1/19/2011	**53,000**	130	49	110	4.50 Bk	51	62	<0.36	410	4.0	0.041 BJkq	0.230 Bak	0.100 BJkq	<0.007	<0.017	5.1 Jd	12	**4,000**	**200**		
	MW-61B	1/10/2011	**93,000**	52	0.05 Jq	0.35	0.23 Ba	58	71	10	550	11	0.079	<0.010	<0.033	0.11	<0.017	**21**	21	<2.3	**<0.24**		
	MW-61C	1/12/2011	**3,000**	16	0.03 Jq	0.61	0.41 Ba	98	120	1.0	170	11	0.14	<0.010	<0.033	<0.007	<0.017	0.34	7.6	3.4 BJaq	0.65 Jq		
Injection Area	IW-01	1/18/2011	0.081 Jq	23	<0.02	0.49	24	36	44	1.0 Bk	76	13	0.048 BJkq	<0.01	<0.033	<0.007	<0.017	<0.11	2.4 Bk	**85,000**	**390**		
	IW-02	1/18/2011	1.1	28	<0.02	1.5	1600	41	50	3.7 Bk	100	4.2	0.054 BJkq	<0.01	<0.033	<0.007	<0.017	<0.11	1.9 Bk	**19,000**	**360**		
	IW-03	1/17/2011	1.7	22	1.9	7.7	91	31	38	2.4	82	3.2	0.033 BJkq	0.170 Bak	<0.033	<0.007	<0.017	<0.11	1.2	**19,000**	**420**		
	IW-04	1/17/2011	<0.071	69	2.7	14	4200	2.0 Jq	2.4 Jq	0.85	200	20	0.057 Jq	0.170 Ba	<0.033	0.075	<0.017	<0.11	0.6	**15,000**	**660**	<1.00	<0.5
	IW-05	1/19/2011	**100**	23	0.42	2.4	8.5	53	65	0.80 Bk	150	2.8	0.031 BJkq	<0.010	<0.033	<0.007	<0.017	0.53 Jd	4.9 Bk	**11,000**	**260**		
Large Motor Washout Area	F33-TW2	1/7/2011	<0.071	17	<0.02	<0.01	130	300	370	2.5	480	9.6	0.045 Jq	0.240 Ba	<0.033	<0.007	<0.017	<0.11	60	**1,800**	**420**		
	F33-TW3	1/13/2011	0.34	16	<0.02	<0.01	8.5	280	340	3.9	410	5.6	0.085	<0.010	<0.033	<0.007	<0.017	0.11 Jeq	69	150	15	<1.00	
	F33-TW6	1/7/2011	<0.071	12	<0.02	<0.01	2.5	280	340	1.8	380	9.3	<0.006	<0.010	<0.033	<0.007	<0.017	<0.11	46	100	**180**		
	MW-70	1/13/2011	3.1	17	<0.02	<0.01	0.12 Ba	270	330	4.4	390	7.2	0.16	<0.010	<0.033	<0.007	<0.017	<0.11	74	6.3 BJaq	<0.24	<1.00	
	MW-82	1/10/2011	<0.071	12	0.06 Jq	<0.01	0.38 Ba	250	310	1.8	400	5.4	0.062 Jq	0.260 Ba	<0.033	<0.007	<0.017	0.14 Jq	48	2.7 Jq	2.2 Jq		
	MW-83	1/10/2011	1.5	15	<0.02	<0.01	0.04 BJaq	250	300	3.4	400	1.2	0.050 Jq	0.210 Ba	<0.033	<0.007	<0.017	0.11 Jq	61	2.5 Jq	<0.24		
Riparian Area	MW-101	1/11/2011	<0.071	6.1	0.06 Jq	0.02 Jq	0.18 Ba	72	88	0.98	170	1.3	<0.006	<0.010	<0.033	<0.007	<0.017	<0.11	30	510	**110**		0.5 (J)
	MW-102	1/17/2011	<0.071	5.3	0.08 Jq	0.02 Jq	83	120	140	0.91	160	1.9	0.089	<0.01	<0.033	<0.007	0.030 Jq	<0.11	16	130	**110**		0.6
Rocket Motor Production Area	MW-19	1/11/2011	**140**	6.4	0.05 Jq	0.02 Jq	0.23 Ba	85	100	0.94	140	11	0.059 Jq	<0.010	<0.033	<0.007	<0.017	<0.11	7.9	35	**90**	<1.00	0.4 (J)
	MW-44	1/19/2011	**990**	8.6	<0.02	<0.01	0.10 Bak	91	110	0.40 BJkq	230	5.3	0.056 BJkq	<0.010	0.095 BJkq	<0.007	<0.017	**12 Jd**	16	180 Bk	0.25 BJkq		
	MW-49	1/10/2011	**370**	5.2	<0.02	<0.01	0.04 BJaq	61	74	0.88	140	13	0.120 Jf	<0.010	<0.033	0.089	<0.017	4.3	5.9	<2.3	<0.24		
	MW-49	1/14/2011										5											
	MW-50	1/18/2011	**450**	5.8 Bk	<0.02	<0.01	0.09 BJkq	52	63	0.63 BJkq	130	5.3	<0.006	<0.010	<0.033	<0.007	<0.017	4.1	6.3	270	0.58 BJkq		
	MW-51	1/18/2011	**620**	6.6 Bk	<0.02	0.02 BJkq	7.2	62	76	2.3 Bk	180	3.0	0.059 BJkq	<0.010	<0.033	<0.007	<0.017	5.6	7	**340**	1.3 BJkq		
	MW-52	1/18/2011	**720**	5.9 Bk	<0.02	<0.01	0.09 BJkq	62	76	0.92 Bk	170	11	0.074 Bk	<0.010	<0.033	<0.007	<0.017	8.1	8.1	270	<0.24		
MDL			0.071	0.50	0.02	0.01	0.1	1.7	1.7	0.36	11	0.6	0.006	0.010	0.033	0.007	0.017	0.11	0.37	2	0.24	1	0.5
MCL/DWNL			6	-	-	-	-	-	-	-	-		-	-	-	-	1	10	250	300	50 (1)	-	-

Notes: Only analytes positively detected are presented in this table. For a complete list, refer to the laboratory data package.
µg/L - micrograms per liter.
mg/L - milligrams per liter.
MDL - Method detection limit
DWNL - California Department of Public Health drinking water notification level.
MCL - California Department of Public Health Maximum Contaminant Level
(1) DWNL
"-" - MCL or DWNL not available.
Bold - MCL or DWNL exceeded.

<# - Analyte not detected, method detection limit concentration is shown.
B - The result is < 5 times the blank contamination. Cross contamination is suspected and the data is considered unusable.
J - The analyte was positively identified, but the analyte concentration is an estimated value.
a - The analyte was found in the method blank.
d - The laboratory control sample recovery was outside control limits.
e - A holding time violation occurred.
k - The analyte was found in a field blank.
q - The analyte detection was below the Practical Quantitation Limit (PQL).
(J) - Estimated gene copies below PQL but above LQL.

Table 4.1-5 Summary of Detected Organic Analytes in Monitoring Wells - Second Quarter 2011

Area	Sample Name	Sample Date	1,4 - Dioxane	Chloroform	1,1-Dichloro ethane	1,2-Dichloro ethane	1,1-Dichloro ethene	c-1,2-Dichloro ethene	t-1,2-Dichloro ethene	1,1,1-Trichloro ethane	1,1,2-Trichloro ethane	Trichloro ethene	Trichloro fluoromethane	Tetrachloro ethene	Vinyl Chloride
	All results are reported in µg/L unless otherwise stated.														
MW-43	MW-43	5/4/2011	**8.3**	<0.46	0.52	<0.21	**6.5**	0.23 Jq	<0.10	<0.12	<0.31	**5.9**	<0.16	<0.23	<0.13
MW-48	MW-48	5/4/2011	**1.8**	<0.46	<0.098	<0.21	<0.12	<0.18	<0.10	<0.12	<0.31	<0.25	<0.16	<0.23	0.13 Jq
Area B	MW-05	5/5/2011	**29**	**2**	2	**0.51**	**98**	0.32 Jq	<0.10	0.38 Jq	0.35 Jq	**110**	<0.16	0.31 Jq	<0.13
	MW-54	5/4/2011	**22**	<0.46	0.9	**0.52**	**60**	0.23 Jq	<0.10	0.26 Jq	<0.31	**51**	<0.16	<0.23	<0.13
Area F	F34-TW1	5/4/2011	**10**	<0.46	<0.098	<0.21	0.27 Jq	<0.18	<0.10	<0.12	<0.31	0.79	<0.16	<0.23	<0.13
	MW-85B	5/3/2011	<0.10	<0.46	<0.098	<0.21	<0.12	<0.18	<0.10	<0.12	<0.31	**20**	<0.16	<0.23	<0.13
	MW-86B	5/3/2011	0.66	<0.46	<0.098	<0.21	0.16 Jq	0.71	0.24 Jq	<0.12	<0.31	**100**	0.21 Jq	<0.23	<0.13
	MW-87B	5/2/2011	**4.7**	<0.46	<0.098	<0.21	1.5	<0.18	<0.10	<0.12	<0.31	**11**	<0.16	<0.23	<0.13
	MW-92	5/3/2011	<0.10	<0.46	<0.098	<0.21	<0.12	<0.18	<0.10	<0.12	<0.31	**13**	<0.16	<0.23	<0.13
	MW-93	5/2/2011	**4.8**	<0.46	<0.098	<0.21	<0.12	<0.18	<0.10	<0.12	<0.31	<0.25	<0.16	<0.23	<0.13
Riparian Area	MW-106	5/5/2011	**20**	<0.46	1.8	0.29 Jq	**31**	1.8	2	<0.12	<0.31	**26**	<0.16	<0.23	0.40 Jq
	MW-109	5/5/2011	**27**	0.5	2.7	**0.56**	**58**	2.8	0.21 Jq	<0.12	<0.31	**60**	<0.16	<0.23	0.25 Jq
MDL			<0.10	<0.46	<0.098	<0.21	<0.12	<0.18	<0.10	<0.12	<0.31	<0.25	<0.16	<0.23	<0.13
MCL/DWNL			1 (1)	-	5	0.5	6	6	10	200	5	5	150	5	0.5

Notes: Only analytes positively detected are presented in this table. For a complete list, refer to the laboratory data package.

µg/L - micrograms per liter.

mg/L - milligrams per liter.

MDL - Method detection limit

DWNL - California Department of Public Health drinking water notification level.

MCL - California Department of Public Health Maximum Contaminant Level

(1) DWNL

"-" - MCL or DWNL not available.

Bold - MCL or DWNL exceeded.

<# - Analyte not detected, method detection limit concentration is shown.

J - The analyte was positively identified, but the analyte concentration is an estimated value.

q - The analyte detection was below the Practical Quantitation Limit (PQL).

Table 4.1-6 Summary of Detected Inorganic Analytes, Chlorite and Hypochorite in Monitoring Wells - Second Quarter 2011

Area	Sample Name	Sample Date	Per chlorate µg/L	Chlorite µg/L	Hypo- chlorite µg/L	Chloride mg/L	Methane ug/L	Alkalinity, Total (as CaCO3) mg/L	Bicar- bonate (as CaCO3) mg/L	Nitrite as N - mg/L	Nitrate as N - mg/L	Sulfate mg/L	Dissolved Organic Carbon - mg/L	Dissolved Solids mg/L	Acetic Acid mg/L	Lactic Acid and HIBA mg/L	Propionic Acid - mg/L	Pentanoic Acid - mg/L	Iron - ug/L	Man- ganese µg/L	Functional Genes Perchorate Reductase (pcrA) - cells/mL	Dechlorina- ting Bacteria Dehalo- coccoides spp.(DHC) cells/mL
MW-43	MW-43	5/4/2011	**51**	<20 UJcp	<50 Rcp	5	250	77	94	<0.017	0.77	9.6	<0.36	180	0.12	<0.010	0.1	<0.012	18 Jq	4.0 Jq		
MW-48	MW-48	5/4/2011	0.27	<2.0 UJcp	<50 Rcp	14	1,100 Je	150	180	<0.017	0.23	15	2.7	280	0.14	<0.010	0.14	<0.012	29	**160**		
Area B	MW-05	5/5/2011	**1,400**	<2000 UJcp	<50 Rcp	10	<0.0220	88	110	<0.017	**11**	11	<0.36	220	<0.0060	0.29 Jf	0.095	<0.012	<2.3	13		
	MW-54	5/4/2011	**1,000**	<2000 UJcp	<50 Rcp	7	<0.0220	62	76	<0.017	9.4	8.7	<0.36	220	0.094	<0.010	0.086	<0.012	<2.3	<0.24		
Area F	F34-TW1	5/4/2011	1.3	<2.0 UJcp	<50 Rcp	45	110 Jc	330	410	0.12	0.38	110	8.3	640	0.33	<0.010	0.095 Jf	<0.012	96	**60**	27,200	27.3
	MW-85B	5/3/2011	**<0.071**	<2.0 UJcp	<50 Rcp	29	4.2	87	100	<0.017	<0.11	85	<0.36	300	0.3	<0.010	0.068	0.07	26	2.3 Jq	<0.10	0.20 Jq
	MW-86B	5/3/2011	0.25	<2.0 UJcp	<50 Rcp	56	120	120	140	<0.017	<0.11	92	1.4	360	0.23	<0.010	0.096	0.073	**1,500**	**87**	6,860	54.1
	MW-87B	5/2/2011	**24**	<20 UJcp	<50 Rcp	41	0.18	300	370	<0.017	**25**	220	1.6	900	0.19	<0.010	0.07	<0.012	82	1.2 Jq	<0.10	<0.10
	MW-92	5/3/2011	**20**	<20 UJcp	<50 Rcp	75	38	150	190	<0.017	9.1	70	7.8	460	0.29	<0.010	0.064	<0.012	**900**	1.3 Jq	<0.10	1.5
	MW-93	5/2/2011	**9.1**	<2.0 UJcp	<50 Rcp	30	0.35	310	380	<0.017	**17**	54	5.9	660	0.35	<0.010	0.094	<0.012	**1,100**	0.47 Jq	<0.10	0.5
Riparian Area	MW-106	5/5/2011	**42**	<20 UJcp	<50 Rcp	32	6.5	220	260	<0.017	<0.11	110	5.4	500	0.093	0.61	0.1	<0.012	5.5 Jq	**320**	<0.10	9.7
	MW-109	5/5/2011	**430**	<200 UJcp	<50 Rcp	7.7	3.8	110	140	0.13	3.2	20	3.2	200	<0.0060	0.42	0.066	<0.012	28	**310**	<0.10	0.3
		MDL	0.071	2	50	0.5	0.02	1.7	1.7	0.017	0.54	0.37	0.36	11	0.0060	0.010	0.0070	0.012	2.3	0.24	0.10	0.10
		MCL/DWNL	6	-	-	-	-	-	-	1	10	250	-	-	-	-	-	-	300	50 (1)	-	-

Notes: Only analytes positively detected are presented in this table. For a complete list, refer to the laboratory data package.

µg/L - micrograms per liter.

mg/L - milligrams per liter.

MDL - Method detection limit

DWNL - California Department of Public Health drinking water notification level.

MCL - California Department of Public Health Maximum Contaminant Level

(1) DWNL

"-" - MCL or DWNL not available.

Bold - MCL or DWNL exceeded.

<# - Analyte not detected, method detection limit concentration is shown.

J - The analyte was positively identified, but the analyte concentration is an estimated value.

c - The MS and/or MSD recoveries were outside control limits.

e - a holding time violation occurred.

f - The duplicate/replicate sample's relative percent difference (RPD) was outside the control limit.

q - The analyte detection was below the Practical Quantitation Limit (PQL).

U - The analyte was not detected above the method detection limit (MDL).

p - Professional judgment determined the data should be qualified.

R - The sample result is rejected and not usable for any purpose. The presence or absence of the analyte cannot be verified.

Table 4.1-7 Summary Statistics of Validated Organic and Inorganic Analytes - Fourth Quarter 2010

Parameter	Total Number of Samples Analyzed	Total Detections (1)	Number of Detections Exceeding MCL or DWNL (1)	MCL / DWNL	Units	Minimum Concentration Detected	Maximum Concentration Detected
Organic Analytes							
1,4-Dioxane	25	24	23	1 (2)	µg/L	1.0	570
Benzene	25	6	2	1	µg/L	0.21	3.1
Chloroethane	25	2	0	-	µg/L	0.67	1.20
Carbon Tetrachloride	25	3	2	0.5	µg/L	0.39	7.20
Chloroform	25	10	0	-	µg/L	0.47	27
1,1-Dichloroethane	25	17	5	5	µg/L	0.23	190
1,2-Dichloroethane	25	16	7	0.5	µg/L	0.21	210
1,1-Dichloroethene	25	18	17	6	µg/L	0.51	7,500
c-1,2-Dichloroethene	25	14	7	6	µg/L	0.20	130
t-1,2-Dichloroethene	25	7	0	10	µg/L	0.40	4.2
Methylene Chloride	25	20	0	-	µg/L	0.15	2.20
Toluene	25	2	0	150	µg/L	0.22	0.32
1,1,1-Trichloroethane	25	12	0	200	µg/L	0.13	5.6
1,1,2-Trichloroethane	25	7	4	5	µg/L	0.35	15
Trichloroethene	25	18	17	5	µg/L	1.2	1,900
Tetrachloroethene	25	5	2	5	µg/L	0.30	7.9
Vinyl Chloride	25	9	6	0.5	µg/L	0.22	36
Inorganic Analytes							
Perchlorate	25	19	12	6	µg/L	0.081	93,000
Chloride	25	25	0	-	mg/L	5.20	130
Ethene	25	13	0	-	µg/L	0.030	49
Ethane	25	15	0	-	µg/L	0.020	110
Methane	25	25	0	-	µg/L	0.040	4,200
Alkalinity, Total (as CaCO3)	25	25	0	-	mg/L	2.00	300
Bicarbonate (as CaCO3)	25	25	0	-	mg/L	2.40	370
Total Organic Carbon	6	6	0	-	mg/L	1.70	3.1
Dissolved Organic Carbon	25	24	0	-	mg/L	0.40	13
Dissolved Solids	25	25	0	-	mg/L	76	550
Hydrogen	25	25	0	-	nM	1.20	20
Acetic Acid	25	21	0	-	mg/L	0.031	0.16
Lactic Acid and HIBA	25	9	0	-	mg/L	0.16	0.26
Pyruvic Acid	25	2	0	-	mg/L	0.10	0.10
Propionic Acid	25	5	0	-	mg/L	0.074	0.11
Nitrite as N	25	1	0	1	mg/L	0.030	0.03
Nitrate as N	25	14	2	10	mg/L	0.11	21
Sulfate	25	25	0	250	mg/L	0.60	74
Iron	25	23	12	300	µg/L	2.50	85,000
Dissolved Manganese	25	20	13	50 (2)	µg/L	0.25	660
Functional Genes Perchorate Reductase (pcrA)	5	0	0	-	cells/ mL	0.00	0
Dechlorinating Bacteria Dehalococcoides spp.(DHC)	5	4	0	-	cells/ mL	0.40	9

Notes:

DWNL - California Department of Public Health drinking water notification level.
MCL - California Department of Public Health Maximum Contaminant Level
(1) Number of detections excludes samle duplicates, trip blanks and equipment blanks.
(2) DWNL
"-" - MCL or DWNL not available.
mg/L - milligrams per liter.
µg/L - micrograms per liter.

Table 4.1-8 Summary Statistics of Validated Organic and Inorganic Analytes - Second Quarter 2011

Parameter	No. Samples	Total Detections (1)	Number of Detections Exceeding MCL or DWNL	MCL / DWNL	Units	Minimum Concentration	Maximum Concentration
Organic Analytes							
1,4-Dioxane	12	10	9	1 (2)	µg/L	0.66	29
Chloroform	12	2	-	-	µg/L	0.50	2.0
1,1-Dichloroethane	12	5	0	5	µg/L	0.52	2.7
1,2-Dichloroethane	12	4	3	0.5	µg/L	0.29	0.56
1,1-Dichloroethene	12	8	5	6	µg/L	0.16	98
c-1,2-Dichloroethene	12	6	0	6	µg/L	0.23	2.8
t-1,2-Dichloroethene	12	3	0	10	µg/L	0.21	2.0
1,1,1-Trichloroethane	12	2	0	200	µg/L	0.26	0.38
1,1,2-Trichloroethane	12	1	0	5	µg/L	0.35	0.35
Trichloroethene	12	10	9	5	µg/L	0.79	110
Trichlorofluoromethane	12	1	0	150	µg/L	0.21	0.21
Tetrachloroethene	12	1	0	5	µg/L	0.31	0.31
Vinyl Chloride	12	3	0	0.5	µg/L	0.13	0.40
Inorganic Analytes							
Perchlorate	12	11	8	6	µg/L	0.25	1,400
Chloride	12	12	-	-	mg/L	5.00	75
Methane	12	10	-	-	µg/L	0.18	1,100
Alkalinity, Total (as CaCO3)	12	12	-	-	mg/L	62	330
Bicarbonate (as CaCO3)	12	12	-	-	mg/L	76	410
Nitrite as N	12	2	0	1	mg/L	0.12	0
Nitrate as N	12	9	3	10	mg/L	0.23	25
Sulfate	12	12	0	250	mg/L	8.70	220
Dissolved Organic Carbon	12	8	-	-	mg/L	1.40	8
Dissolved Solids	12	12	-	-	mg/L	180	900
Acetic Acid	12	10	-	-	mg/L	0.09	0
Lactic Acid and HIBA	12	3	-	-	mg/L	0.29	1
Propionic Acid	12	12	-	-	mg/L	0.06	0
Pentanoic Acid	12	2	-	-	mg/L	0.07	0
Iron	12	10	3	300	µg/L	5.50	1,500
Manganese	12	11	5	50 (2)	µg/L	0.47	320
Functional Genes Perchorate Reductase (pcrA)	8	2	-	-	cell/mL	6,860	27,200
Dechlorinating Bacteria Dehalococcoides spp.(DHC)	8	7	-	-	cell/mL	0.20	54

Notes:

DWNL - California Department of Public Health drinking water notification level.
MCL - California Department of Public Health Maximum Contaminant Level
(1) Number of detections excludes samle duplicates, trip blanks and equipment blanks.
(2) DWNL
"-" - MCL or DWNL not available.
mg/L - milligrams per liter.
µg/L - micrograms per liter.

4.1.2 Ex-Situ Perchlorate Biodegradation Test Results

Water samples were collected from the first set of sample containers on the day the soil and groundwater were first mixed to determine baseline. The second set of water samples were collected approximately 24 hours later. The results of the first two samples were reviewed to determine the sampling frequency laboratory turnaround times for the next sampling event. The sampling frequency and laboratory turnaround times for subsequent samples were adjusted throughout the test based on the rate of perchlorate degradation. Water samples were collected throughout the test and analyzed for perchlorate, nitrate, and DOC, along with the standard field parameters. Water samples were analyzed for DOC opposed to TOC due to the turbidity. The laboratory results from the biodegradation test are summarized in Table 4.1-9.

The results of the biodegradation tests showed that within 72 hours, perchlorate in water samples (samples A-2, B-2 and C-2) decreased from 450 µg/L (at time zero) to less than 100 µg/L. Water samples collected 72 hours after analysis of A-2, B-2, and C-2, resulted in non-detectable concentrations in samples B-3 and C-3 and a concentration of 0.13 µg/L in sample A-3. A fifth set of water samples were collected which confirmed the absence of perchlorate. The initial concentrations of Nitrate as N detected in water samples did not inhibit perchlorate reduction. With the exception of sample A-3, nitrate concentrations after 144 hours diminished to non-detectable concentrations while DOC in Trials A and B steadily increased over the test duration. DOC in Trial C had some variability however the concentrations increased from 5.5 to 7.6 mg/L over the test duration. Overall, the results indicate that perchlorate in groundwater within the riparian area is amenable to biodegradation under normal site conditions due to the high organic carbon content in the solid matrix.

Statistical time trend analysis of the perchlorate concentrations measured during the Field Biodegradation Tests (Figure 4-1) indicates an equivalent first order perchlorate degradation rate of 0.06 hour-^{1} with a 95 percent confidence interval on the reaction rate of 0.04 hour^{-1}. This equates to a perchlorate half-life on the order of 7 to 42 hours, which is consistent with guidance documents (ITRC, 2005, 2007, and 2009) indicating the perchlorate reaction rate is quick relative to groundwater flow travel times (for example, the groundwater flow travel time across the Potrero Canyon Unit plume is on the order of 12 years). However, it should be noted that laboratory microcosm degradation rates are typically more rapid than those encountered in the field under natural conditions and on a much larger scale.

Table 4.1-9 Contaminant Attenuation Field Biodegradation Test Results

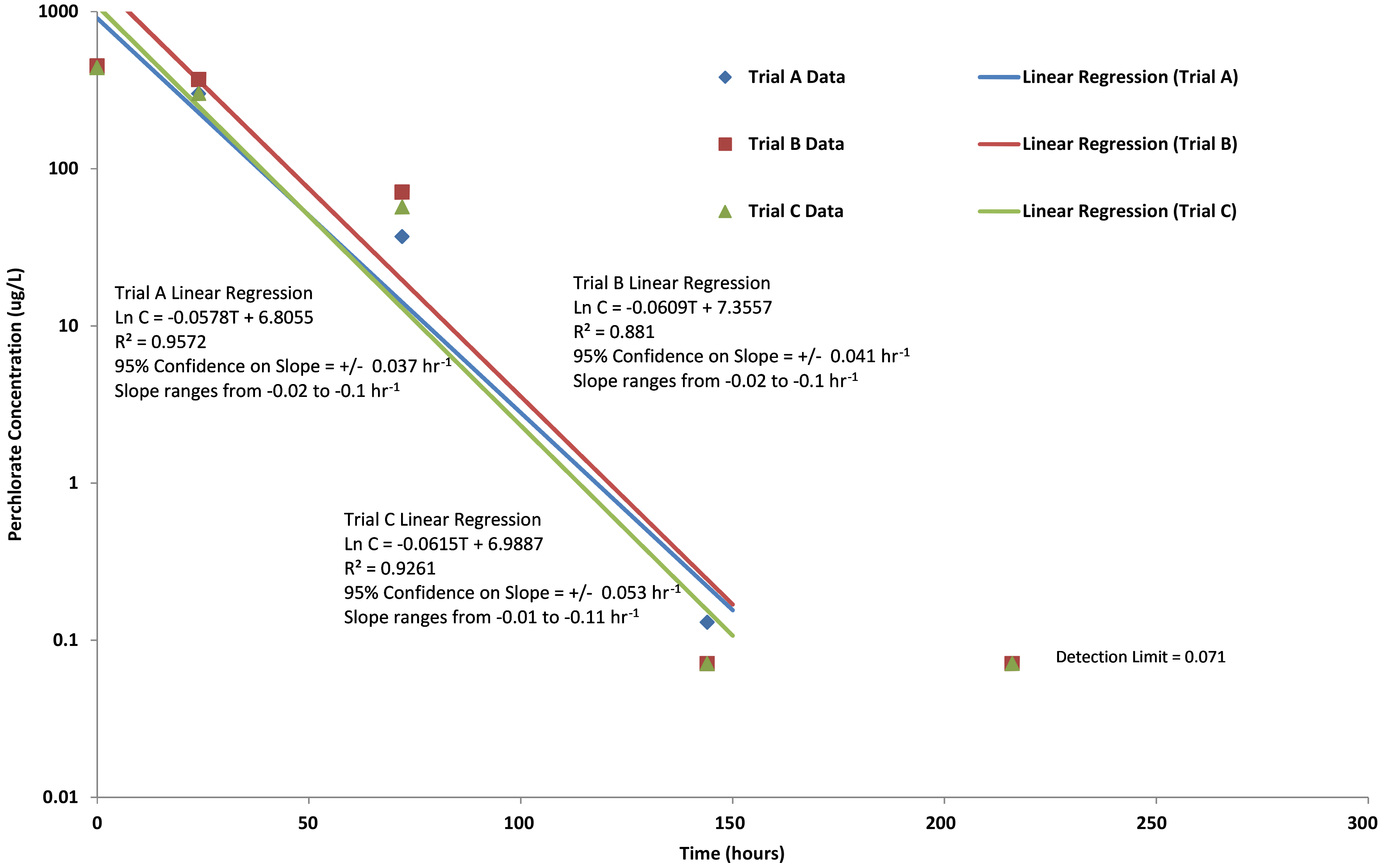
Sample Name	Sample Date	Time Lapsed (hours)	Matrix	Perchlorate (µg/L or µg/kg)	Dissolved Organic Carbon (mg/L)	pH (pH Units)	Nitrate as N (mg/L or mg/kg)	Total Organic Carbon (mg/L or mg/kg)
Baseline								
MNASOIL	7/8/2011		S	<1.3		7.2	1.7 Jq	14,000
MW-109	7/12/2011		W	490			3.1	0.51 Jq
Trial A								
A-O	7/12/2011	0	W	440	3.8		3.4	
A-1	7/13/2011	24	W	300	5.4		1.3	
A-2	7/15/2011	72	W	37	7.5		0.14 Jq	
A-3	7/18/2011	144	W	0.13	9.1		0.16 Jq	
A-4	7/20/2011	216	W	<0.071	9.8		<0.11	
A-5	7/22/2011	264	W		10			
Trial B								
B-O	7/12/2011	0	W	450	4		3.5	
B-1	7/13/2011	24	W	370	3.7		2.1	
B-2	7/15/2011	72	W	71	7.2		0.11 Jq	
B-3	7/18/2011	144	W	<0.071	7.8		<0.11	
B-4	7/20/2011	216	W	<0.071	7.4		<0.11	
Trial C								
C-O	7/12/2011	0	W	440	5.5		3.2	
C-1	7/13/2011	24	W	300	4		1.3	
C-2	7/15/2011	72	W	57	8		0.2	
C-3	7/18/2011	144	W	<0.071	2.9		<0.11	
C-4	7/20/2011	216	W	<0.071	7.6		0.14 Jq	

Notes:

µg/L - micrograms per liter.
µg/kg - micrograms per kilogram.
mg/L - milligrams per liter.
mg/kg - milligrams per kilogram.

S – Soil
W – Water
q - The analyte detection was below the Practical Quantitation Limit (PQL).
J - The analyte was positively identified, but the analyte concentration is an estimated value.

Figure 4-1 Statistical Analysis of Perchlorate Concentration vs. Time in Biodegradation Tests



4.1.3 Microbial Characteristics and Analyses of Perchlorate Biodegradation

4.1.3.1 Perchlorate Reducing Microorganisms and MBTs

Perchlorate has been shown to biodegrade via a sequential three-step process. It is used as a substitute for oxygen or nitrate in the microbial respiratory process. Several strains of microorganism have been identified and classified that have the ability to consume perchlorate in this respiratory process. The process proceeds from perchlorate to chlorate to chlorite, culminating in the formation of innocuous products, namely chloride and oxygen (Bruce E. Logan, 1998).

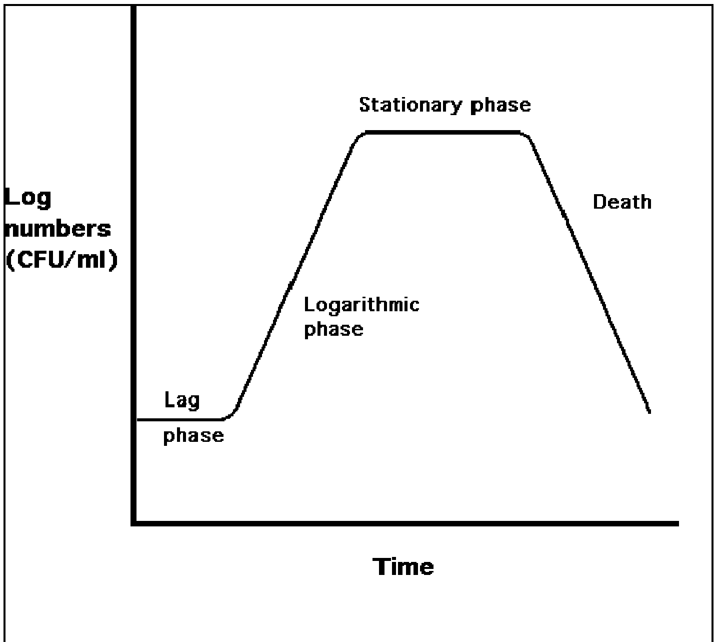
The ability of several genera of microorganisms to degrade perchlorate in different environmental and geochemical conditions has been examined by researchers and practitioners. These conditions include dissolved oxygen (DO), oxidation-reduction potential (ORP), organic carbon (TOC or DOC), and nitrate. An organic carbon source (natural or augmented) is essential to provide a substrate or energy source for the microbial respiratory process. Dissolved oxygen is the most critical terminal electron acceptor which competes with perchlorate for respiration because it is more thermodynamically favored by microorganisms. Generally, oxic conditions hinder the ability of native microorganisms to use perchlorate for respiration. Nitrate has also been shown to compete and inhibit chlorate respiration, although most perchlorate reducing microorganisms (PRBs) can also reduce nitrate. Although this is not always the case, low concentrations of nitrate are preferred for perchlorate biodegradation (Lieberman and Borden, 2008).

In general, it has been understood for many years that the ability to degrade perchlorate is not restricted to a single bacterial species. It is likely that PRBs are ubiquitous in the environment. Many PRBs have been isolated that belong to commonly known genera, classes, and strains of microorganisms. The majority of these isolates belong to the subclass Proteobacteria and include the genera Dechloromonas and Dechlorosoma (Jianlin Xu et al, 2003). Most of these microorganisms exhibit a broad range of metabolic capabilities including the oxidation of hydrogen, simple organic acids and alcohols, and reduced humic substances (Chaudhuri et al, 2002). Several strains of Pseudomonas have also been identified that have the ability to degrade perchlorate. In addition, several mixed cultures or consortia of microorganisms have been noted to use perchlorate as an electron acceptor (respiratory mechanism) using a variety of carbon substrates such as acetate, butyrate, citrate, glucose, and fructose (Logan et al, 1998). As important, most of these microorganisms are facultative (can survive under aerobic and anaerobic conditions) as well as microaerophilic (low levels of oxygen), important factors for natural attenuation (Chaudhuri et al).

In more recent years, there has been a switch in microbial enumeration and testing with greater application of molecular biological tools (MBT). The identification of the enzyme, perchlorate reductase, which is common to all perchlorate-reducing bacteria, has resulted in the development of molecular tools to check the presence of this enzyme in contaminated soil and groundwater as a tool for natural attenuation. Estimating the abundance of PRBs using microbial enumerations is more useful for optimization and restricted to pure cultures and isolates, and not for larger microbial communities which exist in the subsurface. Newer, sensitive real-time PCR methods are now available that can be used to enumerate the proportion of active perchlorate-reducing bacteria in a total population by targeting specific genes found in these microorganisms. The functional gene encoding perchlorate reductase is pcrABCD. The pcr gene appears to be present exclusively in PRB, and the enzyme catalyzes the rate-limiting step in perchlorate reduction. (Mamie Nozawa-Inoue et al, 2008). DNA-based and RNA-based assays can be performed for this gene and are commercially available via Microbial Insights Laboratory in Rockford, Tennessee. Results and analyses of this enzyme would help directly or indirectly infer the microbial activity and its abundance and relative stress within an environmental system.

4.1.3.2 Perchlorate Uptake and Microbial Growth Kinetics

In comparison to the progress made on microbial species identification and MBTs, there is limited research on the absolute growth kinetics and patterns of PRBs. This holds good for single isolates or mixed cultures. Microbial growth can be expressed in several ways, expressed as a function of substrate (carbon source such as TOC or acetate or other compounds) or perchlorate (respiratory uptake). Either way, the assumption is that the selected function has only one dependent factor for growth of PRBs. In other words, if perchlorate concentration is selected as the dependent factor, then the growth of PRBs is dependent only on the availability of perchlorate and all other nutrients and environmental conditions do not limit growth. Growth of microorganisms (in a batch or in continuous systems) follows a (i) typical initial lag or acclimation phase, followed by a (ii) logarithmic or exponential growth phases; (iii) a stationary or optimal phase, and finally, (iv) a logarithmic death phase (Metcalf & Eddy, 1991).



Hypothetical bacterial growth curve.

The classical growth phenomenon is particularly true for environmental media which generally includes a lag phase (which can vary depending on the type of contaminant, its history in the environment, pathways such as aerobic or anaerobic, and the availability of carbon substrate in the case of microbial reduction). In the case of perchlorate, the lag phase is likely to be short, particularly if the contaminant has existed in the environment for a long time and there is plentiful supply of organic carbon. The log phase is geometric and rapid, as long as perchlorate is present, and the onset of the log-death phase could also be immediate and rapid, following the consumption of all of the perchlorate in the media.

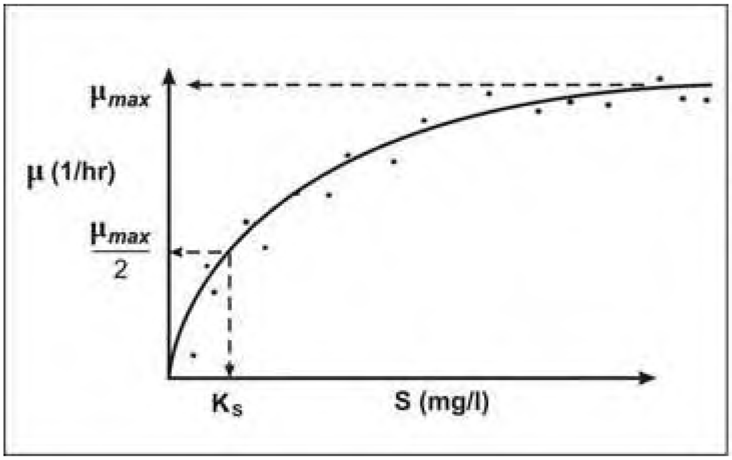
The most common expression of microbial growth kinetics is expressed by the Monod equation, which relates specific growth rate, μ, to perchlorate concentration in the following equation.

$$\mu = \hat{\mu} \frac{S}{K_S + S}$$

where,

S = concentration of limiting nutrient
μ = specific growth rate coefficient
$\hat{\mu}$ or μmax = maximum specific growth rate

K_s = half saturation coefficient



$$\mu = \mu_{max}\left(\frac{S}{S+K_S}\right) \quad (5)$$

Monod's equation represents mixed order kinetics as can be seen from the depiction below. At very low perchlorate concentrations, and where the saturation constant Ks is high, it becomes a first-order equation. Logan et al (1998, 2001) have determined these growth constants for several substrates using both bacterial isolates and mixed cultures. Based on their findings, PRB isolates appear to have high growth rates and high cell yields in the laboratory. However, they also determined a much lower growth yield for mixed cultures likely to be encountered in the field (Logan, 2001). The saturation constant varies considerably, indicating no specific pattern with this constant, even though the conclusion was that perchlorate reduction would follow first-order kinetics under typical environmental conditions where perchlorate is in the parts per billion range. A more recent study (Mamie Nozawa-Inoue, 2005) examined vadose zone conditions augmented with acetate and concluded that a first-order approximation was not suitable. What remains unknown from these studies is the end response to growth, endogenous decay, and other microbial deregulators following depletion of the perchlorate. Based on the fact that the perchlorate-reducing mechanism is anaerobic (which generally has lower biomass production compared to aerobic systems), has much lower growth yields, and utilizes specialized enzymes that carry out the progress, it is possible there is a very quick change in microbial and enzymatic make-up following perchlorate depletion. In other words, growth rates could precipitate and plummet rapidly following perchlorate extinguishment.

4.1.3.3 Geochemistry and Microbial Response

Geochemical data was collected from wells in the riparian area (Large Motor Washout Area and Maintenance Shop and Warehouse Area) and analyzed and summarized for a host of geochemical factors including DO, ORP, dissolved organic carbon (DOC), nitrate, sulfate, methane, ferrous iron, and manganese. This data is summarized in this report (Section 4.1.2.3) and in the initial contaminant attenuation technical memorandum (Tetra Tech, 2010f). In Spring, 2011, samples were collected from several of these area wells with known geochemistry and shipped to the Microbial Insights Laboratory for molecular biological analyses which included pcrA using qPCR techniques. These results are attached in Appendix E. Of the eight wells analyzed, only two had detectable concentrations (cells per ml) for pcrA. These were wells MW-86B (6.86E+03 cells per ml) and F34-TW1 (2.72E+04 cells per ml). A closer examination of the geochemistry at these locations indicated that both these locations were anoxic and were non-detect for nitrate, and had very little perchlorate in the groundwater itself (although there could have been perchlorate in the surrounding saturated mass). These two wells also had higher methane concentrations (120 ppb and 110 ppb respectively). Therefore, it appears that the absence or prior removal of nitrate, coupled with anoxic conditions are critical for the establishment and sustenance of PRBs at this site. The continual presence of a carbon source is also important, and the presumption at these two locations is that organic carbon is not a limiting nutrient, which appears to be the case at native DOC concentrations of 1.4 mg/L and 8.3 mg/L, respectively.

In contrast, wells in the area which had higher nitrate concentrations, namely MW87B and MW-92 had much higher concentrations at 25 mg/L and 9.1 mg/L respectively. Furthermore, these locations were also more oxic. Both these conditions have led to persistence of perchlorate in these vicinities (20 ppb and 24 ppb of perchlorate) and the absence of PRBs. The situation is somewhat similar at three other site wells for which microbial analyses was performed in Spring 2010. These are wells MW-19, EW-13, and MW-70. In all of these wells, nitrate was non-detect, which meant there is unlikely to be any competition for respiration from this anion. However, all these wells were oxic, which meant that they do not possess the reducing conditions required for growth of PRBs. In all of these wells, perchlorate lingers at measureable concentrations. Well MW-109 also has a somewhat hindered geochemical situation with persistent perchlorate due to competitive inhibition due to the presence of nitrate (3.1 mg/L in July, 2011). Despite the slightly higher DOC of 3.2 mg/L at this location, very little fermentation of the organic carbon organic carbon may be occurring to critical VFAs such as lactate (as evidenced by the negligible concentration of this VFA at 0.0060 mg/L in this well) which are often critical to microbial activity, particularly PRBs.

4.1.3.4 Bench-Scale Testing and Inferences

In addition to the MBT analyses summarized in Section 3 and their reliance on geochemical conditions, a brief bench-scale test was undertaken using site soil (from the organic-rich riparian area just above the saturated zone) and groundwater with known higher concentrations of perchlorate (MW-109 was the well selected for groundwater to be used for this test). The test was requested by DTSC to provide another line of evidence that natural biodegradation of perchlorate was occurring in the riparian area. The outline, approach, and layout of this test were submitted in a technical memorandum dated May, 2011. The test was performed in-house at the Tetra Tech San Bernardino office.

Results of this test are summarized and plotted in Table 4.1-9. In all three trials, there was some decrease after 24 hours, but a much more rapid decrease in perchlorate concentrations between 24 hours and 72 hours of the inception of the test. This decrease also coincided with the rapid decrease in nitrate during the same period. Therefore, while some perchlorate destruction does appear to occur during nitrate reduction, its destruction intensifies only in the absence of nitrate. After 6 days, the concentrations were below detection limits for perchlorate. A sample was collected and sent to Microbial Insights for pcrA determinations 9 days after inception of the bench-scale test. The results showed an absence of pcrA at the detection level. hile this result was surprising, it provided a hint to the response that can be expected to PRB presence at this site. The lag or acclimation period is very short (24 to 72 hours), followed by likely logarithmic increase in PRBs and destruction, and followed by a rapid logarithmic decrease in PRB presence, much faster than could have been envisioned prior to the test, following the typical growth and death response described in Section 4.1.4.2.

In order to unambiguously determine the presence of PRBs via the pcrA test, a second sample of soil and groundwater was collected in August 2011 from the exact same locations as in July 2011, and assembled in identical fashion to the microcosm set-up as the July 2011 bench-scale test. A sample was immediately dispatched to Microbial Insights where it was analyzed for pcrA in both soil and water phases on August 22, 2011. Microbial analyses was performed within 48 hours of the set-up of the microcosm. This resulted in pcrA counts in both the soil and the water at E+7 range, which indicated that PRBs were in reality, very abundant in the site soil and are key to the destruction of perchlorate.

4.1.3.5 Conclusions

The preceding theory and results of microbial growth, site geochemistry, and response of key enzymes in the field (groundwater data), laboratory microcosms, and the final test on microbial identification carried out in August, 2011 indicate that the appropriate ingredients exist for natural perchlorate degradation. In addition to other lines of evidence from the modeling and the depiction of oxidative-reductive plumes, and the estimates of mass fluxes of the critical geochemical parameters, the presence of PRBs has also been established.

Geochemical data indicates that in the presence of organic carbon, the absence of nitrate (or low levels of nitrate), and the absence of dissolved oxygen induces facultative native microorganisms to develop the ability to respire perchlorate. This is a finding that is very common to most other perchlorate sites. The bench scale tests have also indicated that the organic source from the field in the riparian area has the right carbon constituents that native microorganism can use as a source of energy. The groundwater that was used for this test was from a location where geochemical conditions were not appropriate for microbial reduction. Despite this restraint, the introduction of carbon from soil from the site itself rapidly modified geochemical conditions and induced complete perchlorate biodegradation. A final finding or hypothesis based on microbial theory (that has been described here) is that PRBs survive as long as there is a prime respiratory source, i.e., perchlorate. Once the perchlorate is extinguished, it is much harder to use advanced microbial techniques to identify PRBs; which likely explains why pcrA was not found in several of the site groundwater samples and in the July bench-scale sample but was found in the August bench-scale sample; capturing their presence when they are active is critical as is the case with the two wells which have the optimal geochemical conditions, and in the final microcosm test which resorted to an early determination of the key enzyme, pcrA.

4.2 LABORDE CANYON CONTAMINANT ATTENUATION RESULTS

4.2.1 Site Geology and Lithology

The drilling conducted as part of this investigation was focused on collecting samples to assess organic carbon concentrations in soil. The scope of work consisted of drilling four soil borings adjacent to existing monitoring wells. Three of the borings were successfully installed; the fourth boring was a hand auger boring which was refused at a depth of less than five feet, and was therefore not sampled. Because the soil borings were drilled adjacent to existing monitoring wells, little new information with respect to geologic conditions was obtained. Two stratigraphic units (Quaternary alluvium and the STF) were encountered during this investigation. General observations are provided below.

Quaternary Deposits

Alluvium/colluvium was observed at all three of the locations drilled during this investigation. The thickness of the quaternary deposits ranged from approximately 15 feet in boring SBA-SB104 to approximately 25 feet in boring WDA-SB104. The quaternary deposits consisted of interbedded sands, silty sands, clayey sands, and thin gravel lenses.

San Timoteo formation

The STF was observed in all three of the locations drilled during this investigation. Materials encountered in the STF include deeply weathered sandstones and mudstones. Competent STF was encountered at depth in borings K-54-SB144 and WDA-SB104.

4.2.2 Analytical Results

4.2.2.1 Data Quality Review

The quality control samples were reviewed as described in the PSAP (Tetra Tech Inc., 2010d). The data for the soil sampling activities were contained in analytical data packages generated by E.S. Babcock and Sons Laboratories Inc. These data packages were reviewed using the latest versions of the National Functional Guidelines for Organic and Inorganic Data Review documents from the EPA (EPA, 2008 and 2010).

Preservation criteria, holding times, field blanks, laboratory control samples (LCS), method blanks, duplicate environmental samples, spiked samples, and surrogate and spike recovery data were reviewed. Within each environmental sample the sample specific quality control spike recoveries were examined. These data examinations include comparing statistically calculated control limits to percent recoveries of all spiked analytes and duplicate spiked analytes. Relative Percent Difference (RPD) control limits are compared to actual spiked (MS/MSD) RPD results. Surrogate recoveries were examined for all organic compound analyses and compared to their control limits.

Environmental samples were analyzed for Total Organic Carbon (TOC) by Method SW90060. There were no errors in the analytical data. All quality control criteria were met in the analyses. The data may be used as reported and are of known precision and accuracy.

4.2.2.2 Soil Results

A total of 26 soil samples (including 3 duplicate samples) were collected from three borings and analyzed for TOC and total solids. Positive detections of TOC were found in 10 samples, at concentrations ranging from 720 mg/kg to 2,500 mg/kg. The highest TOC concentration was detected in boring WDA-SB104 at 5 feet bgs. The highest TOC concentrations were detected in the upper 20 feet of the subsurface. The results of these analyses are shown in Table 4.2-1. Laboratory analytical data packages are provided in Appendix E.

Table 4.2-1 Soil Sampling Results for Total Organic Carbon – Laborde Canyon

Sample Name	Depth	Sample Date	Total Organic Carbon (mg/kg)
K-54-SB144-6'	6	3/21/2011	2200
K-54-SB144-13'	13	3/21/2011	1500 Jq
K-54-SB144-18'	18	3/21/2011	<500
K-54-SB144-25'	25	3/21/2011	<500
K-54-SB144-29'	29	3/21/2011	1000 Jq
K-54-SB144-33'	33	3/21/2011	770 Jq
K-54-SB144-39'	39	3/21/2011	<500
K-54-SB144-43'	43	3/21/2011	<500
K-54-SB144-48'	48	3/21/2011	<500
SBA-SB104-6.5'	7	4/26/2011	<490
SBA-SB104-11.5'	12	4/26/2011	<500
WDA-SB104-5'	5	4/25/2011	2500
WDA-SB104-10'	10	4/25/2011	1700 Jq
WDA-SB104-15'	15	4/25/2011	720 Jq
WDA-SB104-21.5'	22	4/25/2011	<490
WDA-SB104-26.5'	27	4/25/2011	<480
WDA-SB104-31.5'	32	4/25/2011	1200 Jq
WDA-SB104-38'	38	4/25/2011	<500
WDA-SB104-41.5'	42	4/25/2011	<500
WDA-SB104-47'	47	4/25/2011	1400 Jq
WDA-SB104-51.5'	52	4/25/2011	<500
WDA-SB104-56.5'	57	4/25/2011	<500

Notes: ft bgs – feet below ground surface.

Samples were collected from each boring at various depths to determine physical properties to support development of the contaminant attenuation model. Physical property test results indicate that most of the samples submitted are comprised of silty sands with only one sample determined as low plasticity silt (K-54-SB144-31.5). The physical property testing results are summarized in Table 4.2-2. Laboratory analytical data packages are provided in Appendix E.

Table 4.2-2 Soil Sampling Results for Physical Properties – Laborde Canyon

Sample Name	Depth (ft bgs)	Moisture Content (%) (ASTM D2216)	Dry Density (pcf) (ASTM D2937)	Specific Gravity (ASTM D854)	Total Porosity (%) (API RP40)
SBA-SB104-10.5	10.5	21.0	104.4	2.738	38.89
WDA-SB104-20.5	20.5	7.9	98.6	2.739	42.31
WDA-SB104-38	38.0	12.0	104.1	2.745	39.23
WDA-SB104-41	41.0	4.4	115.7	2.701	31.35
K-54-SB144-31	31.0	9.0	98.1	2.717	42.14
K-54-SB144-31	36.0	8.0	97.9	2.731	42.55

Notes: ft bgs – feet below ground surface.

4.2.2.3 Groundwater Results

Summaries of the analytical results for perchlorate reductase from Fourth Quarter 2010 and Second Quarter 2011 are presented in Tables 4.2-3. Laboratory analytical data packages are provided in Appendix E.

Table 4.2-3 Summary of Perchlorate Reductase in Monitoring Wells – Fourth Quarter 2010 and Second Quarter 2011

Sample Name	Sample Date	Functional Genes Perchorate Reductase (pcrA) cells/mL
TT-MW2-41A	1/27/2011	<1.00
TT-MW2-42A	1/27/2011	<1.00
TT-MW2-24	2/1/2011	<1.00
TT-MW2-39	2/1/2011	<1.00
TT-MW2-7	5/16/2011	0.7
MDL		0.1

Notes: ml – milliliter

4.3 PLANT DENSITY SURVEY RESULTS

4.3.1 Potrero Canyon Unit and 2

The plant density survey was conducted in the riparian habitat distributed along Potrero and Bedsprings Creeks at Potrero Canyon Unit and in the South Laborde Canyon at Laborde Canyon. The data collected was used to aid in the plant survey water budget at both sites. The plant species identified in the riparian area at Potrero Canyon Unit include mulefat, elderberry, arroyo willow, fremont cottonwood, California false indigo, California wildrose, tree tobacco, and tamarisk. The plant species identified at Laborde Canyon consist of four-wing salt bush, tamarisk, mulefat, honeysuckle, tree tabacco, tripbush, fremont cottonwood, black willow, arroyo willow, scrub oak, and rhamnus crocea. A summary of the plant survey results including species, individuals per quadrat, density and percent coverage are summarized in Table 4.4.-1 and Table 4.4-2.

4.4 PLANT SURVEY WATER BUDGET

Plant density and percent cover data were surveyed for large tree and shrub obligate/facultative phreatophyte species at 64 plant transect locations covering a total of 14.7 acres at Beaumont Sites 1 and 2 (Section 4.3). The purpose of the plant density survey is to provide an independent verification of the evapotranspiration estimates for the riparian area, and not a complete evaluation of all aspects of phytoremediation, some of which are being evaluated in the groundwater plant uptake study submitted with the human health and ecological risk assessments.

Each plant survey transect covered a 100 foot by 100 foot area (0.23 acres), and there were a total of 43 plant survey locations at Potrero Canyon Unit and 21 plant survey locations at Laborde Canyon. These data are given for Sites 1 and 2 in Tables 4.4-1 and 4.4-2, respectively. Data for the dominant tree and shrub species at Sites 1 and 2 are also plotted versus groundwater depth at the survey locations (Figures 4-2 and Figure 4-3, respectively).

Table 4.4-1

Plant Data for Bedsprings Creek Riparian Area Plant Survey

LMC Beaumont Site 1

Transect	Species		Indviduals/ quadrat	Density (indv/acre)	Cover (%)
	Common name	Scientific name			
Site 1 Plants (Bedsprings Creek Riparian Area)					
1	Elderberry	Sambucus nigra caerulea	4	17.2	<1
	Arroyo willow	Salix lasiocarpa	3	12.9	<1
	Mulefat	Baccharis salicifolia	14	60.2	<1
2	Elderberry	Sambucus nigra caerulea	2	8.6	9
	Arroyo willow	Salix lasiocarpa	1	4.3	<1
	Mulefat	Baccharis salicifolia	19	81.7	25
3	Elderberry	Sambucus nigra caerulea	3	12.9	<1
	Arroyo willow	Salix lasiocarpa	9	38.7	30
	Mulefat	Baccharis salicifolia	59	253.7	3
	Fremont cottonwood	Populus fremonti	3	12.9	<1
4	Elderberry	Sambucus nigra caerulea	1	4.3	<1
	Arroyo willow	Salix lasiocarpa	35	150.5	65
	Mulefat	Baccharis salicifolia	23	98.9	5
	Fremont cottonwood	Populus fremonti	1	4.3	<28
5	Elderberry	Sambucus nigra caerulea	2	8.6	<1
	Arroyo willow	Salix lasiocarpa	9	38.7	15
	Mulefat	Baccharis salicifolia	6	25.8	5
	Fremont cottonwood	Populus fremonti	7	30.1	20
6	Arroyo willow	Salix lasiocarpa	8	34.4	15
	Mulefat	Baccharis salicifolia	64	275.2	15
7	Elderberry	Sambucus nigra caerulea	3	12.9	<1
	Arroyo willow	Salix lasiocarpa	6	25.8	1
	Mulefat	Baccharis salicifolia	27	116.1	2
8	Arroyo willow	Salix lasiocarpa	20	86	35
	Mulefat	Baccharis salicifolia	23	98.9	2
	Fremont cottonwood	Populus fremonti	3	12.9	2
	California false indigo	Amorpha californica	2	8.6	<1

Table 4.4-1
Plant Data for Bedsprings Creek Riparian Area Plant Survey
LMC Beaumont Site 1

Transect	**Species**		**Indviduals/ quadrat**	**Density (indv/acre)**	**Cover (%)**
	Common name	**Scientific name**			
9	Elderberry	Sambucus nigra caerulea	5	21.5	<1
	Arroyo willow	Salix lasiocarpa	11	47.3	15
	Mulefat	Baccharis salicifolia	10	43	<1
	Fremont cottonwood	Populus fremonti	13	55.9	35
	California false indigo	Amorpha californica	3	12.9	<1
10	Elderberry	Sambucus nigra caerulea	5	21.5	<1
	Arroyo willow	Salix lasiocarpa	11	47.3	15
	Mulefat	Baccharis salicifolia	40	172	10
	Fremont cottonwood	Populus fremonti	13	55.9	35
	California false indigo	Amorpha californica	1	4.3	<1
	California wildrose	Rosa californica	2	8.6	<1
11	Elderberry	Sambucus nigra caerulea	3	12.9	2
	Arroyo willow	Salix lasiocarpa	4	17.2	5
	Fremont cottonwood	Populus fremonti	4	17.2	2
12	Arroyo willow	Salix lasiocarpa	13	55.9	10
	Mulefat	Baccharis salicifolia	37	159.1	1
	Fremont cottonwood	Populus fremonti	1	4.3	4
13	Elderberry	Sambucus nigra caerulea	5	21.5	1
	Arroyo willow	Salix lasiocarpa	17	73.1	13
	Mulefat	Baccharis salicifolia	36	154.8	5
	tree tobacco	Nicotiana glauca	1	4.3	<1
15	Elderberry	Sambucus nigra caerulea	3	12.9	1
	Mulefat	Baccharis salicifolia	27	116.1	4
	California false indigo	Amorpha californica	5	21.5	<1
	tree tobacco	Nicotiana glauca	2	8.6	<1
				0	
16	Arroyo willow	Salix lasiocarpa	9	38.7	20
	Mulefat	Baccharis salicifolia	17	73.1	1
	Fremont cottonwood	Populus fremonti	30	129	60
	California false indigo	Amorpha californica	3	12.9	<1
17	Elderberry	Sambucus nigra caerulea	7	30.1	2
	Arroyo willow	Salix lasiocarpa	16	68.8	25
	Mulefat	Baccharis salicifolia	2	8.6	<1
19	Mulefat	Baccharis salicifolia	40	172	5
	Fremont cottonwood	Populus fremonti	1	4.3	<1

Table 4.4-1
Plant Data for Bedsprings Creek Riparian Area Plant Survey
LMC Beaumont Site 1

Transect	Species		Indviduals/ quadrat	Density (indv/acre)	Cover (%)
	Common name	Scientific name			
20	Elderberry	Sambucus nigra caerulea	3	12.9	<1
	Arroyo willow	Salix lasiocarpa	5	21.5	<1
	Mulefat	Baccharis salicifolia	57	245.1	4
	Fremont cottonwood	Populus fremonti	4	17.2	<1
	California false indigo	Amorpha californica	4	17.2	<1
	tree tobacco	Nicotiana glauca	2	8.6	<1
21	Arroyo willow	Salix lasiocarpa	7	30.1	10
	Mulefat	Baccharis salicifolia	86	369.8	55
	Fremont cottonwood	Populus fremonti	3	12.9	3
	tamarisk	Tamarix ramosissima	1	4.3	<1
22	Elderberry	Sambucus nigra caerulea	4	17.2	<1
	Arroyo willow	Salix lasiocarpa	6	25.8	<1
	Mulefat	Baccharis salicifolia	20	86	10
	Fremont cottonwood	Populus fremonti	2	8.6	2
				0	
24	Elderberry	Sambucus nigra caerulea	5	21.5	1
	Arroyo willow	Salix lasiocarpa	21	90.3	6
	Mulefat	Baccharis salicifolia	45	193.5	2
	Fremont cottonwood	Populus fremonti	24	103.2	18
25	Elderberry	Sambucus nigra caerulea	1	4.3	<1
	Arroyo willow	Salix lasiocarpa	34	146.2	65
	Mulefat	Baccharis salicifolia	2	8.6	<1
	Fremont cottonwood	Populus fremonti	2	8.6	<1
26	Elderberry	Sambucus nigra caerulea	3	12.9	<1
	Arroyo willow	Salix lasiocarpa	25	107.5	10
	Mulefat	Baccharis salicifolia	58	249.4	7
	Fremont cottonwood	Populus fremonti	9	38.7	5
27	Arroyo willow	Salix lasiocarpa	16	68.8	5
	Fremont cottonwood	Populus fremonti	21	90.3	50
28	Arroyo willow	Salix lasiocarpa	32	137.6	45
	Fremont cottonwood	Populus fremonti	7	30.1	30
29	Arroyo willow	Salix lasiocarpa	31	133.3	51
	Mulefat	Baccharis salicifolia	15	64.5	<1
	Fremont cottonwood	Populus fremonti	7	30.1	30
30	Arroyo willow	Salix lasiocarpa	16	68.8	30

Table 4.4-1

Plant Data for Bedsprings Creek Riparian Area Plant Survey

LMC Beaumont Site 1

Transect	Species		Indviduals/ quadrat	Density (indv/acre)	Cover (%)
	Common name	**Scientific name**			
	Mulefat	Baccharis salicifolia	15	64.5	10
	Fremont cottonwood	Populus fremonti	7	30.1	40
31	Arroyo willow	Salix lasiocarpa	18	77.4	12
	Fremont cottonwood	Populus fremonti	7	30.1	15
32	Elderberry	Sambucus nigra caerulea	2	8.6	<1
	Arroyo willow	Salix lasiocarpa	12	51.6	20
	Mulefat	Baccharis salicifolia	18	77.4	3
	Fremont cottonwood	Populus fremonti	12	51.6	20
	Tree tobacco	Nicotiana glauca	2	8.6	<1
33	Arroyo willow	Salix lasiocarpa	20	86	20
	Mulefat	Baccharis salicifolia	8	34.4	<1
	Fremont cottonwood	Populus fremonti	6	25.8	13
	Tree tobacco	Nicotiana glauca	3	12.9	<1
34	Elderberry	Sambucus nigra caerulea	1	4.3	<1
	Arroyo willow	Salix lasiocarpa	14	60.2	2
	Mulefat	Baccharis salicifolia	45	193.5	68
	Fremont cottonwood	Populus fremonti	1	4.3	<1
35	Elderberry	Sambucus nigra caerulea	3	12.9	<1
	Arroyo willow	Salix lasiocarpa	2	8.6	3
	Fremont cottonwood	Populus fremonti	23	98.9	40
	Tree tobacco	Nicotiana glauca	3	12.9	<1
36	Elderberry	Sambucus nigra caerulea	2	8.6	<1
	Arroyo willow	Salix lasiocarpa	16	68.8	35
37	Elderberry	Sambucus nigra caerulea	8	34.4	4
	Arroyo willow	Salix lasiocarpa	43	184.9	30
38	Elderberry	Sambucus nigra caerulea	2	8.6	<1
	Arroyo willow	Salix lasiocarpa	14	60.2	15
39	Elderberry	Sambucus nigra caerulea	1	4.3	<1
	Arroyo willow	Salix lasiocarpa	24	103.2	38
41	Arroyo willow	Salix lasiocarpa	17	73.1	18
42	Elderberry	Sambucus nigra caerulea	3	12.9	<1
	Arroyo willow	Salix lasiocarpa	25	107.5	40

Table 4.4-1

Plant Data for Bedsprings Creek Riparian Area Plant Survey

LMC Beaumont Site 1

Transect	Species		Indviduals/ quadrat	Density (indv/acre)	Cover (%)
	Common name	Scientific name			
43	Elderberry	Sambucus nigra caerulea	2	8.6	<1
	Arroyo willow	Salix lasiocarpa	8	34.4	15
Site 1 Plants (Lower Potrero Creek Riparian Area)					
RP01	Fremont cottonwood	Populus fremontii	3	13	3
	Elderberry	Sambucus nigra caerulea	1	4	<1
	Mulefat	Baccharis salicifolia	47	202	17
RP02	Fremont cottonwood	Populus fremontii	5	22	1
	Mulefat	Baccharis salicifolia	13	56	1
RP03	Mulefat	Baccharis salicifolia	2	9	8
	Fremont cottonwood	Populus fremontii	7	30	4
RP04	Fremont cottonwood	Popluls fremontii	13	56	20
	Mulefat	Baccharis salicifolia	10	43	<1
	Arroyo willow	Salix lasiolepis	2	9	<1
RP05	Fremont cottonwood	Populus fremontii	3	13	30
	Mulefat	Baccharis salicifolia	31	133	4
	Arroyo willow	Salix lasiolepis	4	17	12
RP06	Fremont cottonwood	Populus fremontii	1	4	2
	Arroyo willow	Salix lasiolepis	5	22	1
	Mulefat	Baccharis salicifolia	1	4	<1
RP07	Fremont cottonwood	Populus fremontii	2	9	1
	Mulefat	Baccharis salicifolia	27	116	4
	Arroyo willow	Salix lasiolepis (shrub)	6	26	7
RP08	Fremont cottonwood	Populus fremontii	8	34	2
	Mulefat	Baccharis salicifolia	30	129	3
	Arroyo willow	Salix lasiolepis	3	13	<1
RP09	Fremont cottonwood	Populus fremontii	1	4	<1
	Mulefat	Baccharis salicifolia	7	30	<1
	Arroyo willow (thicket)	Salix lasiolepis	n/a	n/a	25
RP10	Fremont cottonwood	Populus fremontii	4	17	<1
	Arroyo willow (thicket)	Salix lasiolepis	n/a	n/a	38
	Mulefat	Baccharis salicifolia	4	17	<1
RP11	Fremont cottonwood	Populus fremontii	14	60	3

Table 4.4-1

Plant Data for Bedsprings Creek Riparian Area Plant Survey

LMC Beaumont Site 1

Transect	Species		Indviduals/ quadrat	Density (indv/acre)	Cover (%)
	Common name	Scientific name			
	Arroyo willow (shrub)	Salix lasiolepis	n/a	n/a	12
	Mulefat	Baccharis salicifolia	12	52	<1
RP12	Fremont cottonwood	Populus fremontii	1	4	3
	Arroyo willow (shrub)	Salix lasiolepis	n/a	n/a	50
	Mulefat	Baccharis salicifolia	21	90	2
RP14	Arroyo willow (thicket)	Salix lasiolepis	n/a	n/a	30
	Fremont cottonwood	Populus fremontii	1	4	<1
				0	
RP19	Fremon's cottonwood	Populus fremontii	9	39	17
	Mulefat	Baccharis salicifolia	27	116	1
	Arroyo willow	Salix lasiolepis	1	4	<1
				0	
RP22	Fremont cottonwood	Populus fremontii	4	17	2
	Mulefat	Baccharis salicifolia	9	39	<1
	Tamarisk	Tamarix ramosissima	1	4	<1
				0	
RP23	Fremont cottonwood	Populus fremontii	6	26	22
	Mulefat	Baccharis salicifolia	23	99	20
	Arroyo willow (thicket)	Salix lasiolepis	8	34	20
RP24	Fremont cottonwood	Populus fremontii	7	30	28
	Mulefat	Baccharis salicifolia	15	65	1
	Arroyo willow (thicket)	Salix lasiolepis	4	17	11
RP25	Fremont cottonwood	Populus fremontii	2	9	1
	Mulefat	Baccharis salicifolia	10	43	<1
	Arroyo willow (thicket)	Salix lasiolepis	n/a	n/a	33
RP26	Mulefat	Baccharis salicifolia	8	34	<1
	Arroyo willow (thicket)	Salix lasiolepis	n/a	n/a	<1
RP27	Arroyo willow (thicket)	Salix lasiolepis	n/a	n/a	<1
	Mulefat	Baccharis salicifolia	40	172	2
RP28	Fremont cottonwood	Populus fremontii	5	22	1
	Arroyo willow	Salix lasiolepis	3	13	<1

Table 4.4-2. Plant Data for Laborde Canyon Riparian Area Plant Survey
LMC Beaumont Site 2

Transect	Species		Indviduals/ quadrat	Density (indv/acrea	Cover (%)
	Common name	Scientific name			
No1	Four-wing Saltbush	Atriplex canescens	17	73.1	4
	Tamarisk	Tamarix ramosissima	15	64.5	7
				0	
No2	Four-wing Saltbush	Atriplex canescens	3	12.9	<1
	Tamarisk	Tamarix ramosissima	48	206.4	56
	Mulefat	Baccharis salicifolia	13	55.9	<1
No3	not surveyed				
No4	Four-wing Saltbush	Atriplex canescens	3	12.9	<1
	Tamarisk	Tamarix ramosissima	13	55.9	2
No5	not surveyed				
No6	Mulefat	Baccharis salicifolia	15	64.5	5
	honeysuckle	Lonicera sp.	1	4.3	<1
				0	
No7	Four-wing Saltbush	Atriplex canescens	25	107.5	5
	Tamarisk	Tamarix ramosissima	1	4.3	<1
	Mulefat	Baccharis salicifolia	32	137.6	3
	tree tobacco	Nicotiana glauca	1	4.3	<1
				0	
No8	Tamarisk	Tamarix ramosissima	2	8.6	<
	Mulefat	Baccharis salicifolia	25	107.5	4
	tripbush	Symphoricarpos sp.	1	4.3	35
				0	
No9	Four-wing Saltbush	Atriplex canescens	15	64.5	2
	Tamarisk	Tamarix ramosissima	17	73.1	12
	Mulefat	Baccharis salicifolia	2	8.6	<1
				0	
No15	Four-wing Saltbush	Atriplex canescens	18	77.4	2
	Tamarisk	Tamarix ramosissima	56	240.8	40
				0	
No17	Four-wing Saltbush	Atriplex canescens	17	73.1	4
	Tamarisk	Tamarix ramosissima	3	12.9	1
	Mulefat	Baccharis salicifolia	31	133.3	3
	Fremont's cottonwood	Populus fremontii	1	4.3	<1
No 18	Four-wing Saltbush	Atriplex canescens	3	12.9	<1
	Tamarisk	Tamarix ramosissima	4	17.2	<1
	Mulefat	Baccharis salicifolia	26	111.8	7
	black willow	Salix goodingii	2	8.6	<1

Table 4.4-2. Plant Data for Laborde Canyon Riparian Area Plant Survey
LMC Beaumont Site 2

Transcect	**Species**		**Indviduals/ quadrat**	**Density (indv/acrea**	**Cover (%)**
	Common name	**Scientific name**			
No20	Four-wing Saltbush	Atriplex canescens	2	8.6	<1
	Tamarisk	Tamarix ramosissima	25	107.5	17
	Mulefat	Baccharis salicifolia	29	124.7	3
	elderberry	Sambucus nigra caerula	1	4.3	<1
S3	Four-wing Saltbush	Atriplex canescens	23	98.9	11
	Tamarisk	Tamarix ramosissima	1	4.3	<1
	Mulefat	Baccharis salicifolia	38	163.4	33
				0	
S5	Four-wing Saltbush	Atriplex canescens	7	30.1	<1
	Tamarisk	Tamarix ramosissima	2	8.6	1
	Mulefat	Baccharis salicifolia	29	124.7	4
	Fremont's cottonwood	Populus fremontii	1	4.3	<1
	Arroyo willow	Salix lasiolepis	1	4.3	1
S6	Four-wing Saltbush	Atriplex canescens	41	176.3	15
	Mulefat	Baccharis salicifolia	35	150.5	12
S10	Four-wing Saltbush	Atriplex canescens	3	12.9	<1
	Tamarisk	Tamarix ramosissima	1	4.3	<1
	Mulefat	Baccharis salicifolia	64	275.2	40
	Arroyo willow	Salix lasiolepis	2	8.6	<1
N12	Tamarisk	Tamarix ramosissima	1	4.3	<1
	Mulefat	Baccharis salicifolia	43	184.9	40
	Fremont's cottonwood	Populus fremontii	1	4.3	<1
	Tripbush	Symphoricarpos sp.	1	4.3	5
N13	Four-wing Saltbush	Atriplex canescens	18	77.4	8
	Tamarisk	Tamarix ramosissima	3	12.9	2
	Mulefat	Baccharis salicifolia	45	193.5	40
	Scrub oak	Quercus berberidifolia	1	4.3	<1
N16	Four-wing Saltbush	Atriplex canescens	4	17.2	4
	Tamarisk	Tamarix ramosissima	1	4.3	<1
	Mulefat	Baccharis salicifolia	34	146.2	35
	Arroyo willow	Salix lasiolepis	1	4.3	<1
N19	Four-wing Saltbush	Atriplex canescens	4	17.2	2
	Mulefat	Baccharis salicifolia	32	137.6	4
	Arroyo willow	Salix lasiolepis	2	8.6	<1
	Fremont's cottonwood	Populus fremontii	1	4.3	<1
	Rhamnus crocea	coffeeberry	1	4.3	<1
	honeysuckle	Lonicera sp.	1	4.3	<1

Figure 4-2 Correlation of Plant Density with Depth to Groundwater in Site 1 Plant Density Survey Locations

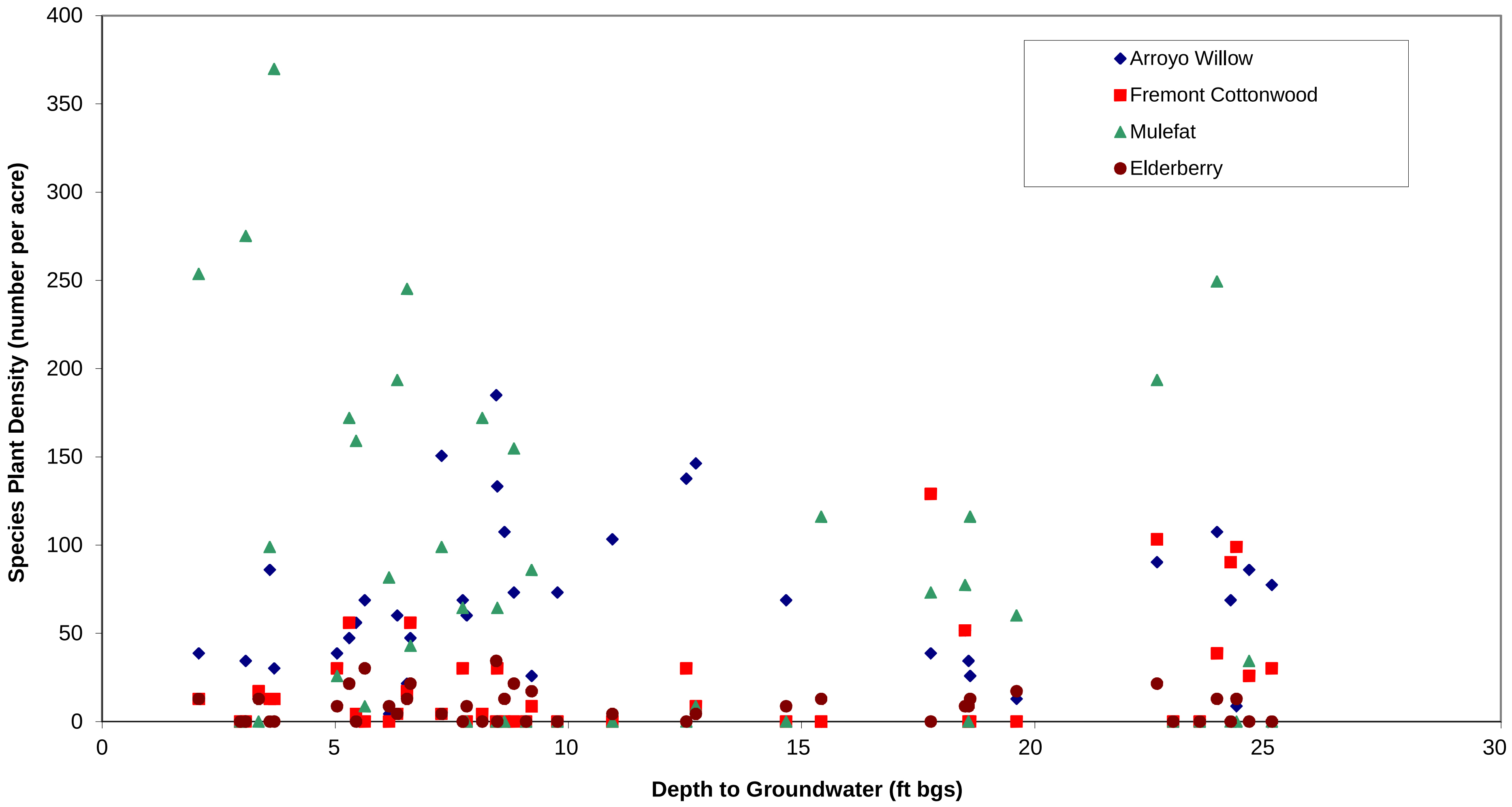
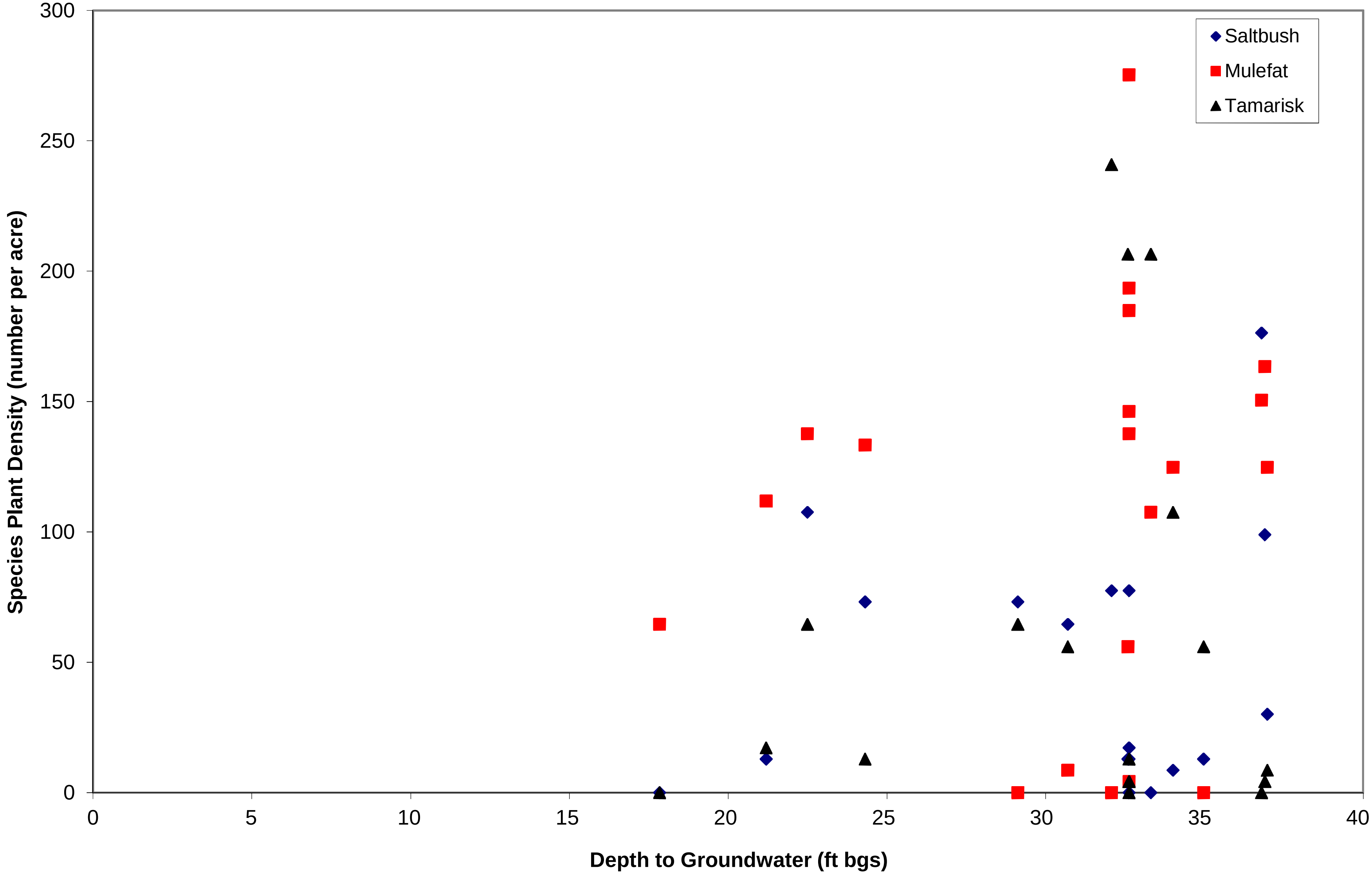


Figure 4-3 Correlation of Plant Density with Depth to Groundwater in Site 2 Plant Density Survey Locations



For the dominant shrub species at Potrero Canyon Unit (mulefat), the plant density appears fairly well correlated with groundwater depth, with higher plant density values at shallower groundwater depths. In contrast, for the dominant tree species at Potrero Canyon Unit (arroyo willow and Fremont’s cottonwood), the plant density appears either uncorrelated with groundwater depth, or there are slightly higher plant density values at deeper groundwater depths. For both the dominant tree and shrub species at Laborde Canyon (mulefat, tamarisk, and fourwing saltbush), the plant density appears somewhat correlated with groundwater depths, with higher plant density values at deeper groundwater depths.

The plant density and percent cover data for Sites 1 and 2 is used along with the riparian area acreage and typical plant water uptake rates to develop Potrero Canyon Unit and Laborde Canyon plant groundwater budgets for the various species detected in the plant survey (Table 4.4-3). The plant survey groundwater budgets were developed as follows:

Extrapolation of plant survey species density and percent cover data from the survey locations to the entire riparian area – The plant density and percent cover data from the 0.23 acre surveyed locations were interpolated to determine the spatial distribution of species plant density and percent cover throughout the entire riparian area. These spatial distributions of species plant density and percent cover can then be used to calculate the total number of plants for each species and the average percent cover for various areas of interest within the entire riparian area. Since this water budget focuses on plant water uptake from groundwater, the water budget area was limited to riparian areas where the groundwater is shallow enough to be used by plants, which was taken to be less than 10 feet bgs for shrubs and less than 25 feet bgs for trees. For Potrero Canyon Unit, 25 feet bgs essentially corresponds to the entire Bedsprings Creek riparian area of 50 acres, while 10 feet bgs corresponds to approximately 40 percent of the Bedsprings Creek riparian area in a 20 acre area roughly bounded by the monitoring wells MW-13, MW-43, P-02, OW-02, and MW-42. For Laborde Canyon, the 25 feet bgs area corresponds to the Laborde Canyon area between the site boundary and the southern limit of the Offsite riparian area (3.2 acres), while the 10 feet bgs area corresponds to roughly one-half that region (1.6 acres). Note that for Laborde Canyon, much of the surveyed plant vegetation is located south of the Offsite Riparian area where the depth to groundwater is in excess of 25 feet, so the primary plant groundwater budget given in Table 4.4-1 excludes the plants in this area since groundwater is unlikely to be pulled from such depths by plants. Note that a separate water budget for the plants in this deep groundwater area is also presented separately.

Table 4.4-3 Plant Groundwater Use Summary, Sites 1 and 2

Site 2 Plants (Offsite Riparian Area)				Abundance			Water Use (Min)			Water Use (Max)		
Common Name	Scientific name	USDA Moisture Use	USDA Type	Average Density (number per acre)	Number of Plants	Average Percent Cover	gpd per plant[1]	ft per year[1]	Acre-Ft/Yr	gpd per plant[1]	ft per year[1]	Acre-Ft/Yr
Arroyo Willow	Salix lasiolepis	High	Tree	1.36	4	0.21	10		0.05	50		0.24
Black Willow	Salix goodingii		Tree	0.45	1	0.05	10		0.02	50		0.08
Elderberry	Sambucus nigra caerulea	Medium	Tree	0.23	1	0.05	11.86		0.01	24.03		0.02
Four-wing Saltbush	Atriplex canescens	Medium	Shrub	45.94	148	3.32		2.61	0.139		4.07	0.217
Fremont's Cottonwood	Populus fremontii	High	Tree	0.91	3	0.21	13		0.04	95		0.31
Honeysuckle	Lonicera sp.		Vine, Shrub	0.45	1	0.11		1.23	0.002		2.04	0.003
Mulefat	Baccharis salicifolia	Medium	Shrub	111.57	359	12.37		2.61	0.519		4.07	0.810
Coffeeberry	Rhamnus crocea	Low	Tree, Shrub	0.23	1	0.05		1.23	0.001		2.04	0.002
Scrub Oak	Quercus berberidifolia	Low	Tree	0.23	1	0.05	3.49		0.003	8.73		0.007
Tamarisk	Tamarix ramosissima		Tree, Shrub	56.35	76	2.25	32.2		2.74	200		17.04
Tree Tobacco	Nicotiana glauca		Tree, Shrub	0.23	1	0.05		2.61	0.002	4.23	4.07	0.003
Tripbush	Symphoricarpos sp.	Medium	Tree, Shrub	0.45	1	2.11	11.86			24.03		0.04
								Total	3.53		Total	18.78

Site 1 Plants (Bedsprings Creek Riparian Area)				Abundance			Water Use (Min)			Water Use (Max)		
Common Name	Scientific name	USDA Moisture Use	USDA Type	Average Density (number per acre)	Number of Plants	Average Percent Cover	gpd per plant[1]	ft per year[1]	Acre-Ft/Yr	gpd per plant[1]	ft per year[1]	Acre-Ft/Yr
Arroyo Willow	Salix lasiocarpa	High	Tree	56.00	2,800	16.65	10		31	50		157
California False Indigo	Amorpha californica		Shrub	36.18	36	0.14		2.61	0.07		4.07	0.11
California Wildrose	Rosa californica	High	Subshrub	0.21	4	0.03		5.07	0.03		7.05	0.04
Elderberry	Sambucus nigra caerulea	Medium	Tree	8.64	432	0.97	11.86		6	24.03		12
Fremont's Cottonwood	Populus fremonti	High	Tree	21.38	1,069	10.01	13		16	95		114
Mulefat	Baccharis salicifolia	Medium	Shrub	92.96	1,859	6.87		2.61	3.59		4.07	5.60
Tamarisk	Tamarix ramosissima		Tree	0.21	10	0.05	32.2		0.4	200		2
Tree Tobacco	Nicotiana glauca		Shrub	1.12	22	0.13		2.61	0.07		4.07	0.11
								Plant Total	57		Plant Total	291
Site 1 Ponds		Area Min (acre)	Pan Evap. (in/yr)		Area Max (acre)			Pond Evap (ft/yr)	Acre-Ft/Yr		Pond	Acre-Ft/Yr
Cattle Ponds in Riparian Area		0.5	75		1			4.4	2.19		4.4	4.38
								Total Plants and Ponds	59		Total Plants and Ponds	295

Site 1 Plants (Lower Potrero Creek Riparian Area)				Abundance			Water Use (Min)			Water Use (Max)		
Common Name	Scientific name	USDA Moisture Use	USDA Type	Average Density (number per acre)	Number of Plants	Average Percent Cover	gpd per plant[1]	ft per year[1]	Acre-Ft/Yr	gpd per plant[1]	ft per year[1]	Acre-Ft/Yr
Arroyo Willow	Salix lasiocarpa	High	Tree	32.29	1,130	12.89	10		13	50		63
Elderberry	Sambucus nigra caerulea	Medium	Tree	0.23	8	0.05	11.86		0.11	24.03		0.21
Fremont's Cottonwood	Populus fremonti	High	Tree	21.38	748	7.53	13		10.90	95		79.68
Mulefat	Baccharis salicifolia	Medium	Shrub	76.27	2,669	3.74		2.61	3.42		4.07	5.33
Tamarisk	Tamarix ramosissima		Tree	0.23	8	0.05	32.2		0.29	200		1.78
								Plant Total	27		Plant Total	150

[1] Adapted from ITRC, 2009, Wullschleger et al., 1998, and USDA, 2011 unless indicated otherwise

[2] Owens and Moore, 2007 salt cedar 32.2 gpd

[3] Hoddenbach, 1987 salt cedar 200 gpd

Table 4.4-3 Plant Groundwater Use Summary, Sites 1 and 2 (Cont)

Site 1 Bedsprings Creek	
Area (Acres) GW < 25 ft	50
Area (Acres) GW < 10ft	20

Site 2	
Area (Acres) GW < 25 ft	3.21
Area (Acres) GW < 10 ft	1.61

Site 1 Potrero Creek	
Area (Acres) GW < 25 ft	35
Area (Acres) GW < 10 ft	35

Tree Water Use (GPD) for Various USDA Moisture Use Categories					
Low Moisture Use -Lower Bound	Low Moisture Use - Upper Bound	Medium Moisture Use -Lower Bound	Medium Moisture Use -Upper Bound	High Moisture Use -Lower Bound	High Moisture Use - Upper Bound
3.49	8.73	11.86	24.03	33.07	66.94
Shrub Water Use (ft/yr) for Various USDA Moisture Use Categories					
Low Moisture Use -Lower Bound	Low Moisture Use - Upper Bound	Medium Moisture Use -Lower Bound	Medium Moisture Use -Upper Bound	High Moisture Use -Lower Bound	High Moisture Use - Upper Bound
1.23	2.04	2.61	4.07	5.07	7.05

Estimates of water use rates for various plants – Published values of plant water use (ITRC, 2009; Hoddenbach, 1987; Owens and Moore, 2007; Robinson, 1958; and Wullschleger et al., 1998) were used to estimate potential ranges of plant water use for the Beaumont sites, where water use for trees was estimated on a per plant basis (gallons per day) and water use for shrubs was estimated on an area specific basis (acre-ft per year/acre). For plants without specific water use estimates, the low, medium, and high moisture use categories given in the USDA plant profile (USDA, 2011) were used to approximate the range of plant water use, where the aforementioned published plant water use estimates were used to develop the low, medium, and high water use rates given in the bottom of Table 4.4-1. While this low, medium, and high water use categorization procedure is uncertain, note that it has little practical impact on the final total water budget, since published water use estimates were available for the abundant species that drive the water budget (arroyo willow, Fremont's cottonwood, mulefat, and tamarisk).

Estimates of total riparian area groundwater use by plants – The site survey plant density and cover data; estimates of water use rates for various plants; and the riparian area acreage were used to calculate a range of total annual groundwater use by the plants observed in the Potrero Canyon Unit and 2 plant surveys. For the trees, groundwater use is calculated by multiplying the estimated total number in trees in the riparian area by the ranges of plant specific water use in gallons per day, yielding a water use estimate in gallons per day or acre-feet per year (this corresponds to multiplying the 6th and 8th columns or 6th and 11th columns in Table 4.4-3). The total number in trees was estimated using the average tree density within the riparian area of interest (Table 4.4-3, 5th column in plants per acre) and the acreage of that riparian area as given in the bottom of Table 4.4-3. For the shrubs, groundwater use is calculated by multiplying the average species percent cover in the riparian area; the riparian area acreage; and the ranges of plant specific water use in acre-feet per year per acre, yielding a water use estimate in acre-feet per year (this corresponds to multiplying the 7th and 9th columns or 7th and 12th columns with the acreage values given at the bottom of Table 4.4-3).

For Potrero Canyon Unit, open water is present perennially in the cattle ponds, which is believed to be fed by the artesian groundwater in this area. Therefore, a small amount of additional groundwater use was added to the riparian area groundwater discharge rate due to the evaporation that occurs at the cattle ponds. This was estimated using adjusted pan evaporation rates (WRCC, 2011) and pond acreage.

For Potrero Canyon Unit, the total groundwater use by the six plants identified in the survey and the site ponds is estimated to range from 57 to 291 acre-feet per year, with over 90 percent of the water use attributed to two species (arroyo willow and Fremont's cottonwood). For Laborde Canyon, the total groundwater use by the twelve plants identified in the survey is estimated to range from 3.5 to 18 acre-feet per year, with over 90 percent of the water use attributed to one species (tamarisk).

For Potrero Canyon Unit, this total groundwater use of 57 to 291 acre-feet per year is only for the 50 acre riparian area within Bedsprings Creek. However, about one-half mile west of the Bedsprings Creek riparian area there is an additional 35 acres of riparian area located in Middle and Lower Potrero Creek where similar phreatophyte vegetation is present and depth to groundwater is shallow enough to support phreatophytes. Using the plant survey data collected in Lower Potrero Creek, the plants in the Middle and Lower Potrero Creek riparian area could also use an additional 27 to 150 acre-feet per year of water, however, due to the perennial streamflow that exists is this area, it is not known how much of this 27 to 150 acre-feet per year is pulled from groundwater versus the perennial streamflow.

For Laborde Canyon, this total groundwater use of 3.5 to 18 acre-feet per year is only for the riparian area where groundwater is shallow enough to support phreatophytes. However, there is an additional 3.5 acres of riparian vegetation located below the Offsite riparian area where similar phreatophyte vegetation exists but depth to groundwater is generally too great to support phreatophytes, and by analogy to Laborde Canyon Offsite Riparian area plant water budget estimate, the plants in this lower area of Laborde Canyon could use an additional 4 to 19 acre-feet per year of water. However, none of this plant water in the lower reaches of Laborde Canyon is thought to be consumed by groundwater.

4.4.1 Comparison of Plant Groundwater Uptake Budget with Evapotranspiration Estimates in Site MODFLOW Groundwater Model

For Potrero Canyon Unit, total groundwater use by plants and the site ponds in the Bedsprings Creek riparian areas is estimated to range from 59 to 295 acre-feet per year and average 177 acre-feet per year; by comparison the amount of evapotranspiration in the Bedsprings Creek riparian areas is estimated in the Potrero Canyon Unit groundwater model to average 140 acre-feet per year during the period from 1992 through 2009.

For Laborde Canyon, total groundwater use by plants in the Offsite riparian area is estimated to range from 3.5 to 18 acre-feet per year and average 11 acre-feet per year; by comparison the amount of evapotranspiration in the Offsite riparian area is estimated by Laborde Canyon groundwater model to average 2.5 acre-feet per year during the period from 2006 through 2010.

4.4.2 Uncertainty in the Plant Groundwater Uptake Budget

As indicated by the large range of values given in the plant groundwater budget, there is considerable uncertainty in the total amount of groundwater used by plants. Since the surveyed area actually covers a fairly large fraction of the total riparian areas (for example, the surveyed area at Potrero Canyon Unit actually covers almost ten acres), it is believed that the main uncertainty factor in the groundwater budget is the plant specific water use rates, as opposed to the plant abundance estimates. However, it is useful to note that the average plant groundwater use value of 177 acre-feet per year for Potrero Canyon Unit is fairly close to the Potrero Canyon Unit groundwater model average of 140 acre-feet per year, which is fairly good agreement for water budget estimates that are derived totally independent of each other.

For Laborde Canyon, the agreement is not very good, as the average plant groundwater use value of 11 acre-feet per year is much greater than the groundwater model average of 2.5 acre-feet per year, however, the groundwater model water budget is thought to be highly uncertain.

4.5 CONTAMINANT CONCENTRATION TIME TREND ANALYSIS

Potrero Canyon Unit

Statistical analysis of COPC time trends (Table 4.5-1) from August 1986 to July 2011 confirms the observation that the overall extent and magnitude of the plume is relatively unchanged over the nearly 20 year monitoring period, though there had been a small reduction in plume mass near the RMPA groundwater extraction and treatment system when that system was active. Generally, a very small percentage of the wells (less than 10 percent) have increasing trends; a moderate percentage of the wells (15 to 30 percent) have decreasing trends; a moderate percentage of the wells (15 to 30 percent) have no statistically significant trends; and the greatest percentage of the wells (35 to 55 percent) have statistically significant stable trends.

The temporal trend analyses performed for the routine groundwater monitoring program utilizes data from Second Quarter 2002 to Second Quarter 2011. This period was chosen because operation of the RMPA groundwater pump and treat system was discontinued in 2002. Figures

Statistical Analysis of Groundwater Monitoring Data
LMC Beaumont Site 1
Data from 1986 to August 2010

	1,1-DICHLOROETHENE						1,4-DIOXANE						PERCHLORATE						TRICHLOROETHYLENE					
	Number of	Number of	LR Mean	MK	Magnitude of Trend		Number of	Number of	LR Mean	MK	Magnitude of Trend		Number of	Number of	LR Mean	MK	Magnitude of Trend		Number of	Number of	LR Mean	MK	Magnitude of Trend	
Well	Samples	Decections	(µg/L)	Trend	(%/yr)	(µg/L/yr)	Samples	Decections	(µg/L)	Trend	(%/yr)	(µg/L/yr)	Samples	Decections	(µg/L)	Trend	(%/yr)	(µg/L/yr)	Samples	Decections	(µg/L)	Trend	(%/yr)	(µg/L/yr)
EW-01	12	12	290.00	PD	-20.1	-58.22													11	11	140.00	D	-9.3	-13.03
EW-02	12	12	260.00	PD	-11.5	-29.89													10	10	150.00	I	3.8	5.75
EW-08	5	5	17.00	S															5	5	10.00	S		
EW-09	5	5	420.00	S															5	5	140.00	NT		
EW-10	5	5	810.00	S															4	4	220.00	I		
EW-11	15	15	1000.00	NT															8	8	530.00	NT		
EW-12	15	15	2600.00	S															11	11	1300.00	NT		
EW-13	32	32	7400.00	I	4.2	310.62	14	14	2100.00	NT			14	14	1500.00	D	-56.6	-848.63	27	27	1400.00	I	3.7	51.10
EW-14	5	5	2100.00	S															4	4	430.00	S		
EW-15	21	21	7500.00	NT			5	5	380.00	PD	-7.1	-27.05	5	5	64000.00	D	-13.0	-8292.80	17	17	1300.00	S		
EW-16	17	17	6900.00	NT			1	1	480.00	N/A			1	1	17000.00	N/A			13	13	1500.00	NT		
EW-17	2	2	480.00	N/A															2	2	200.00	N/A		
EW-18	17	17	5900.00	S			1	1	520.00	N/A			1	1	53000.00	N/A			11	11	1600.00	NT		
F33-TW1	2	2	0.50	N/A			2	2	3.00	N/A			2	0	0.18	ND			2	1	0.22	N/A		
F33-TW2	11	5	0.24	PD	-31.0	-0.07	11	11	3.50	NT			11	1	0.19	NT			11	0	0.10	ND		
F33-TW3	11	8	0.63	PD	-42.0	-0.26	11	11	4.10	S			11	2	0.14	S			11	7	0.35	PD	-20.1	-0.07
F33-TW4	2	2	0.30	N/A			2	2	2.70	N/A			2	0	0.18	ND			2	0	0.10	ND		
F33-TW5	2	0	0.10	ND			2	2	2.60	N/A			2	0	0.18	ND			2	0	0.10	ND		
F33-TW6	11	1	0.10	PD	-10.4	-0.01	11	11	3.10	NT			11	0	0.08	ND			11	1	0.12	NT		
F33-TW7	7	1	0.08	NT			7	6	2.70	S			7	0	0.04	ND			7	0	0.10	ND		
F34-TW1	6	4	0.18	S			6	6	5.10	I	23.7	1.21	6	1	0.42	NT			6	5	0.58	NT		
IW-01	2	1	1.50	N/A			1	0	0.05	ND			1	1	0.08	N/A			2	1	1.10	N/A		
IW-02	3	2	17.00	N/A			1	1	1.00	N/A			1	1	1.10	N/A			3	3	6.00	N/A		
IW-03	4	4	180.00	D	-4.2	-7.56	1	1	24.00	N/A			1	1	1.70	N/A			4	4	40.00	S		
IW-04	14	13	24.00	NT			11	11	22.00	S			11	6	160.00	D	-69.4	-110.96	13	13	13.00	I	1.7	0.22
IW-05	3	3	110.00	N/A			1	1	26.00	N/A			1	1	100.00	N/A			3	3	29.00	N/A		
MW-01	12	12	210.00	D	-2.2	-4.60	7	7	2.50	S			8	8	870.00	S			12	12	270.00	D	-1.6	-4.19
MW-02	18	18	340.00	PD	-3.7	-12.41	8	8	110.00	S			10	10	2900.00	S			14	14	210.00	D	-2.9	-6.13
MW-03	11	5	0.83	NT			6	1	0.24	S			7	3	15.00	NT			11	7	0.84	NT		
MW-04	18	18	120.00	D	-9.9	-11.83	1	1	14.00	N/A			2	2	1300.00	N/A			14	14	140.00	D	-5.7	-7.92
MW-05	25	25	150.00	D	-2.9	-4.38	10	10	27.00	NT			11	11	2700.00	D	-4.6	-123.19	19	19	130.00	S		
MW-06	14	13	21.00	NT			6	5	14.00	NT			7	6	190.00	NT			14	14	12.00	NT		
MW-07	22	21	13.00	NT			9	7	4.50	NT			10	10	170.00	NT			18	18	37.00	NT		
MW-08	11	1	0.26	S			7	2	0.92	NT			8	2	69.00	D	-20.1	-13.85	11	2	0.24	S		
MW-09	12	0	0.17	ND			9	8	4.60	PI	7.7	0.35	10	1	10.00	D	-20.1	-2.01	12	0	0.16	ND		
MW-10	14	11	8.60	NT			1	1	0.50	N/A			2	1	52.00	N/A			12	8	6.90	NT		
MW-100	8	0	0.08	ND			8	5	0.23	NT			8	1	0.07	NT			8	0	0.10	ND		
MW-101	6	6	52.00	S			6	6	24.00	NT			6	0	0.04	ND			6	6	44.00	D	-7.8	-3.45
MW-102	6	6	22.00	S			6	6	20.00	NT			6	0	0.04	ND			6	6	19.00	S		
MW-103	3	3	3.00	N/A			3	3	13.00	N/A			3	3	71.00	N/A			3	3	6.10	N/A		
MW-104	3	3	54.00	N/A			3	3	32.00	N/A			3	0	0.04	ND			3	3	1.50	N/A		
MW-105	3	3	100.00	N/A			3	3	33.00	N/A			3	0	0.04	ND			3	3	74.00	N/A		
MW-106	3	3	26.00	N/A			3	3	24.00	N/A			3	2	32.00	N/A			3	3	16.00	N/A		
MW-107	3	3	6.70	N/A			3	3	12.00	N/A			3	3	21.00	N/A			3	3	7.90	N/A		
MW-108	3	3	65.00	N/A			3	3	26.00	N/A			3	3	78.00	N/A			3	3	45.00	N/A		
MW-109	3	3	59.00	N/A			3	3	27.00	N/A			3	3	470.00	N/A			3	3	62.00	N/A		
MW-11	21	13	2.10	NT			5	1	0.25	S			6	4	18.00	NT			16	8	2.30	NT		
MW-12	10	0	0.24	ND			7	2	0.85	NT			8	1	13.00	D	-18.3	-2.37	10	0	0.21	ND		
MW-13	17	5	5.30	NT			13	3	0.35	NT			14	1	7.60	D	-18.3	-1.39	17	3	4.10	NT		
MW-14	13	4	1.40	D	-6.6	-0.09	9	5	1.20	NT			10	9	17.00	D	-11.0	-1.86	13	5	2.90	D	-2.7	-0.08
MW-15	21	18	2.50	NT			17	16	6.60	PD	1.6	0.11	18	1	5.90	D	-20.1	-1.18	21	18	1.10	I	5.1	0.06
MW-16	5	0	0.19	ND			3	1	1.10	N/A			4	0	25.00	ND			5	0	0.18	ND		
MW-17	26	24	10.00	D	-5.7	-0.57	10	10	28.00	S			11	11	680.00	NT			22	20	9.10	S		
MW-18	21	21	4.50	D	-4.6	-0.21	17	15	5.50	S			18	17	10.00	D	-9.9	-0.99	21	20	2.00	D	-3.7	-0.07
MW-19	30	30	21.00	I	5.3	1.11	11	11	64.00	NT			12	11	160.00	S			25	25	9.40	I	5.1	0.48
MW-20	13	13	61.00	D	-10.0	-6.12	3	2	3.80	N/A			3	3	440.00	N/A			9	9	57.00	D	-8.8	-4.99
MW-21	2	2	240.00	N/A															2	2	78.00	N/A		
MW-22	13	13	110.00	NT			8	8	34.00	NT			8	8	630.00	NT			13	13	71.00	NT		
MW-23	4	4	43.00	S			1	1	4.50	N/A			3	2	66.00	N/A			4	4	26.00	D	-4.6	-1.19
MW-24	3	3	6100.00	N/A									1	1	5100.00	N/A			3	3	2000.00	N/A		
MW-25	2	2	5100.00	N/A									1	1	6800.00	N/A			2	2	1400.00	N/A		
MW-26	26	26	3900.00	NT			9	9	400.00	I	8.4	33.58	9	9	7600.00	D	-2.2	-166.44	21	21	2800.00	S		
MW-27	10	3	4.70	D	-10.8	-0.51	7	2	1.30	D	-29.2	-0.38	8	6	15.00	NT			10	4	4.90	D	-8.2	-0.40
MW-28	10	10	26.00	NT			8	8	34.00	NT			8	8	130.00	NT			10	10	22.00	PI	1.6	0.36
MW-29	13	13	32.00	S			2	2	27.00	N/A			2	2	17.00	N/A			8	8	44.00	NT		
MW-30	5	3	18.00	NT			3	2	3.90	N/A			3	3	62.00	N/A			5	4	4.60	NT		
MW-31	10	4	7.10	D	-8.8	-0.62	7	2	0.68	D	-18.3	-0.12	7	7	2.60	I	2.7	0.07	10	4	4.00	PD	-5.7	-0.23
MW-32	10	3	2.40	PD	-5.7	-0.14	6	1	0.24	S			6	3	0.58	NT			10	4	2.30	NT		

Statistical Analysis of Groundwater Monitoring Data
LMC Beaumont Site 1
Data from 1986 to August 2010

	1,1-DICHLOROETHENE						1,4-DIOXANE						PERCHLORATE						TRICHLOROETHYLENE					
Well	Number of Samples	Number of Decections	LR Mean (µg/L)	MK Trend	Magnitude of Trend		Number of Samples	Number of Decections	LR Mean (µg/L)	MK Trend	Magnitude of Trend		Number of Samples	Number of Decections	LR Mean (µg/L)	MK Trend	Magnitude of Trend		Number of Samples	Number of Decections	LR Mean (µg/L)	MK Trend	Magnitude of Trend	
					(%/yr)	(µg/L/yr)					(%/yr)	(µg/L/yr)					(%/yr)	(µg/L/yr)					(%/yr)	(µg/L/yr)
MW-34	14	9	11.00	NT			9	3	0.39	NT			9	9	65.00	NT			14	11	10.00	NT		
MW-35	14	3	1.30	D	-7.5	-0.10	10	1	0.30	PD	-10.6	-0.03	10	3	0.48	NT			14	4	0.90	D	-5.7	-0.05
MW-36	25	13	1.40	D	-4.2	-0.06	10	2	0.91	PD	-9.7	-0.09	10	4	4.00	NT			21	10	1.40	D	-4.0	-0.06
MW-37	12	10	2.60	PI	4.4	0.11	9	8	5.50	S			9	1	0.49	NT			12	7	1.50	NT		
MW-38	4	1	3.50	NT			1	1	0.50	N/A			1	1	1.80	N/A			4	1	0.68	NT		
MW-39	13	13	94.00	NT			1	1	10.00	N/A			1	1	810.00	N/A			9	9	68.00	I	7.5	5.09
MW-40	20	20	20.00	PD	-1.8	-0.37	10	9	18.00	S			10	10	710.00	S			15	15	30.00	NT		
MW-41	17	17	160.00	D	-12.0	-19.27													12	12	150.00	S		
MW-42	18	18	160.00	D	-4.2	-6.72	8	8	26.00	S			8	5	65.00	D	-52.9	-34.40	14	14	100.00	D	-2.6	-2.56
MW-43	8	8	24.00	PD	-6.0	-1.45	6	6	13.00	PD	-6.8	-0.88	6	6	91.00	PD	-3.7	-3.32	7	7	10.00	S		
MW-44	14	14	190.00	D	-4.0	-7.63	1	1	25.00	N/A			1	1	990.00	N/A			9	9	160.00	NT		
MW-45	13	13	32.00	D	-6.6	-2.10	10	10	12.00	D			10	10	210.00	D	-5.7	-11.88	13	13	18.00	D	-4.9	-0.89
MW-46	14	13	3.10	S			10	9	8.40	S			10	6	5.00	NT			14	12	2.30	NT		
MW-47	12	1	0.43	D	-5.1	-0.02	10	4	1.70	D	-11.7	-0.20	10	10	10.00	D	-8.8	-0.88	12	1	0.36	PD	-3.7	-0.01
MW-48	7	1	2.80	NT			5	3	2.50	NT			5	0	0.19	ND			7	1	0.48	NT		
MW-49	27	26	49.00	NT			10	9	15.00	S			10	10	630.00	PD	-4.4	-27.59	22	22	25.00	S		
MW-50	18	18	170.00	D	-10.6	-17.99	2	2	12.00	N/A			2	2	360.00	N/A			13	13	41.00	NT		
MW-51	18	17	250.00	D	-15.3	-38.33	1	1	19.00	N/A			1	1	620.00	N/A			13	13	86.00	D	-5.5	-4.71
MW-52	19	19	420.00	D	-10.4	-43.69	1	1	22.00	N/A			1	1	720.00	N/A			14	14	150.00	D	-5.5	-8.21
MW-53	10	10	57.00	D	-14.8	-8.43	8	8	5.80	D	-20.1	-1.16	8	8	170.00	D	-20.1	-34.13	10	10	17.00	D	-9.7	-1.64
MW-54	10	10	390.00	NT			8	8	20.00	NT			8	8	820.00	S			10	10	120.00	NT		
MW-55	22	22	330.00	NT			7	7	57.00	I	12.0	6.87	7	7	1500.00	I	9.1	136.88	17	17	160.00	NT		
MW-56A	22	18	63.00	D	-13.7	-8.62	6	2	10.00	NT			6	2	0.62	NT			17	13	40.00	D	-10.6	-4.23
MW-56B	11	11	73.00	D	-2.4	-1.73	6	5	6.50	S			6	6	360.00	S			11	11	48.00	S		
MW-56C	26	26	130.00	D	-4.7	-6.17	9	9	21.00	NT			9	9	920.00	PD	-3.7	-33.58	21	21	99.00	D	-3.5	-3.43
MW-56D	9	9	210.00	D	-6.4	-13.41	3	3	22.00	N/A			3	3	660.00	N/A			8	8	94.00	D	-3.5	-3.26
MW-57A	18	18	220.00	PD	-6.6	-14.45	3	3	25.00	N/A			3	3	1100.00	N/A			13	13	120.00	D	-4.9	-5.91
MW-57B	7	7	120.00	D	-4.9	-5.91	3	3	27.00	N/A			3	3	540.00	N/A			7	7	71.00	S		
MW-57C	6	6	220.00	D	-6.4	-14.05	2	2	23.00	N/A			2	2	640.00	N/A			6	6	82.00	D	-4.0	-3.29
MW-57D	7	7	370.00	D	-8.6	-31.74	3	3	30.00	N/A			3	3	1100.00	N/A			7	7	160.00	D	-5.8	-9.34
MW-58A	9	9	150.00	D	-6.2	-9.31	3	3	23.00	N/A			3	3	270.00	N/A			8	8	75.00	D	-3.8	-2.87
MW-58B	6	6	98.00	D	-10.2	-10.02	3	3	27.00	N/A			3	3	570.00	N/A			6	6	53.00	D	-5.7	-3.00
MW-58C	8	8	260.00	D	-8.6	-22.30	3	3	25.00	N/A			3	3	1000.00	N/A			8	8	110.00	PD	-5.3	-5.82
MW-58D	20	20	200.00	D	-8.6	-17.16	5	5	27.00	NT			5	5	670.00	NT			15	15	150.00	D	-6.6	-9.86
MW-59A	8	7	14.00	S			3	2	0.66	N/A			3	3	860.00	N/A			8	8	16.00	S		
MW-59B	20	20	330.00	D	-2.6	-8.43	6	6	48.00	NT			6	6	4500.00	NT			15	15	240.00	PD	-2.0	-4.82
MW-59C	8	8	130.00	NT			3	3	22.00	N/A			3	3	4400.00	N/A			7	7	82.00	I	8.9	7.33
MW-59D	18	18	420.00	NT			14	14	43.00	NT			14	14	6200.00	I	1.8	113.15	17	17	280.00	I	2.9	8.18
MW-60A	19	19	270.00	I	7.1	19.22	14	14	110.00	I	4.9	5.42	14	14	4700.00	I	21.9	1029.30	19	19	170.00	I	10.2	17.37
MW-60B	15	15	36.00	I	7.1	2.56	10	8	5.10	I	23.7	1.21	10	10	1400.00	D	-4.0	-56.21	14	14	9.30	I	5.1	0.48
MW-61A	11	11	3800.00	NT			4	4	30.00	NT			4	4	11000.00	S			10	10	180.00	D	-4.7	-8.54
MW-61B	16	16	11000.00	D	-2.6	-281.05	9	9	460.00	I	2.9	13.43	9	9	86000.00	S			15	15	1900.00	D	-2.4	-45.08
MW-61C	10	10	88.00	I	4.2	3.69	7	7	5.90	I	5.1	0.30	7	7	2900.00	NT			10	10	18.00	I	4.2	0.76
MW-61D	3	3	48.00	N/A															3	3	4.30	N/A		
MW-62A	26	26	150.00	D	-6.6	-9.86	10	9	30.00	S			10	10	1200.00	S			20	20	110.00	D	-3.1	-3.41
MW-62B	5	5	470.00	D	-38.3	-180.13													4	4	180.00	NT		
MW-63	9	9	64.00	NT			1	1	25.00	N/A			1	1	1500.00	N/A			5	5	37.00	S		
MW-64	1	1	890.00	N/A			1	1	46.00	N/A			1	1	1700.00	N/A			1	1	140.00	N/A		
MW-65	3	3	530.00	N/A															3	3	130.00	N/A		
MW-66	24	24	160.00	D	-2.6	-4.09	11	11	25.00	NT			11	11	1300.00	S			19	19	160.00	PD	-1.2	-1.96
MW-67	15	1	0.17	S			15	7	0.62	PI	5.8	0.04	15	1	0.25	S			15	0	0.24	ND		
MW-68	11	11	9.70	I	29.2	2.83	11	11	9.30	I	32.9	3.06	11	11	6800.00	I	21.9	1489.20	11	4	4.60	NT		
MW-69	9	9	6.10	NT			9	9	8.30	D	-10.6	-0.88	9	9	2000.00	D	-12.2	-244.55	9	9	12.00	NT		
MW-70	15	2	0.28	D	-31.0	-0.09	16	16	2.80	PI	5.3	0.15	16	11	9.50	NT			16	1	0.20	D	-14.8	-0.03
MW-71A	5	0	0.27	ND			5	0	0.22	ND			5	0	0.19	ND			5	0	0.27	ND		
MW-71B	7	2	0.33	NT			7	0	0.21	ND			7	7	270.00	NT			7	1	0.26	NT		
MW-71C	6	0	0.24	ND			6	0	0.20	ND			6	6	150.00	PD	-120.5	-180.68	6	0	0.24	ND		
MW-72A	5	0	0.27	ND			5	0	0.22	ND			5	0	0.19	ND			5	0	0.27	ND		

Statistical Analysis of Groundwater Monitoring Data
LMC Beaumont Site 1
Data from 1986 to August 2010

	1,1-DICHLOROETHENE						1,4-DIOXANE						PERCHLORATE						TRICHLOROETHYLENE					
Well	Number of Samples	Number of Decections	LR Mean (µg/L)	MK Trend	Magnitude of Trend (%/yr)	Magnitude of Trend (µg/L/yr)	Number of Samples	Number of Decections	LR Mean (µg/L)	MK Trend	Magnitude of Trend (%/yr)	Magnitude of Trend (µg/L/yr)	Number of Samples	Number of Decections	LR Mean (µg/L)	MK Trend	Magnitude of Trend (%/yr)	Magnitude of Trend (µg/L/yr)	Number of Samples	Number of Decections	LR Mean (µg/L)	MK Trend	Magnitude of Trend (%/yr)	Magnitude of Trend (µg/L/yr)
MW-72B	6	0	0.27	ND			6	0	0.19	ND			6	2	0.38	NT			6	0	0.28	ND		
MW-72C	5	0	0.31	ND			5	0	0.22	ND			5	2	4.60	PD	-62.1	-2.85	5	0	0.31	ND		
MW-73A	5	0	0.31	ND			5	0	0.22	ND			5	5	2.40	NT			5	0	0.31	ND		
MW-73B	6	0	0.27	ND			6	0	0.19	ND			6	3	6.50	S			6	0	0.28	ND		
MW-73C	5	0	0.31	ND			5	0	0.22	ND			5	1	0.28	NT			5	0	0.31	ND		
MW-74A	5	0	0.31	ND			5	0	0.22	ND			5	4	2.60	NT			5	0	0.31	ND		
MW-74B	6	0	0.31	ND			6	2	0.87	NT			6	6	14.00	PD	-47.5	-6.64	6	0	0.31	ND		
MW-74C	6	0	0.27	ND			6	0	0.19	ND			6	6	8.60	NT			6	0	0.28	ND		
MW-75A	6	0	0.29	ND			6	1	0.26	NT			6	0	0.21	ND			6	0	0.30	ND		
MW-75B	8	0	0.25	ND			8	0	0.22	ND			8	6	1.60	S			8	0	0.26	ND		
MW-75C	6	0	0.29	ND			6	0	0.25	ND			6	1	0.28	NT			6	0	0.30	ND		
MW-76A	8	0	0.24	ND			8	7	2.10	I	18.1	0.38	8	0	0.17	ND			8	0	0.25	ND		
MW-76B	8	0	0.25	ND			8	2	0.31	NT			8	0	0.19	ND			8	0	0.26	ND		
MW-76C	5	5	2.50	NT			5	5	6.70	NT			5	0	0.21	ND			5	2	0.60	PI	25.6	0.15
MW-77A	6	0	0.29	ND			6	0	0.25	ND			6	0	0.21	ND			5	0	0.34	ND		
MW-77B	8	0	0.25	ND			8	0	0.22	ND			8	0	0.19	ND			8	0	0.26	ND		
MW-78	6	6	4.40	S			6	5	1.90	NT			6	6	19.00	D	-31.0	-5.89	6	5	1.50	S		
MW-79A	6	0	0.29	ND			6	0	0.25	ND			6	0	0.21	ND			6	1	0.26	S		
MW-79C	5	5	7.20	S			5	5	3.80	S			5	5	79.00	S			5	5	6.80	NT		
MW-80	7	6	1.50	NT			7	7	5.30	PI	8.6	0.45	7	0	0.19	ND			7	3	0.49	NT		
MW-81	6	0	0.29	ND			6	0	0.25	ND			6	0	0.21	ND			6	0	0.30	ND		
MW-82	11	1	0.09	PD	-13.1	-0.01	11	11	3.00	NT			11	0	0.09	ND			11	0	0.10	ND		
MW-83	11	4	0.22	D	-38.3	-0.08	11	11	3.50	S			11	4	0.33	NT			11	3	0.16	S		
MW-84A	5	0	0.10	ND			5	0	0.13	ND			5	2	0.70	PD	-177.0	-1.24	5	0	0.10	ND		
MW-84B	5	0	0.10	ND			5	0	0.13	ND			5	0	0.11	ND			5	0	0.10	ND		
MW-85A	5	0	0.09	ND			5	1	0.16	PD	-89.4	-0.14	5	0	0.13	ND			5	0	0.09	ND		
MW-85B	6	0	0.08	ND			6	2	0.23	NT			6	0	0.18	ND			6	6	38.00	S		
MW-86A	5	0	0.09	ND			5	2	1.40	NT			5	0	0.11	ND			5	0	0.09	ND		
MW-86B	6	4	0.16	S			6	5	1.60	NT			6	2	0.23	NT			6	6	81.00	NT		
MW-87A	5	4	0.27	S			5	5	5.20	S			5	0	0.11	ND			5	5	0.50	NT		
MW-87B	6	6	6.90	PD	-31.0	-2.14	6	6	39.00	PD	-40.2	-15.66	6	6	37.00	NT			6	6	33.00	S		
MW-88	6	1	0.15	S			6	4	0.24	NT			6	6	1500.00	I	62.1	930.75	6	1	0.16	S		
MW-89	6	6	4.50	S			6	6	6.40	NT			6	6	2100.00	NT			6	6	6.70	S		
MW-90	7	7	1.90	S			7	5	0.24	PD	-6.8	-0.02	7	7	200.00	S			7	7	2.20	NT		
MW-91	6	2	0.25	NT			6	6	1.70	I	12.6	0.21	6	6	2100.00	I	13.5	283.61	6	1	0.28	NT		
MW-92	6	0	0.08	ND			6	3	0.17	D	-36.5	-0.06	6	6	25.00	S			6	6	16.00	S		
MW-93	6	5	0.49	S			6	6	12.00	S			6	5	4.50	PI	71.2	3.20	6	5	1.60	S		
MW-94	6	6	0.38	S			6	6	5.80	S			6	3	0.50	NT			6	6	1.50	S		
MW-95	6	0	0.08	ND			6	4	0.25	S			6	1	0.11	D	-45.6	-0.05	6	6	14.00	S		
MW-96	5	0	0.10	ND			5	0	0.13	ND			5	0	0.11	ND			5	0	0.10	ND		
MW-97	5	0	0.10	ND			5	0	0.13	ND			5	0	0.11	ND			5	0	0.10	ND		
MW-98A	5	0	0.09	ND			5	1	0.16	S			5	0	0.11	ND			5	0	0.09	ND		
MW-98B	7	7	14.00	I	17.2	2.40	7	7	9.00	NT			7	7	1400.00	NT			7	7	25.00	PI	12.4	3.10
MW-99	5	5	3.20	S			5	4	1.70	S			5	5	790.00	S			5	5	2.00	S		
OW-01	10	1	1.50	NT			8	0	0.28	ND			8	1	0.31	S			11	1	0.37	NT		
OW-02	19	19	72.00	D	-5.8	-4.20	12	12	15.00	D	-3.5	-0.52	13	13	630.00	D	-4.7	-29.89	19	19	72.00	D	-5.8	-4.20
OW-03	17	17	150.00	D	-11.7	-17.52	1	1	45.00	N/A			2	2	1900.00	N/A			13	13	200.00	D	-10.2	-20.44
OW-08	10	0	0.21	ND			6	0	0.32	ND			7	1	15.00	NT			10	0	0.21	ND		
P-02	11	1	1.40	D	-8.4	-0.12	9	0	0.27	ND			9	0	0.27	ND			11	1	0.40	D	-4.6	-0.02
P-03	9	3	1.80	D	-12.2	-0.22	8	4	0.78	S			8	1	5.10	NT			9	1	0.41	NT		
P-04	4	1	3.40	NT			3	0	0.20	ND			3	0	0.23	ND			4	1	0.66	NT		
P-05	11	3	4.70	D	-9.7	-0.45	9	1	0.31	D	-12.6	-0.04	9	8	5.00	S			11	3	5.40	D	-7.3	-0.39
P-06D	3	3	3.40	N/A			3	3	7.80	N/A			3	2	0.44	N/A			3	3	2.30	N/A		
P-06S	2	0	0.06	ND			2	2	1.10	N/A			2	2	0.74	N/A			2	0	0.09	ND		

Notes:

Trend Categories and Definitions	**1,1-DICHLOROETHENE (# wells)**	**% Total**	**1,4-DIOXANE (# wells)**	**% Total**	**PERCHLORATE (# wells)**	**% Total**	**TRICHLOROETHYLENE (# wells)**	**% Total**
"N/A"-Insufficient Data(< 4 sampling events)	20		43		40		19	
Blank-No data	0		16		14		0	
"ND" - Non Detect	37	23.13	26	21	33	26	38	24
"NT" - No Trend	34	21.25	38	31	37	29	40	25
"S" - Stable	25	15.63	26	21	20	16	28	17
"I" - Increasing	7	4.38	10	8	7	6	12	7
"PI" -Probably Increasing	1	0.63	4	3	1	1	3	2
"D" - Decreasing	44	27.50	9	7	21	17	34	21
"PD" -Probably Decreasing	12	7.50	8	7	7	6	6	4
	160	100.00	121	100.00	126	100.00	161	100.00

showing the spatial distribution of the temporal trends post-remediation (2002 to 2011) for perchlorate, 1,1-DCE, TCE, and 1,4-dioxane are presented in Figures 4-4 through 4-7. A brief summary of the spatial trends by area is provided below.

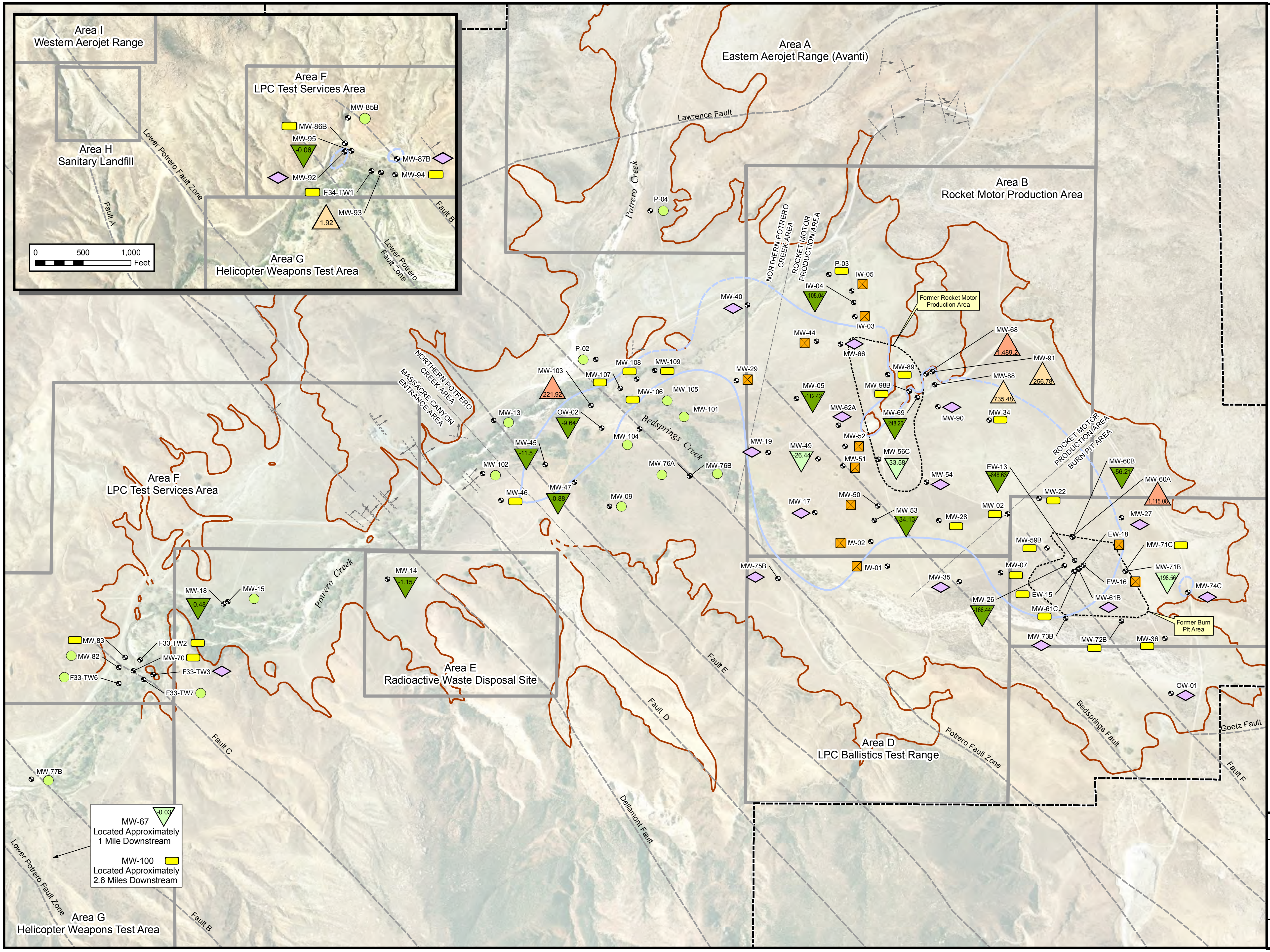
Burn Pit Area – The BPA is the primary source area for all of the Site's COPCs. Seven of the 21 locations with increasing trends identified were from monitoring wells located in this area. There were six wells with decreasing trends also. Relative to the mass of the contaminants present in the source area and the concentrations detected, the changes do not appear unusual. The results are consistent with a continuing source in an area of large groundwater level fluctuations that appears to be at near equilibrium conditions.

Rocket Motor Production Area - The RMPA is a secondary source area for the COPC perchlorate. Six of the 21 locations with increasing trends were monitoring wells located in this area. There were also eight wells with a decreasing trend. The results appear to be consistent with contaminants migrating from the BPA into the RMPA and with a continuing source of perchlorate in the RMPA that is at near equilibrium conditions.

Northern Potrero Creek Area – There are no known contaminant sources in the NPCA. Six of the 21 locations with increasing trends identified were from monitoring wells located in this area. There were also 13 wells with decreasing trends in the NPCA. The magnitudes of the trends are relatively small but the decreasing trends are generally larger than the increasing trends. The COPC plumes diminish significantly through this area both with respect to size and magnitude of the concentrations. It is believed that a significant amount of natural attenuation is occurring in the area. The results appear to be consistent with COPC plumes that are at near equilibrium or possibly decreasing conditions.

Massacre Canyon Entrance Area - The MCEA has secondary source areas for all the COPC's. Two of the 21 locations with increasing trends identified were from monitoring wells located in this area. There were nine wells with decreasing trends also. The magnitude of the trends is very small, all less than 2.0 µg/L per year. All of the Site's guard wells are located in this area. Guard wells MW-15, MW-18, MW-67, and MW-100 primarily displayed stable or decreasing COPC trends, with the exception of MW-15, in which a TCE trend could not be discerned, and MW-67 which had a 1,4-dioxane trend that could not be discerned. In 2010, F34-TW1 was the farthest downgradient well with an increasing trend. F34-TW1 had an increasing 1,4-dioxane trend with a magnitude of 1.16 µg/L/yr. The results appear to be consistent with COPC plumes that are at or near equilibrium conditions.

X:\GIS\Lockheed S1 Q1Q2 11\Trend Perchlorate.mxd



N

0 500 1,000
Feet

Adapted from: March 2007 aerial photograph.

Faults from structural analysis of Potrero Valley, *Lineament and Geologic Mapping Study, Tetra Tech, 2009.*

LEGEND

- ● Well Location
- MCL Contour
  Dashed where inferred
- Bedrock/Alluvium Surface Contact
  Dashed where inferred
- Fault, Accurately Located Showing Dip
- Fault, Approximately Located
- Historical Operational Area Boundary
- Potrero Canyon Unit Property Boundary
  (Lockheed Martin Beaumont Site 1)

Analyte Trend Results

- ▲ 2.00 Increasing
  Confidence in trend >95%
  (change shown in micrograms per liter per year (µg/L/yr)
- △ 2.00 Probably Increasing
  Confidence between 90 and 95%
  (change shown in µg/L/yr)
- ▽ -2.00 Probably Decreasing
  Confidence betwee 90 and 95%
  (change shown in µg/L/yr)
- ▼ -2.00 Decreasing
  Confidence in trend >95%
  (change shown in µg/L/yr)
- ◆ Stable
  Confidence in trend <90, coefficient of variation <1 and Mann-Kendall statistic ≤0
- ▬ No Trend
  Confidence in trend >90% and Mann-Kendall statistic >0 or confidence in trend <90%, coefficient of variation ≥1 and Mann-Kendall statistic ≤0
- ☒ Insufficient Data for Statistical Analysis
- ● All Sample Results Below Detection Limit

Notes:

MCL - Maximum Contaminant Level.

Beaumont Site 1 property boundary is approximate.

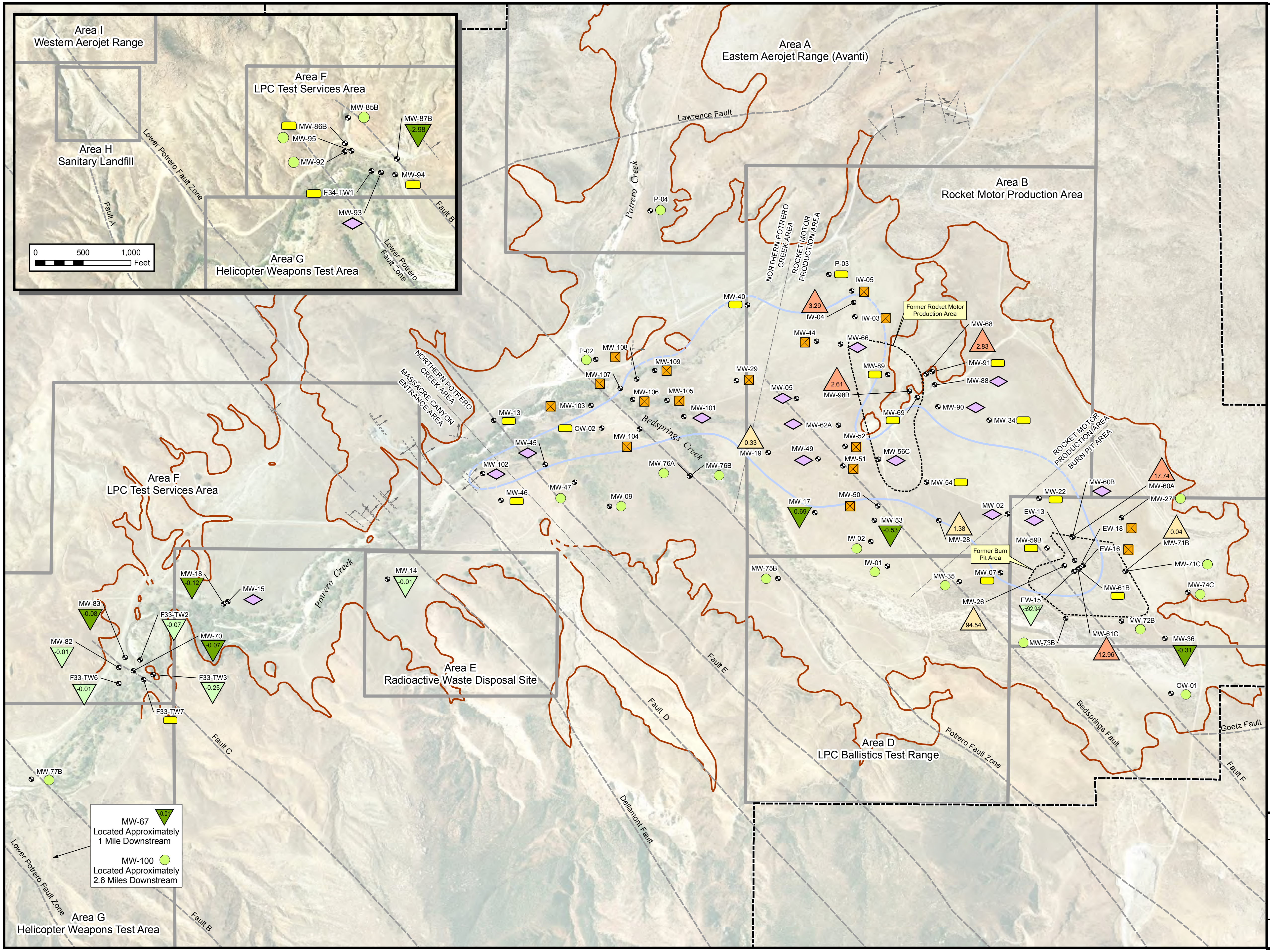
Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 4-4

Perchlorate Statistical Summary Analysis Results with Overlay Extent for Alluvium and Shallow Mount Eden Formation

TETRA TECH

X:\GIS\Lockheed S1 Q1Q2\11\Trend DCE.mxd



N

0 500 1,000 Feet

Adapted from: March 2007 aerial photograph.

Faults from structural analysis of Potrero Valley, *Lineament and Geologic Mapping Study, Tetra Tech, 2009.*

LEGEND

● Well Location

MCL Contour
Dashed where inferred

Fault, Accurately Located Showing Dip

Fault, Approximately Located

Bedrock/Alluvium Surface Contact
Dashed where inferred

Potrero Canyon Unit Property Boundary
(Lockheed Martin Beaumont Site 1)

Historical Operational Area Boundary

Analyte Trend Results

2.00 Increasing
Confidence in trend >95%
(change shown in micrograms per liter per year (µg/L/yr)

2.00 Probably Increasing
Confidence between 90 and 95%
(change shown in µg/L/yr)

-2.00 Probably Decreasing
Confidence betwee 90 and 95%
(change shown in µg/L/yr)

-2.00 Decreasing
Confidence in trend >95%
(change shown in µg/L/yr)

◆ Stable
Confidence in trend <90, coefficient of variation <1 and Mann-Kendall statistic ≤0

▬ No Trend
Confidence in trend >90% and Mann-Kendall statistic >0 or confidence in trend <90%, coefficient of variation ≥1 and Mann-Kendall statistic ≤0

☒ Insufficient Data for Statistical Analysis

● All Sample Results Below Detection Limit

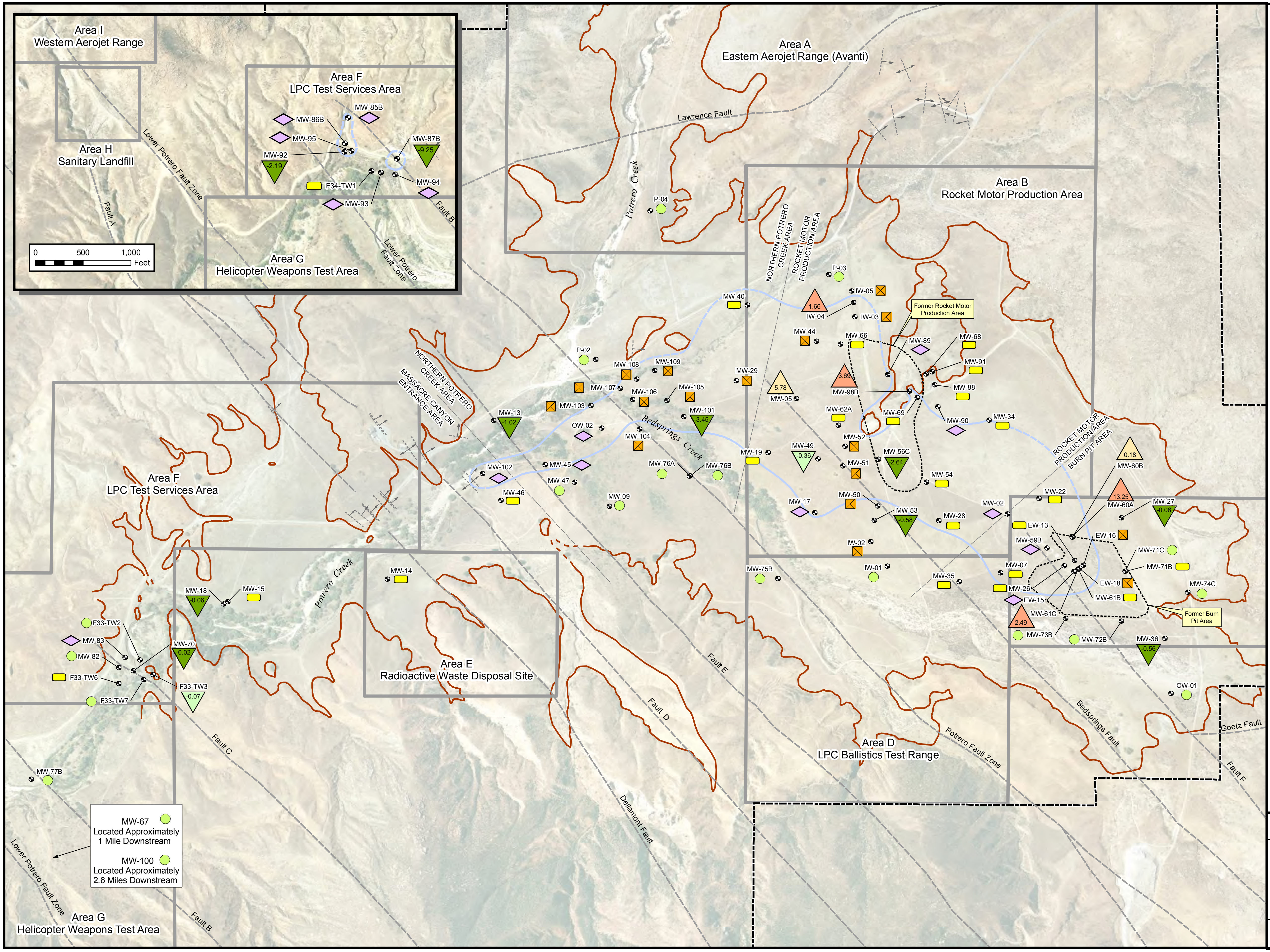
Notes:
MCL - Maximum Contaminant Level.
1,1-DCE - 1,1-Dichloroethene.
Beaumont Site 1 property boundary is approximate.

Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 4-5
1,1-DCE Statistical Summary Analysis Results with Overlay Extent for Alluvium and Shallow Mount Eden Formation

TETRA TECH

X:\GIS\Lockheed S1 Q1Q211\Trend TCE.mxd



N

0 500 1,000 Feet

Adapted from: March 2007 aerial photograph.

Faults from structural analysis of Potrero Valley, *Lineament and Geologic Mapping Study, Tetra Tech, 2009.*

LEGEND

● Well Location

MCL Contour
Dashed where inferred

Fault, Accurately Located Showing Dip

Fault, Approximately Located

Bedrock/Alluvium Surface Contact
Dashed where inferred

Potrero Canyon Unit Property Boundary
(Lockheed Martin Beaumont Site 1)

Historical Operational Area Boundary

Analyte Trend Results

▲ 2.00 Increasing
Confidence in trend >95%
(change shown in micrograms per liter per year (µg/L/yr)

△ 2.00 Probably Increasing
Confidence between 90 and 95%
(change shown in µg/L/yr)

▽ -2.00 Probably Decreasing
Confidence betwee 90 and 95%
(change shown in µg/L/yr)

▼ -2.00 Decreasing
Confidence in trend >95%
(change shown in µg/L/yr)

◆ Stable
Confidence in trend <90, coefficient of variation <1 and Mann-Kendall statistic ≤0

▬ No Trend
Confidence in trend >90% and Mann-Kendall statistic >0 or confidence in trend <90%, coefficient of variation ≥1 and Mann-Kendall statistic ≤0

☒ Insufficient Data for Statistical Analysis

● All Sample Results Below Detection Limit

Notes:
MCL - Maximum Contaminant Level.
Beaumont Site 1 property boundary is approximate.

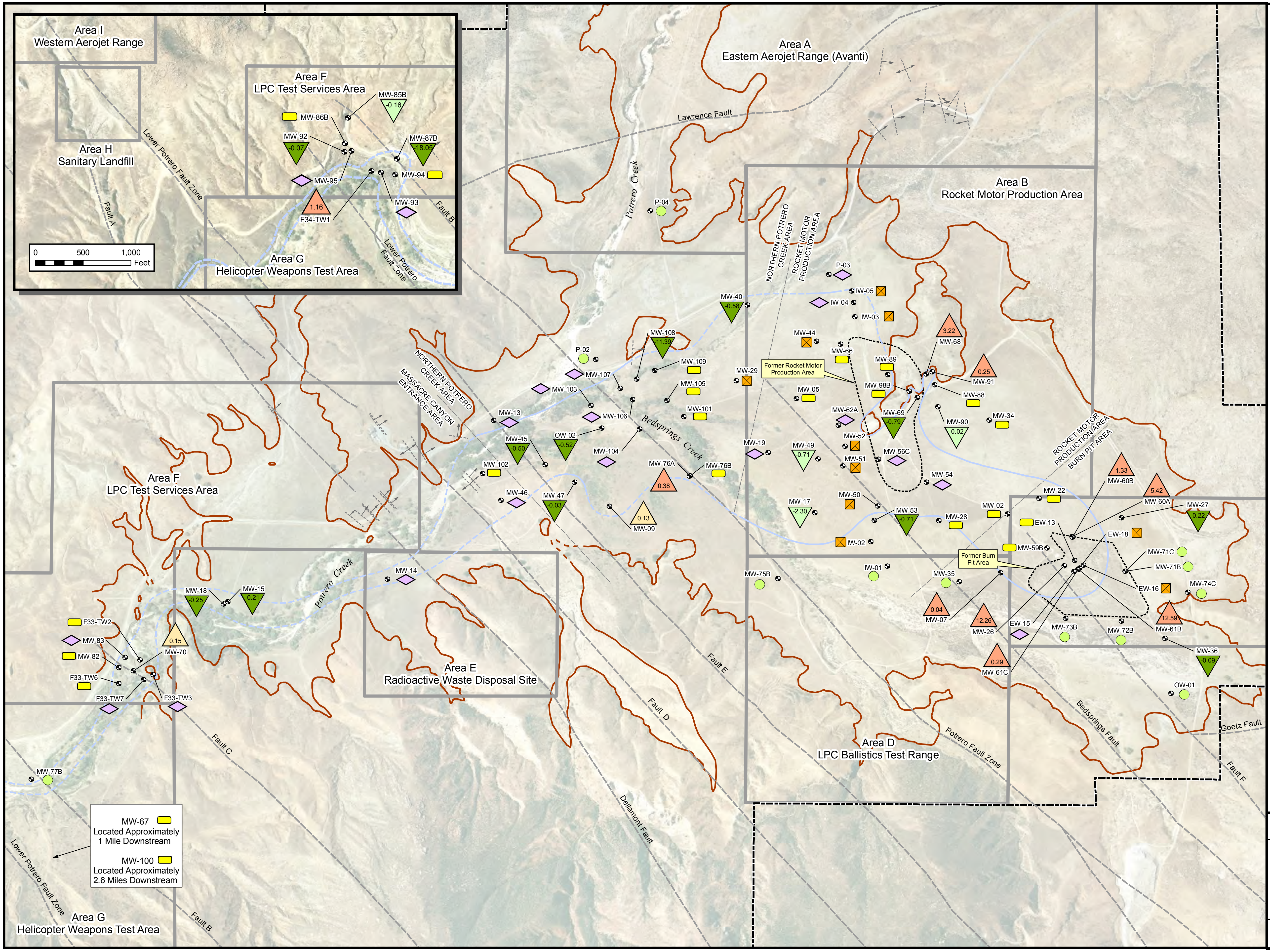
Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 4-6

TCE Statistical Summary Analysis Results with Overlay Extent for Alluvium and Shallow Mount Eden Formation

TETRA TECH

X:\GIS\Lockheed S1 Q1Q211\Trend DIOX.mxd



0 500 1,000 Feet

Adapted from: March 2007 aerial photograph.

Faults from structural analysis of Potrero Valley, *Lineament and Geologic Mapping Study, Tetra Tech, 2009.*

LEGEND

Well Location

DWNL Contour
Dashed where inferred

Fault, Accurately Located Showing Dip

Fault, Approximately Located

Bedrock/Alluvium Surface Contact
Dashed where inferred

Historical Operational Area Boundary

Potrero Canyon Unit Property Boundary
(Lockheed Martin Beaumont Site 1)

Analyte Trend Results

2.00 Increasing
Confidence in trend >95%
(change shown in micrograms per liter per year (µg/L/yr)

2.00 Probably Increasing
Confidence between 90 and 95%
(change shown in µg/L/yr)

-2.00 Probably Decreasing
Confidence betwee 90 and 95%
(change shown in µg/L/yr)

-2.00 Decreasing
Confidence in trend >95%
(change shown in µg/L/yr)

Stable
Confidence in trend <90, coefficient of variation <1 and Mann-Kendall statistic ≤0

No Trend
Confidence in trend >90% and Mann-Kendall statistic >0 or confidence in trend <90%, coefficient of variation ≥1 and Mann-Kendall statistic ≤0

☒ Insufficient Data for Statistical Analysis

● All Sample Results Below Detection Limit

Notes:

DWNL - Drinking Water Notification Level
1,1-DCE - 1,1-Dichloroethene
Beaumont Site 1 property boundary is approximate.

Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 4-7

1,4-Dioxane Statistical Summary Analysis Results with Overlay Extent for Alluvium and Shallow Mount Eden Formation

TETRA TECH

Laborde Canyon

Statistical analysis of COPC time trends (Table 4.5-2) confirms the observation that the overall extent and magnitude of the plume is relatively unchanged over limited 9 year monitoring period,. Generally, a small percentage of the wells (10 percent) have increasing trends; a small percentage of the wells (10 percent) have decreasing trends; and the greatest percentage of the wells (80 percent) have either statistically significant stable trends or no statistically significant trends. Figures showing the spatial distribution of the temporal trends (2002 to 2011) for perchlorate, TCE, and 1,4-dioxane are presented in Figures 4-8 through 4-10. A brief summary of the spatial trends by area is provided below.

Area K – Area K is one of the primary source areas for the Site COPCs. Four of the 11 wells identified with increasing trends were from monitoring wells located in this area. Of these four wells, two (TT-MW2-17S and TT-MW2-29C) are wells which have low-level detections of the increasing concentration analyte. Three of the wells in Area K had decreasing or probably decreasing trends. The remaining 22 wells located in Area K were either non-detect for all analytes or displayed no trend or a stable trend.

Area M – Area M is a secondary source area for the Site COPCs. One of the 11 wells identified with increasing trends was from a monitoring well located in this area. The remaining two wells located in Area M were either non-detect for all analytes or displayed no trend or a stable trend.

Waste Discharge Area – The former WDA is one of the primary source areas for the Site COPCs. Three of the 11 wells identified with increasing trends were from monitoring wells located in this area. Of these three wells, one (TT-MW2-21) one only has low-level detections of the increasing concentration analytes. The remaining three wells located in the former WDA were either non-detect for all analytes or displayed no trend or a stable trend.

Lower Canyon Area (Downgradient or Crossgradient of the Former Waste Discharge Area) – There are no known contaminant sources in the lower canyon area. Two of the 11 wells with increasing trends identified were from monitoring wells located in this area. Three of the wells in the lower canyon had decreasing or probably decreasing trends. The remaining 10 wells located in lower canyon were either non-detect for all analytes or displayed no trend or a stable trend.

Former Wolfskill Property – There are no known contaminant sources on the former Wolfskill Property. One of the 11 wells with increasing trends identified was from monitoring wells located in this area. One of the wells in the lower canyon had a decreasing trend. The remaining two wells

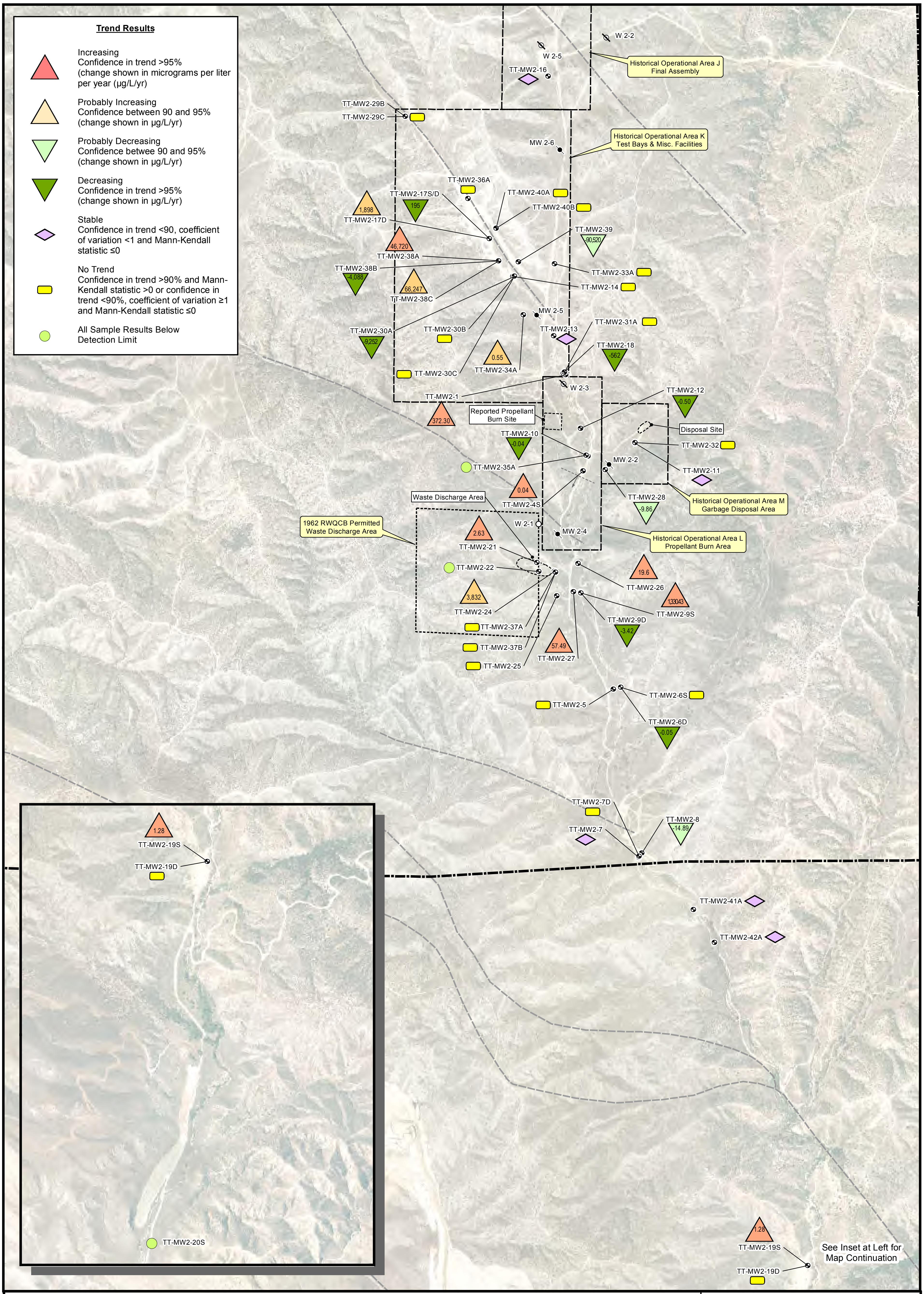
Table 4.5-2
Statistical Analysis of Groundwater Monitoring Data
LMC Beaumont Site 2
Data from May 2004 to June 2010

	Perchlorate						TCE						Methylene Chloride						1,4-Dioxane						RDX					
Well	Number of Samples	Number of Decections	Mean (µg/L)	Trend	Magnitude of Trend (%/yr)	Magnitude of Trend (µg/L/yr)	Number of Samples	Number of Decections	Mean (µg/L)	Trend	Magnitude of Trend (%/yr)	Magnitude of Trend (µg/L/yr)	Number of Samples	Number of Decections	Mean (µg/L)	Trend	Magnitude of Trend (%/yr)	Magnitude of Trend (µg/L/yr)	Number of Samples	Number of Decections	Mean (µg/L)	Trend	Magnitude of Trend (%/yr)	Magnitude of Trend (µg/L/yr)	Number of Samples	Number of Decections	Mean (µg/L)	Trend	Magnitude of Trend (%/yr)	Magnitude of Trend (µg/L/yr)
TT-MW2-1	16	16	5800	I	7.7	444.57	12	0	0.32	ND			12	2	1.90	D	-27.4	-0.52	3	0	11	ND			5	3	0.64	D	-36.5	-0.23
TT-MW2-2	12	1	0.49	S			12	0	0.32	ND			12	3	2.00	PD	-27.4	-0.55	3	0	11	ND								
TT-MW2-4S	16	4	0.83	NT			12	0	0.32	ND			12	3	1.90	PD	-25.6	-0.49	3	0	11	ND			1	0	0.20	ND		
TT-MW2-5	13	13	950	NT			9	0	0.33	ND			9	1	1.70	PD	-20.1	-0.34	5	4	0.78	NT			2	0	0.75	ND		
TT-MW2-6S	13	13	0.68	NT			8	0	0.33	ND			8	2	1.50	D	-17.7	-0.27	2	0	16	ND			1	0	0.20	ND		
TT-MW2-6D	13	4	320	S			9	0	0.33	ND			9	0	1.40	ND			2	0	16	ND								
TT-MW2-7	13	13	440	NT			9	0	0.29	ND			9	1	0.53	NT			3	0	11	ND			2	0	0.20	ND		
TT-MW2-7D	8	2	0.87	NT			7	0	0.31	ND			7	0	0.47	ND			3	0	21	ND								
TT-MW2-8	12	12	350	S			9	0	0.29	ND			9	0	0.52	ND			3	0	11	ND			2	0	0.20	ND		
TT-MW2-9S	12	12	1500	I	51.1	766.50	9	1	0.37	NT			9	0	0.52	ND			4	4	6.40	NT			1	0	0.20	ND		
TT-MW2-9D	12	6	6.30	D	-67.5	-4.25	10	0	0.29	ND			10	0	0.73	ND			2	0	16	ND								
TT-MW2-10	12	0	0.60	ND			9	0	0.29	ND			9	0	0.52	ND			1	0	31	ND			2	0	0.20	ND		
TT-MW2-11	12	12	280	NT			11	11	7.00	I	8.4	0.59	11	1	0.68	S			3	0	21	ND			2	0	0.20	ND		
TT-MW2-12	12	4	1.80	NT			9	0	0.29	ND			9	0	0.52	ND			1	0	31	ND			3	0	0.20	ND		
TT-MW2-13	12	12	3700	PD	-4.9	-182.32	10	0	0.29	ND			10	0	0.73	ND			1	0	31	ND			4	4	0.62	S		
TT-MW2-14	11	11	43000	I	2.7	1177.13	9	0	0.60	ND			9	8	120	D	-96.7	-116.07	1	0	31	ND			3	0	0.20	ND		
TT-MW2-16	10	10	3.80	S			9	0	0.29	ND			9	0	0.52	ND			1	0	31	ND			2	0	0.20	ND		
TT-MW2-17S	11	11	2800	D	-11.9	-332.15	9	1	1.20	I	10.8	0.13	9	0	0.75	ND			1	0	31	ND			1	0	0.20	ND		
TT-MW2-17D	12	12	49000	NT			9	9	0.32	NT			9	0	0.75	ND			1	0	31	ND								
TT-MW2-18	12	12	15000	D	-4.6	-684.38	9	0	0.29	ND			9	0	0.52	ND			1	0	31	ND			2	0	0.20	ND		
TT-MW2-19S	10	8	3.50	I	40.2	1.41	1	0	0.50	ND			1	0	0.50	ND			5	1	1.80	NT			1	0	0.20	ND		
TT-MW2-19D	10	2	2.30	NT															2	0	0.22	ND								
TT-MW2-20S	10	0	0.23	ND															3	0	0.18	ND			1	0	0.20	ND		
TT-MW2-20D	10	1	0.24	D	-36.5	-0.09													2	0	0.22	ND					0.00			
TT-MW2-21	8	2	1.60	I	49.3	0.79	8	5	1.30	I	58.4	0.76	8	6	2.70	I	40.2	1.08	3	0	0.20	ND			1	0	0.20	ND		
TT-MW2-22	8	0	0.62	ND			8	8	250	I	47.5	118.63	8	8	200	D	-102.2	-204.40	5	5	38	S			1	0	0.20	ND		
TT-MW2-23	8	1	0.55	S			8	0	0.31	ND			8	1	0.76	NT			3	0	21	ND			1	0	0.20	ND		
TT-MW2-24	8	8	140000	NT			8	8	94	NT			8	1	1.00	S			4	4	270	NT			2	2	5.20	N/A		
TT-MW2-25	7	1	0.46	NT			7	0	0.19	ND			7	0	0.55	ND			4	0	23	ND			1	0	0.20	ND		
TT-MW2-26	7	7	59	I	45.6	26.92	7	0	0.19	ND			7	1	0.55	NT			4	1	0.98	NT			1	0	0.20	ND		
TT-MW2-27	7	7	110	NT			7	0	0.19	ND			7	0	0.55	ND			4	0	23	ND			1	0	0.20	ND		
TT-MW2-28	6	6	24	S			6	0	0.19	ND			6	1	0.56	NT			3	0	21	ND			1	0	0.20	ND		
TT-MW2-29B	6	2	0.53	NT			6	0	0.19	ND			6	0	0.56	ND			3	0	31	ND			1	0	0.20	ND		
TT-MW2-29C	6	2	1.00	I	100.4	1.00	6	0	0.19	ND			6	1	0.56	NT			3	0	31	ND								
TT-MW2-30A	6	6	17000	S			6	0	0.19	ND			6	1	0.56	NT			3	0	31	ND								
TT-MW2-30B	6	6	4200	NT			6	0	0.19	ND			6	0	0.56	ND			3	0	31	ND								
TT-MW2-30C	6	3	27	NT			6	0	0.19	ND			6	0	0.56	ND			3	0	31	ND								
TT-MW2-31A	6	1	2.10	NT			6	0	0.19	ND			6	0	0.56	ND			3	0	31	ND								
TT-MW2-31B	6	1	39	NT			6	0	0.19	ND			6	0	0.56	ND			3	0	31	ND								
TT-MW2-32	6	1	0.54	NT			6	2	0.36	NT			6	0	0.56	ND			3	0	31	ND								
TT-MW2-33A	5	2	0.63	NT			5	0	0.20	ND			5	0	0.64	ND			3	0	31	ND			2	0	0.38	ND		
TT-MW2-33B	6	0	0.44	ND			6	0	0.19	ND			6	1	0.56	NT			3	0	31	ND			1	0	0.75	ND		
TT-MW2-33C	6	2	40	NT			6	0	0.19	ND			6	0	0.56	ND			3	0	31	ND			1	0	0.75	ND		
TT-MW2-34A	5	3	0.68	NT			5	0	0.20	ND			5	2	0.66	NT			3	0	31	ND			2	0	0.38	ND		
TT-MW2-34B	6	1	0.55	NT			6	0	0.19	ND			6	1	0.56	NT			3	0	31	ND			1	0	0.75	ND		
TT-MW2-34C	6	1	0.51	NT			6	0	0.19	ND			6	1	0.56	NT			3	0	31	ND			1	0	1.00	ND		
TT-MW2-35A	6	0	0.66	ND			6	0	0.19	ND			6	0	0.56	ND			3	0	31	ND								
TT-MW2-35B	6	0	0.44	ND			6	0	0.19	ND			6	0	0.56	ND			3	0	31	ND								
TT-MW2-36A	6	3	1.80	NT			6	0	0.19	ND			6	1	0.56	NT			3	0	31	ND			1	0	0.20	ND		
TT-MW2-36B	6	2	1.30	NT			6	0	0.19	ND			6	0	0.56	ND			3	0	31	ND								
TT-MW2-36C	6	4	0.73	NT			6	0	0.19	ND			6	0	0.56	ND			3	0	31	ND								
TT-MW2-37A	6	6	2400	PI	109.5	2628.00	6	3	0.69	NT			6	1	0.56	NT			4	4	7.00	NT								
TT-MW2-37B	6	3	24	NT			6	0	0.19	ND			6	1	0.57	NT			4	0	23	ND								
TT-MW2-38A	6	6	130000	NT			6	0	0.19	ND			6	0	0.56	ND			3	0	31	ND			1	0	0.20	ND		
TT-MW2-38B	6	6	19000	D	-23.7	-4507.75	6	0	0.19	ND			6	0	0.56	ND			3	0	31	ND								
TT-MW2-38C	6	6	11000	NT			6	0	0.19	ND			6	1	0.56	NT			3	0	31	ND								
TT-MW2-39	6	6	94000	S			6	0	0.19	ND			6	2	0.56	NT			3	0	31	ND			1	0	0.20	ND		
TT-MW2-40A	6	0	0.44	ND			6	0	0.19	ND			6	1	0.56	NT			3	0	31	ND								
TT-MW2-40B	6	3	1.90	NT			6	0	0.19	ND			6	0	0.56	ND			3	0	31	ND								
TT-MW2-40C	6	3	3.90	NT			6	0	0.19	ND			6	1	0.56	NT			3	0	31	ND								
TT-MW2-41A	4	1	0.10	S			1	0	0.17	ND			1	0	0.15	ND			2	0	0.10	ND								
TT-MW2-41B	1	1	0.11	N/A																										
TT-MW2-42A	4	1	0.10	S			1	0	0.17	ND			1	0	0.15	ND			2	0	0.10	ND								
TT-MW2-42B	1	1	0.10	N/A																										

Notes:

Trend Categories and Definitions	Perchlorate (# wells)	% Total	TCE (# wells)	% Total	Methylene Chloride (# wells)	% Total	1,4-Dioxane (# wells)	% Total	RDX (# wells)	% Total
"N/A"-Insufficient Data(< 4 sampling events)	2		0		0		0		1	
Blank-No data	0		5		5		2		29	
"ND" - Non Detect	7	11	50	85	32	54	55	89	32	94
"NT" - No Trend	31	50	5	8	17	29	6	10	0	0
"S" - Stable	10	16	0	0	2	3	1	2	1	3
"I" - Increasing	7	11	4	7	1	2	0	0	0	0
"PI" -Probably Increasing	1	2	0	0	0	0	0	0	0	0
"D" - Decreasing	5	8	0	0	4	7	0	0	1	3
"PD" -Probably Decreasing	1	2	0	0	3	5	0	0	0	0
	62	100	59	100	59	100	62	100	34	100

Path: X:\GIS\Lockheed S2 Q2Q311\Trend_Perc.mxd



LEGEND

- Monitoring Well Location
- Destroyed Production Well Location
- Destroyed Monitoring Well Location
- Reported Production Well Location
- Fault, Accurately Located Showing Dip
- Fault, Approximately Located
- RWQCB Permitted Waste Discharge Area
- Historical Operational Area Boundary
- Beaumont Site 2 Property Boundary

Adapted from:

April 2007 aerial photograph.

Faults from the *Site 2 Lineament Study, Tetra Tech, 2009.*

Note:

Beaumont Site 2 property boundary from Hillwig-Goodrow survey, May 2004.

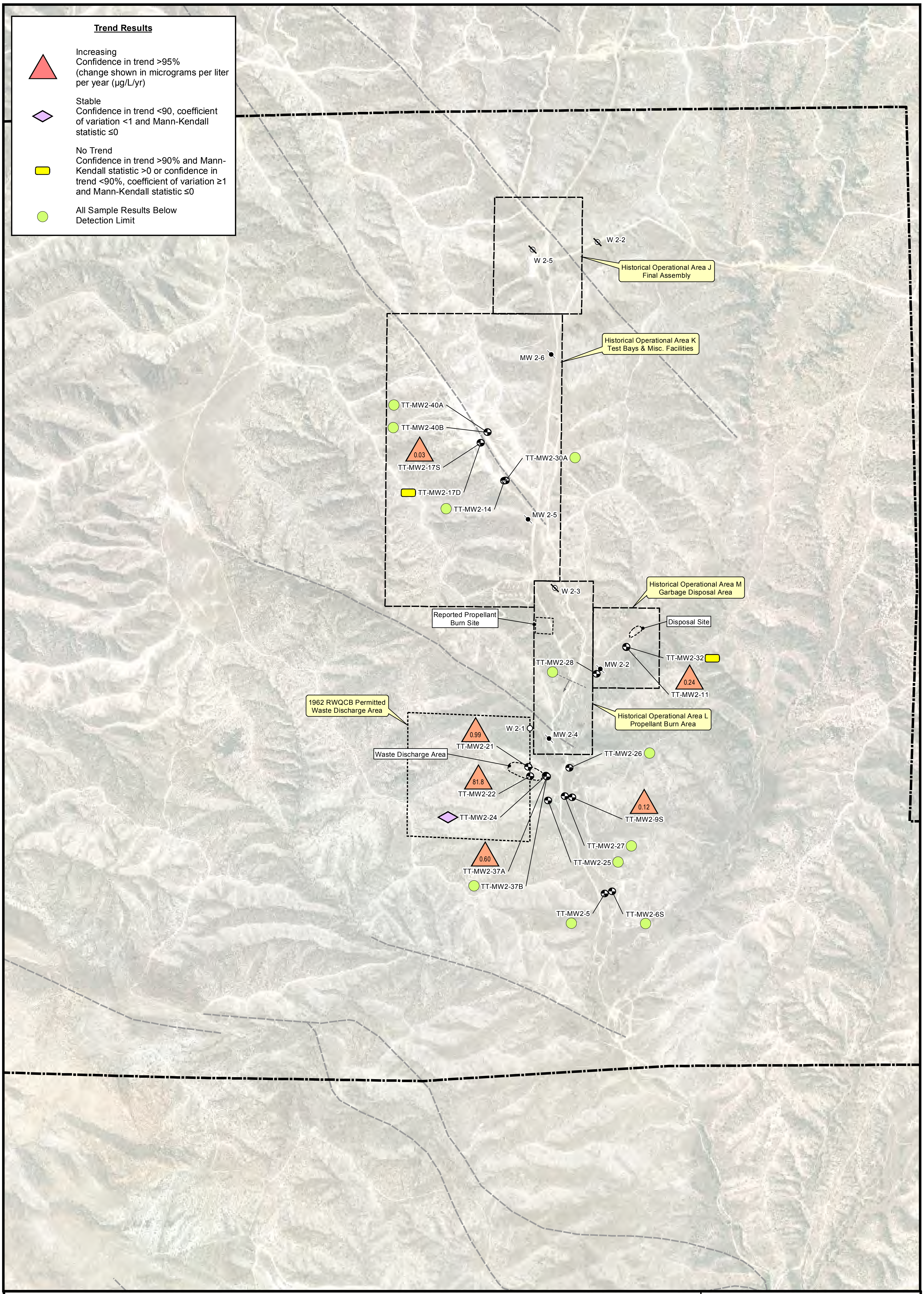
0 500 1,000 Feet

Laborde Canyon
(Lockheed Martin Beaumont Site 2)

Figure 4-8

Perchlorate Statistical Analysis Summary Results

Path: X:\GIS\Lockheed S2 Q2Q311\Trend_TCE.mxd



LEGEND

- Monitoring Well Location
- Destroyed Production Well Location
- Destroyed Monitoring Well Location
- Reported Production Well Location
- Fault, Accurately Located Showing Dip
- Fault, Approximately Located
- RWQCB Permitted Waste Discharge Area
- Historical Operational Area Boundary
- Beaumont Site 2 Property Boundary

Adapted from:

April 2007 aerial photograph.

Faults from the, *Site 2 Lineament Study, Tetra Tech, 2009.*

Note:

Beaumont Site 2 property boundary from Hillwig-Goodrow survey, May 2004.

0 500 1,000
Feet

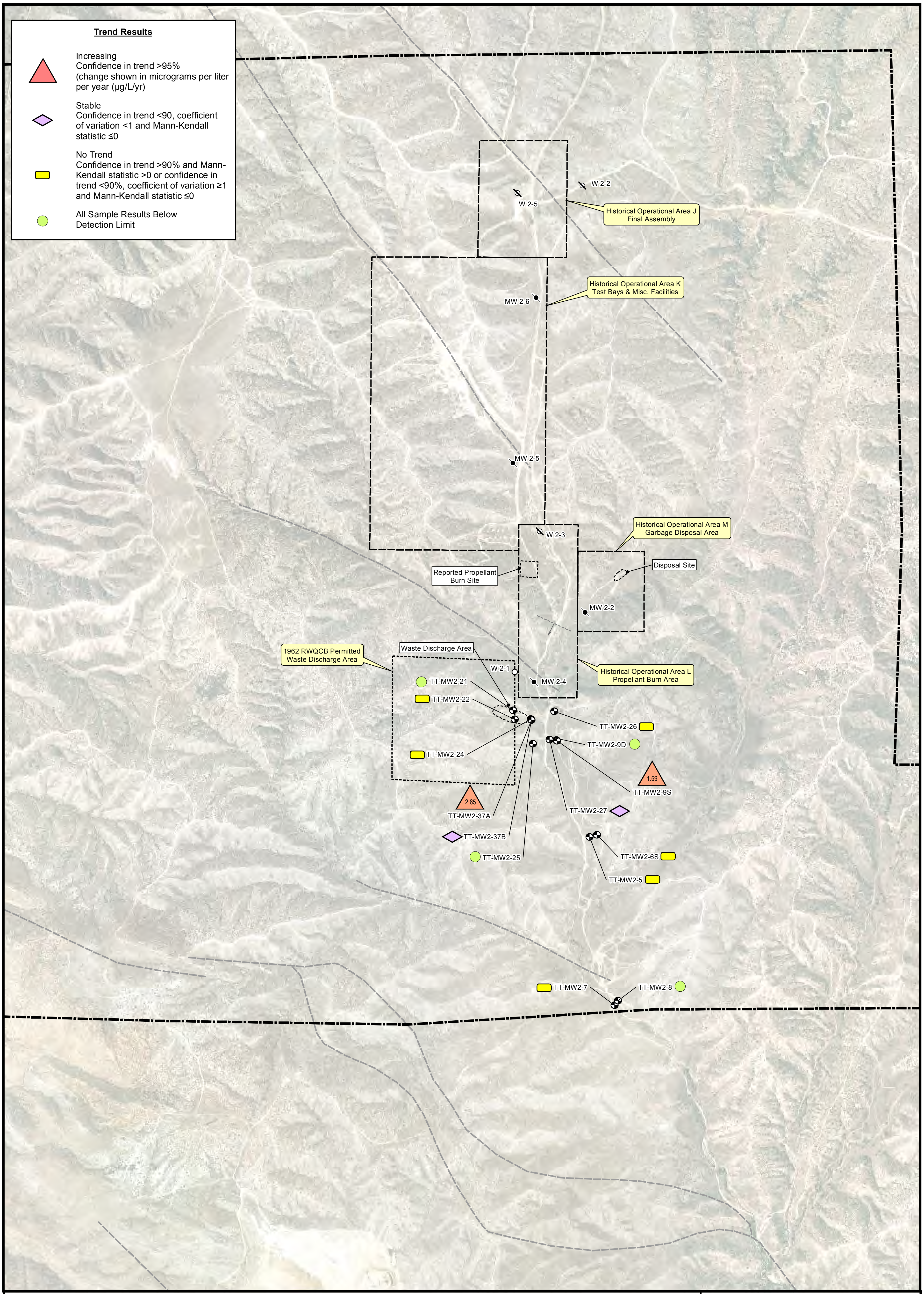
N

Laborde Canyon
(Lockheed Martin Beaumont Site 2)

Figure 4-9

TCE Statistical Analysis Summary Results

Path: X:\GIS\Lockheed S2 Q2Q311\Trend_Diox.mxd



LEGEND

⊕	Monitoring Well Location	⬚	RWQCB Permitted Waste Discharge Area
⊘	Destroyed Production Well Location	⬚	Historical Operational Area Boundary
•	Destroyed Monitoring Well Location	⬚	Beaumont Site 2 Property Boundary
○	Reported Production Well Location		
↗	Fault, Accurately Located Showing Dip		
╱	Fault, Approximately Located		

Adapted from:

April 2007 aerial photograph.

Faults from the, *Site 2 Lineament Study, Tetra Tech, 2009.*

Note:

Beaumont Site 2 property boundary from Hillwig-Goodrow survey, May 2004.

0 500 1,000
Feet

N

Laborde Canyon
(Lockheed Martin Beaumont Site 2)

Figure 4-10

1,4-Dioxane Statistical Analysis Summary Results

located in the lower canyon were either non-detect for all samples analyzed or displayed either no trend or a stable trend.

The relatively short time frame represented by the data analyzed, (half of the wells have less than two years of data), makes it difficult to interpret the observed trends, which could represent plume migration or seasonal fluctuations in concentration due to the continuing drought conditions experienced at the site. As the period of record grows, and the number of data points increases, the trends should become better defined and more reliable long term trends should emerge from the data. In general, the plume morphology has not changed and the majority of the wells and the surface water locations display a stable trend, no trend, or are non-detect.

4.6 SPATIAL TRENDS IN SOIL TOC VALUES

Potrero Canyon Unit

Potrero Canyon Unit Soil TOC data are available from the five soil borings installed in this study (SB-1 through SB-5) and two monitoring wells installed in 2009 (MW-101 and MW-102). These data are plotted versus depth and horizontal location in Figures 4-11 and 4-12, respectively. The plot of TOC data versus depth in Figure 4-8 show an apparent trend, with soil TOC values decreasing with depth. A decrease in soil TOC values with depth is in agreement with the site lithologic data, which show more fine-grained units in the shallow aquifer and more sandy units in the deeper aquifer. Statistical analysis of the data for all the boring and monitoring well locations in Figure 4-11 indicate the correlation between soil TOC concentrations and depth have a mean log slope of -0.039 log cycle per foot with a 95 percent confidence interval on the slope of ± 0.02 log cycle per foot. Thus, the range in slope values is -0.019 to -0.0059 log cycle per foot, indicating there is a decrease in concentration versus depth for the entire range of slope values. Statistical analysis of the data for each of the individual boring and monitoring well locations generally shows a similar decreasing trend in TOC concentration versus depth, where the 95 percent confidence interval on the slope was significantly less than the magnitude of the mean slope, such that the range in slope values is always negative. One notable exception, however, was the data for SB-1, where the confidence intervals for the slope values extended over positive and negative slope ranges and the trend between TOC concentrations and depth is ambiguous.

Figure 4-11 Trends in Site 1 Soil TOC values versus depth

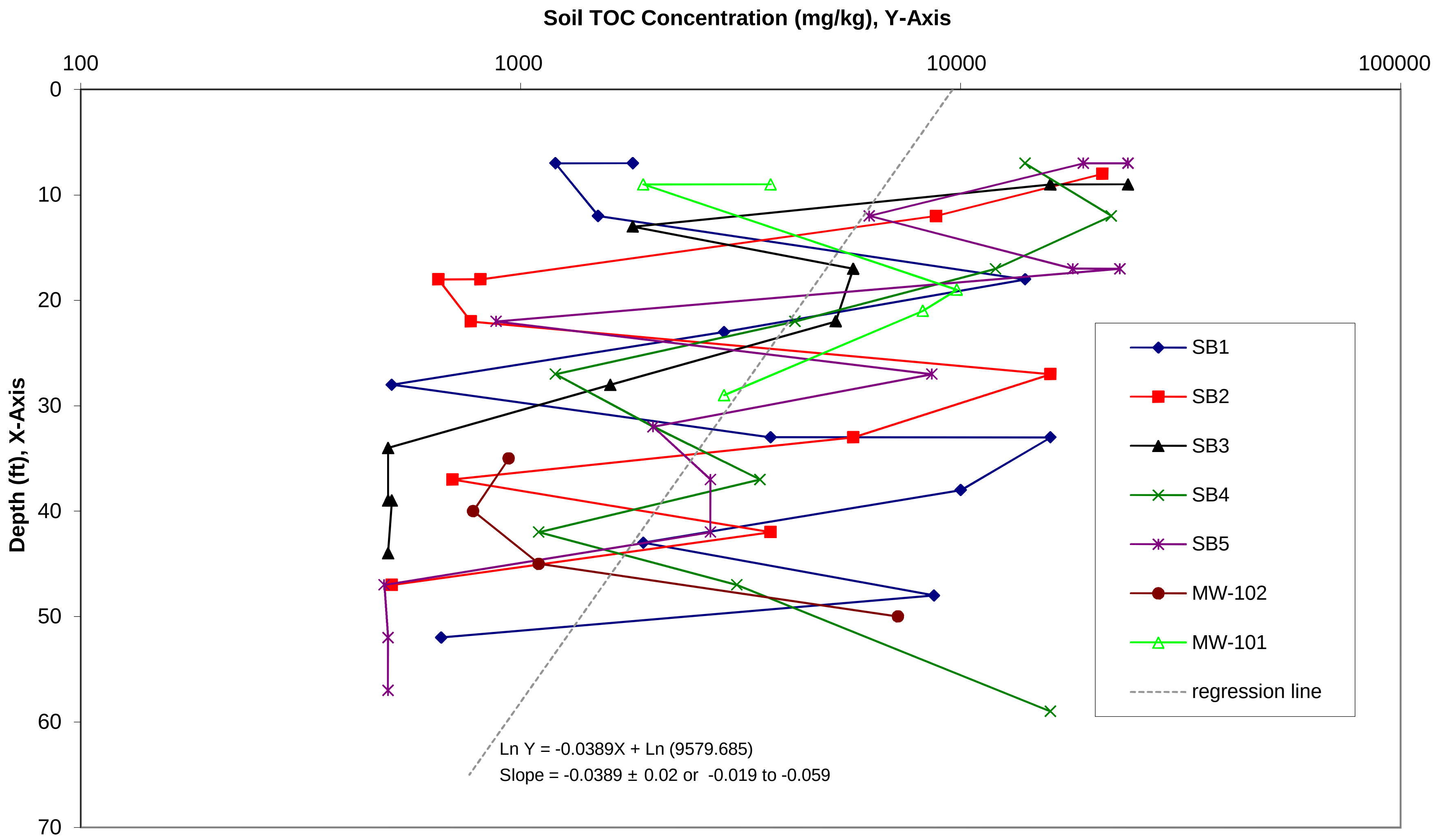
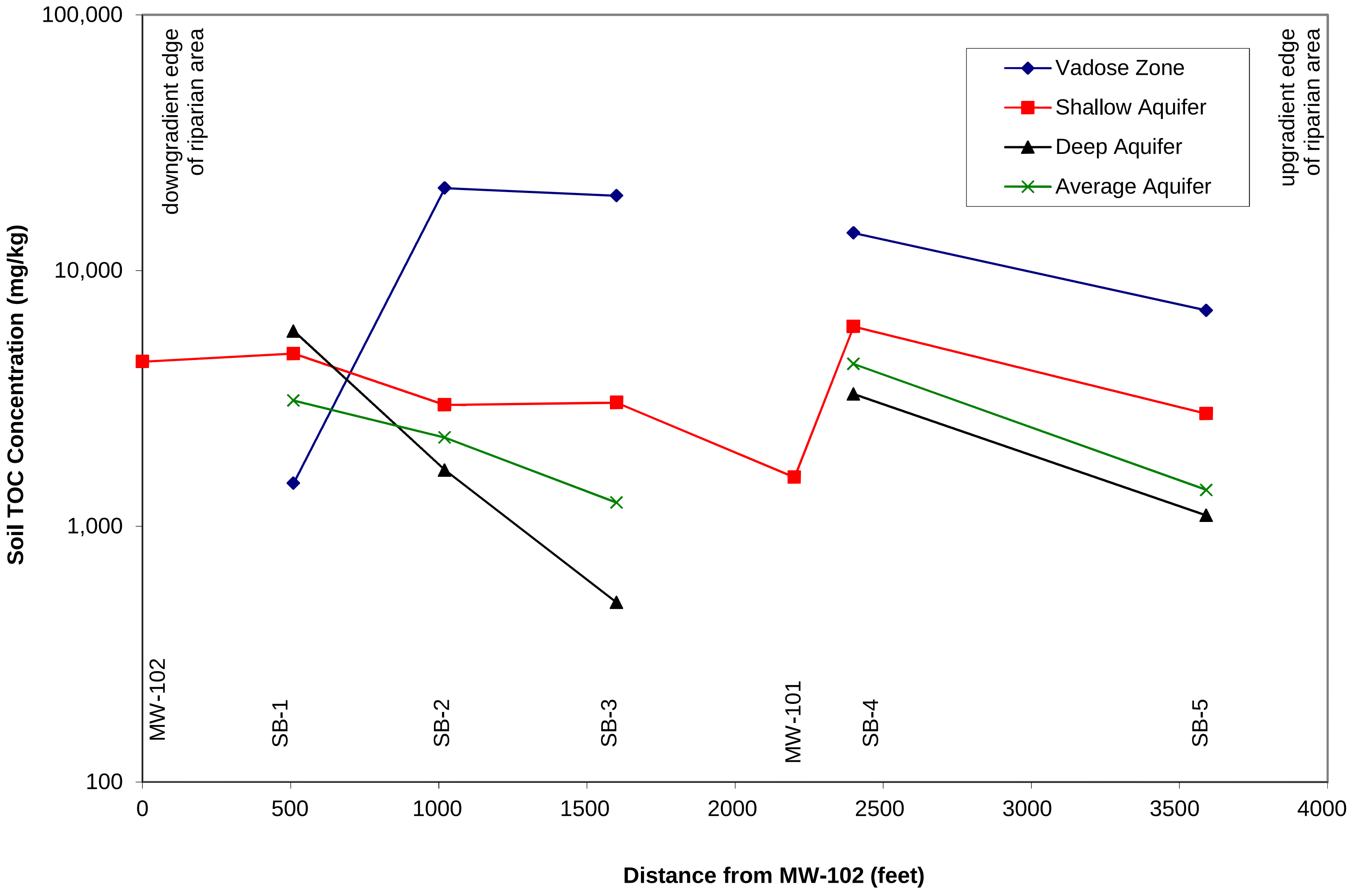


Figure 4-12 Trends in Soil TOC values along Site 1 borings



The site water level data and hydrostratigraphic model were used to group boring and monitoring well data vertically into vadose zone, shallow aquifer (less than 30 feet), and deep aquifer (greater than 30 feet) sample groups, and the data for these groups were averaged and plotted versus horizontal distance in Figure 4-12. The data for the aquifer groups show no obvious trend versus location, with average values varying somewhat randomly along the boring and monitoring well locations. Statistical analysis of these aquifer data also shows no apparent statistically significant log-linear soil TOC concentration trend versus distance. The data for the vadose zone, shallow aquifer, and deep aquifer groups show the general trend for decreasing soil TOC concentrations with depth, with the aforementioned exception at boring SB-1. The vadose zone TOC values suggest there is a possible trend where TOC values may be higher in the middle of the riparian area than at the locations towards the edge of the riparian area.

Based upon the site TOC data in Figures 4-11 and 4-12, the average TOC value for the soils between the MW-102 and SB-5 locations is approximately 11,600 mg/kg for the vadose zone; 2,950 mg/kg for the shallow aquifer; and 1,800 mg/kg for the deep aquifer. Average values for the entire aquifer zone are 2,330 mg/kg, and average values for the samples in both the saturated and unsaturated zone are 3,140 mg/kg. The soil TOC data and estimates of the aquifer and vadose zone soil bulk volume from the Potrero Canyon Unit MODFLOW model are used to calculate the amount of organic carbon present within the soil solid phase (Table 4.6-1). These calculations indicate there is approximately 45 million pounds of organic carbon present in the soil solid phase of the aquifer within the Bedsprings Creek riparian area, with another 19 million pounds of organic carbon present in the vadose zone within the Bedsprings Creek riparian area. Another 227 million pounds of organic carbon may be present in other areas of Bedsprings Creek and in Middle and Lower Potrero Creek, however, this organic carbon pool lies outside the Bedsprings Creek riparian area where site geochemical data suggest COPC degradation is likely occurring. However, it is unknown exactly what percentage of this very large pool of carbon is available to support degradation.

Laborde Canyon

Laborde Canyon Soil TOC data are available from three soil borings installed in this study (K54-SB-144, SBA-SB-104, and WDA-SB-104). These data are plotted versus depth and location in Figures 4-13 and 4-14, respectively. The plot of TOC data versus depth in Figure 4-13 show an apparent trend versus depth, with soil TOC values decreasing with depth. Statistical analysis of the data in Figure 4-13 indicate the correlation between soil TOC concentrations and depth have a mean log slope of -0.016 log cycle per foot with a 95 percent confidence interval on the slope of ± 0.015 log cycle per foot. Thus, the range in slope values is -0.001 to -0.031 log cycle per foot, indicating there is a decrease in concentration versus depth for the entire range of slope values.

Table 4.6-1 Organic Carbon Concentration and Mass, Beaumont Potrero Canyon Unit

Soil Zone	Bulk Volume (acre-ft)	Bulk Density (lb-ft^3)	Average Organic Carbon Concentration (mg/kg)	Organic Carbon Mass (million lbs)
Bedsprings Creek Riparian Area				
Vadose Zone	366	100.1	11,600	19
Shallow Aquifer	2,326	100.1	2,950	30
Deep Aquifer	1,792	104.2	1,800	15
Total Aquifer				45
Total Vadose Zone and Aquifer				63
Remaining Areas of Bedsprings Creek and Middle and Lower Potrero Creek				
Vadose Zone	17,964	100.1	940	74
Shallow Aquifer	22,271	100.1	940	91
Deep Aquifer	14,589	104.2	940	62
Total Aquifer				154
Total Vadose Zone and Aquifer				227

The data for these three locations were averaged and plotted in Figure 4-14, showing there is very little difference in TOC values versus location. Based upon the site TOC data in Figures 4-13 and 4-14, the average TOC value for the soils is approximately 1,000 mg/kg. The average soil TOC value of 1,000 mg/kg and estimates of the soil bulk volume from the Laborde Canyon MODFLOW model are used to calculate the amount of organic carbon present within the soil solid phase (Table 4.6-2). These calculations indicate there is approximately 14 million pounds of organic carbon present in the soil solid phase of the aquifer. It is unknown what percentage of the organic carbon present is available to support degradation.

Table 4.6-2 Organic Carbon Concentration and Mass, Beaumont Laborde Canyon

Soil Zone	Bulk Volume (acre-ft)	Bulk Density (lb-ft^3)	Average Organic Carbon Concentration (mg/kg)	Organic Carbon Mass (million lbs)
Aquifer	3,225	100	1,000	14

Figure 4-13 Trends in Site 2 Soil TOC values versus depth

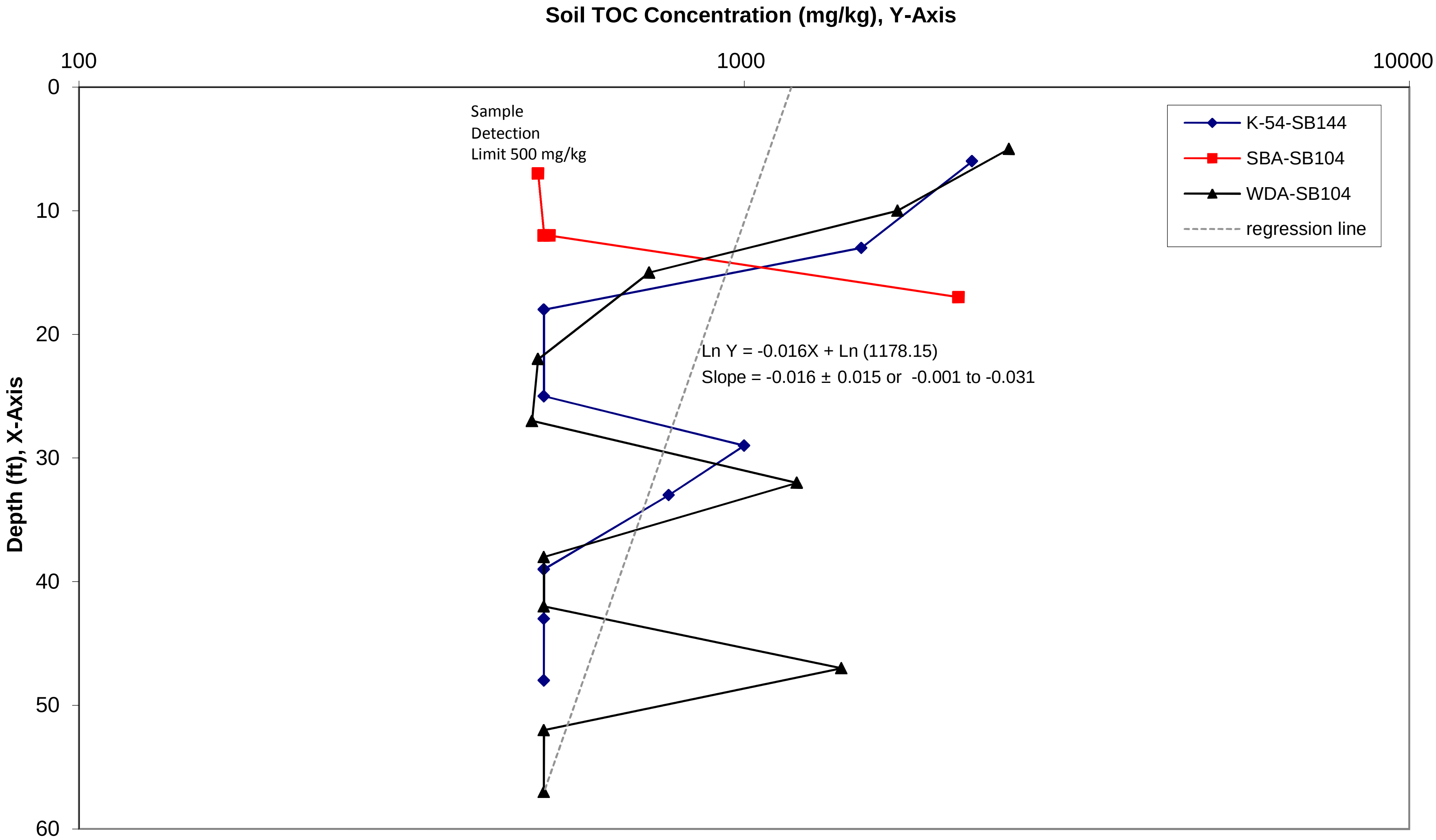
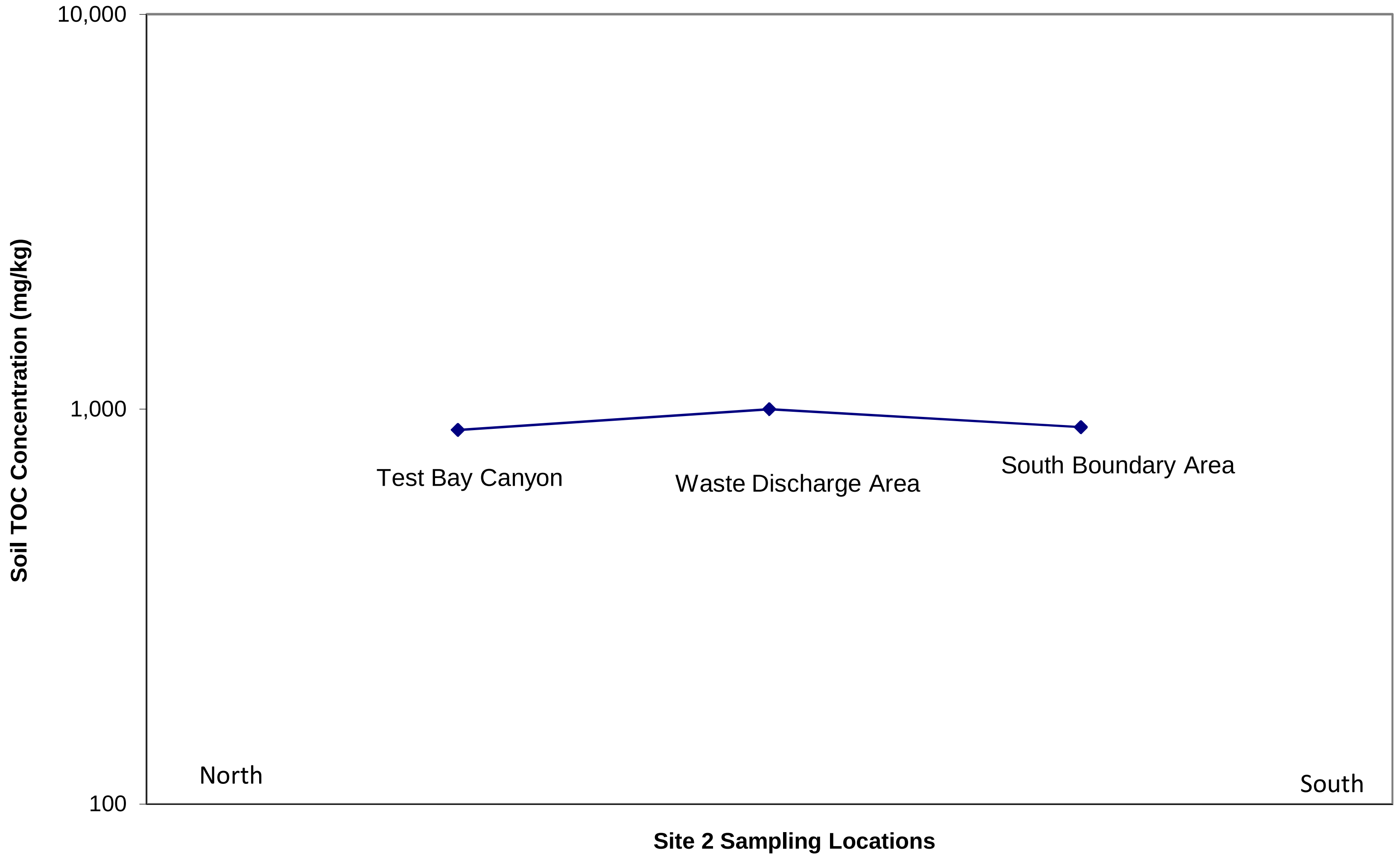


Figure 4-14 Trends in Site 2 Soil TOC values by area



4.7 SPATIAL TRENDS IN NEW GROUNDWATER COPC AND CONTAMINANT ATTENUATION DATA

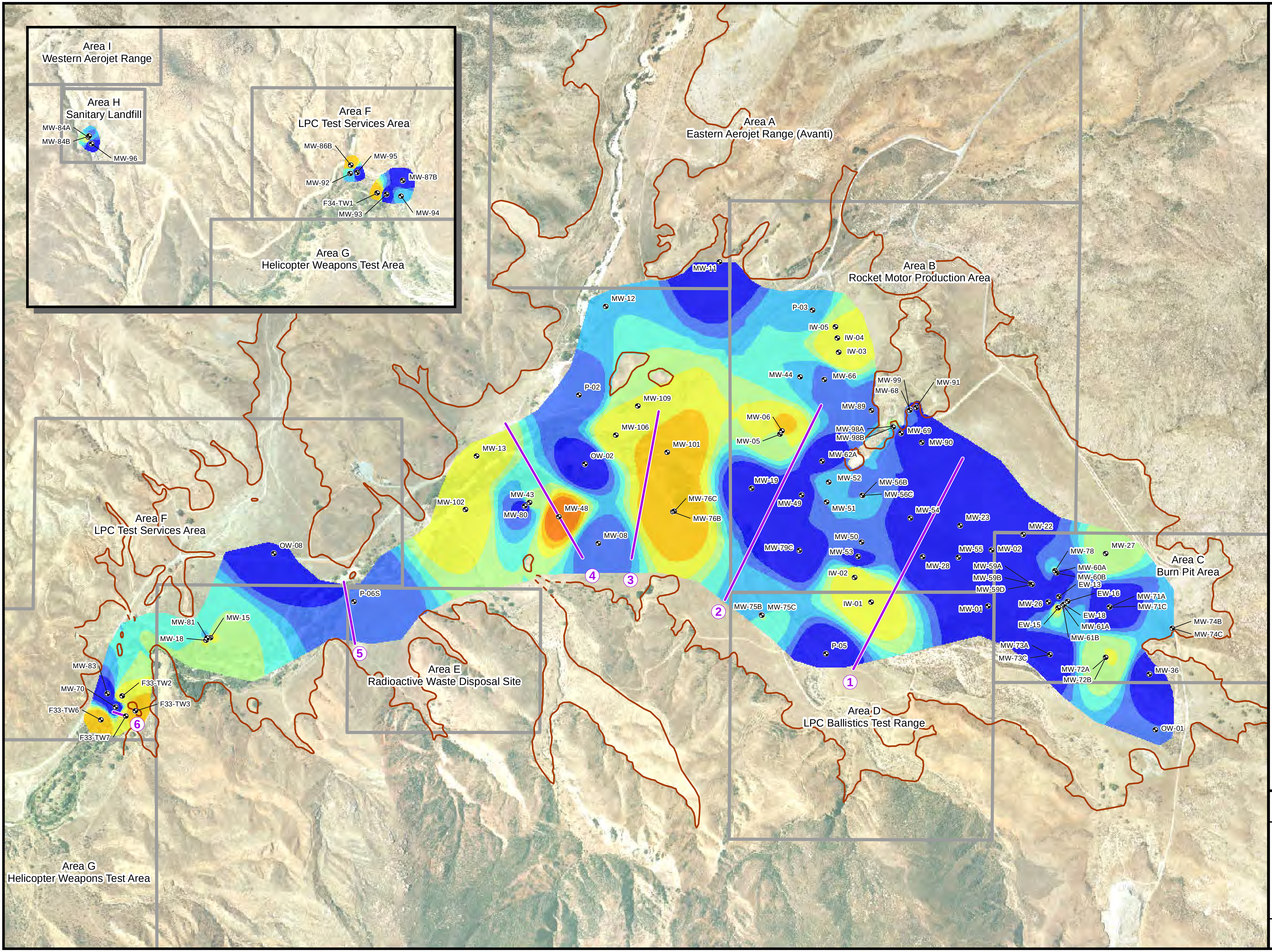
Potrero Canyon Unit

For the Potrero Canyon Unit COPCs (perchlorate, 1,4-dioxane, TCE, and DCE), the new data collected in this study generally matches the spatial trends depicted in Appendix A of the technical memorandum that outlined the recommended focused data collection (Tetra Tech, 2010f). There are some minor deviations in the new data, mostly for perchlorate at the plant uptake wells and at the former RMPA injection wells IW-01 and IW-02. This is attributed to these locations not previously being sampled and therefore no data was available in either of these areas. However, the variations in the new data are within the overall spatial trends previously depicted and are consistent with the existing plume morphology.

For the Potrero Canyon Unit contaminant attenuation parameters (DO, nitrate, manganese, iron, sulfate, methane, and TOC), new data was collected in this study from wells not previously sampled in the following five locations: the BPA; the former RMPA injection wells; crossgradient of the former RMPA extraction well EW-01 (wells MW-50, MW-51, and MW-52); within the riparian zone near the plant uptake study area; and at the Large Motor Washout Area. The new contaminant attenuation data gives a more detailed picture of the spatial trends in these areas, as reflected in the updated redox conditions plotted in Figure 4-15. The new contaminant attenuation parameter data generally adheres to the same large scale spatial trends as the prior less detailed sampling (Figure 7 of Tetra Tech, 2010f), with important deviations from the prior sampling results discussed below.

- BPA – The new contaminant attenuation data in the BPA confirms the prior trends observed in well EW-15, and generally extends these trends to the other BPA extraction wells sampled in this event. This includes low DO concentrations, low nitrate concentrations, elevated manganese concentrations, elevated iron concentrations, normal sulfate concentrations, and low methane concentrations. This is generally consistent with iron reducing conditions. The large perchlorate concentrations present in the BPA extraction wells also confirms that redox conditions do not go strongly below the iron redox level to sulfate reducing or methanogenic conditions. The net result is that the manganese to iron reducing redox conditions previously depicted at a 0.1 acre area around well EW-15 now extends to an area of approximately 0.5 areas covering most all the BPA extraction wells (Figure 4-8). However, since the solvents in groundwater in this area do

X:\GIS\Lockheed 25421-01-0603REDOX.mxd



LEGEND

- Monitoring Well Location
- ① Line Segment Used to Determine Underflow Rate
- Bedrock/Alluvium Surface Contact
  Dashed where inferred
- Historical Operational Area Boundary

Redox Values

Increasingly Reduced

- 🟥 Methanogenesis
- 🟧 Fe(II)/SO4 Reduction
- 🟧 Fe(II) Reduction
- 🟨 Mn(IV) Reduction
- 🟩 Mixed NO3-Fe(II)-SO4 Reduction
- 🟦 NO3 Reduction

Mixed

- 🟦 O2-Fe(II)/SO4
- 🟦 O2-Fe(II)

Oxic

- 🟦 O2

Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 4-15

Redox Conditions for Alluvium and Shallow Mount Eden Wells Second Quarter 2010/2011

TETRA TECH

not experience strong sulfate reducing or methanogenic conditions, there is only a limited amount of the solvent daughter products cis 1,2-DCE and vinyl chloride present. The new data also helps confirm a vertical trend in redox conditions, with the deeper locations of the aquifer as sampled in well MW-61B being higher in redox conditions than the shallower part of the aquifer. For DOC, the high value of 9.3 mg/l previously observed for EW-15 was found to be isolated to this well, as the other BPA wells sampled generally show DOC values in the range of 1 to 3 mg/l, which is about 1 to 2 mg/l above the typical DOC concentrations for the site in this area. The slightly higher DOC values in the BPA extraction wells may be attributed to the high solvent concentrations in the BPA extraction wells, since solvents represent a component of DOC.

- Former RMPA injection wells – The new contaminant attenuation data in the RMPA injection wells confirms the prior trends observed in sampling well IW-4 located on the northeast edge of the site plume, and generally extends these trends to the other injection wells sampled in this event, including IW-01 and IW-02 located on the southwest edge of the site plume. This includes low DO concentrations, low nitrate concentrations, elevated manganese concentrations, highly elevated iron concentrations, depressed sulfate concentrations, and high methane concentrations at two locations (IW-02 and IW-04). The net result is that the low redox conditions previously depicted at a 1 acre area around well IW-04 now extends to an area of approximately 2.5 areas covering the northeast plume injection wells IW-03, IW-04, and IW-05, and a new low redox area is also added that covers an area of approximately 5 areas at the southwest plume injection wells IW-01and IW-02 (see Figure 4-8; This redox trend around injection wells IW-01and IW-02 was speculated based upon the prior IW-04 sampling results, and confirmed with the new samples). Since the solvents in the northeast injection area experience sulfate reducing to methanogenic conditions, there are low levels of the solvent daughter products cis 1,2-DCE and vinyl chloride present in IW-03, IW-04, and IW-05; no solvent daughter products are found in the southwest plume injection wells IW-01 and IW-02, which is attributed to a lack of solvents in these wells. For DOC, the wells sampled generally show DOC values in the range of 1 to 4 mg/l, which is slightly above the typical concentrations for the site in this area.

- RMPA Wells MW-50, MW-51, and MW-52 – The new contaminant attenuation data adds detail to fill in the transition from higher to lower redox trends that was observed upgradient and downgradient of this area in prior sampling, with wells MW-50, MW-51, and MW-52 showing mixed oxic-anoxic redox conditions. In general, DO and nitrate concentrations are rather high in wells MW-50, MW-51, and MW-52, but manganese and iron are both present above background conditions; hence the mixed oxic-anoxic redox conditions (Figure 4-8). Based on the previous data collected, the area immediately upgradient (southeast) and downgradient (northwest) of wells MW-50, MW-51, and MW-52 is oxic, and the area cross-gradient (northeast) of wells MW-50, MW-51, and MW-52 near the former RMPA extraction well EW-01 is anoxic. Thus, the mixed oxic-anoxic redox conditions at MW-50, MW-51, and MW-52 is most likely associated with the anoxic conditions near EW-01, as opposed to the naturally occurring transition from oxic conditions in upgradient recharge areas to reducing conditions in downgradient discharge areas. For DOC, the wells sampled generally show DOC values in the range of 1 to 2 mg/l, which is typical for the site in this area.

- Riparian Area – The new contaminant attenuation data in the Riparian Area is generally consistent with the lower redox trends observed in the previous sampling, with new detail in the plant uptake study area which was previously lacking data. In general, DO and nitrate concentrations are low in the riparian area, and manganese and iron are both present above background conditions; hence redox conditions are iron to sulfate reducing (Figure 4-8) with perchlorate reduction occurring. However, data for new wells MW-106 and MW-109 in the plant uptake study area show slightly higher redox levels (manganese reducing) than redox levels from the prior data in nearby well MW-101 (iron to sulfate reducing). These higher redox conditions in MW-106 and MW-109 may be the cause of the perchlorate concentrations in MW-106 and MW-109, which was not detected in MW-101. Thus, perchlorate reduction in the MW-106 and 109 area may not be occurring to the extent it is in MW-101 and other nearby wells, perhaps delineating a pathway for perchlorate through the riparian area. At other locations in the riparian area such as at well pair MW-43 and MW-45, and well OW-02, the reducing conditions in the shallow aquifer are disrupted by the upward flow of oxic, artesian groundwater from the deep aquifer. While this same mechanism may be causing the reducing conditions in the shallow aquifer at MW-106 and MW-109, there are no deep wells installed in the MW-106 and MW-109 area to confirm or refute this hypothesis; the lack of a deep aquifer well in this area is a possible data gap for future investigations. For DOC, the wells sampled generally show

DOC values in the range of 0.5 to 4 mg/l, which is slightly higher than that previously reported for wells in this area.

- **Large Motor Washout Area (Feature F-33)** – The new contaminant attenuation data in the Large Motor Washout Area is generally consistent with the lower redox trends observed in the previous sampling. The new contaminant attenuation data also finds oxic conditions are present in well MW-70 in addition to the oxic condition previously reported for MW-83. In general in the Large Motor Washout Area, DO and nitrate concentrations are low, and manganese and iron are both present above background conditions; hence redox conditions are iron to sulfate reducing (Figure 4-8). However, data for the wells MW-83 and MW-70 show high redox levels (oxic), and this may be the cause of the perchlorate concentrations in MW-70 (MW-83 did not detect perchlorate, but is located on the perimeter of the site). Thus, perchlorate reduction in the MW-70 area may not be occurring, or it may only be occurring seasonally. For DOC, the wells sampled generally show DOC values in the range of 2 to 4 mg/l, which is similar to that previously reported for wells in this area.

For the Potrero Canyon Unit solvent daughter products cis-1,2-DCE and vinyl chloride, new data was collected within the riparian area near the new plant uptake wells. The new cis-1,2-DCE and vinyl chloride data in the plant uptake wells shows cis 1,2-DCE occurring over a larger area than previously reported, and vinyl chloride at quite high values in well MW-109. However, the deviations reported in the cis-1,2-DCE and vinyl chloride data from the new plant uptake wells are not outside the range of expected variations based upon past sampling events.

Laborde Canyon

For Laborde Canyon, new groundwater contaminant attenuation data was not collected in this study, as the field program was limited to additional soil sampling for TOC; groundwater sampling for quantitative perchlorate reductase assays; and the plant density survey.

SECTION 5 UPDATED CONTAMINANT ATTENUATION CONCEPTUAL SITE MODEL

Sections 5.1 and 5.2 present the updated contaminant attenuation CSMs for Potrero Canyon Unit and Laborde Canyon, respectively. The conceptual models were developed based upon modeling guidance given in ASTM reports (ASTM D 5447-93; ASTM D 5609-94; ASTM D 5490-93; ASTM D 6170-97e, ASTM D 5891), US EPA guidance on natural attenuation (US EPA, 1998 and 2007), and groundwater modeling guides (Anderson and Woessner, 1992).

5.1 POTRERO CANYON UNIT CONTAMINANT ATTENUATION CSM

5.1.1 Summary of Potrero Canyon Unit Flow and COPC Transport CSM

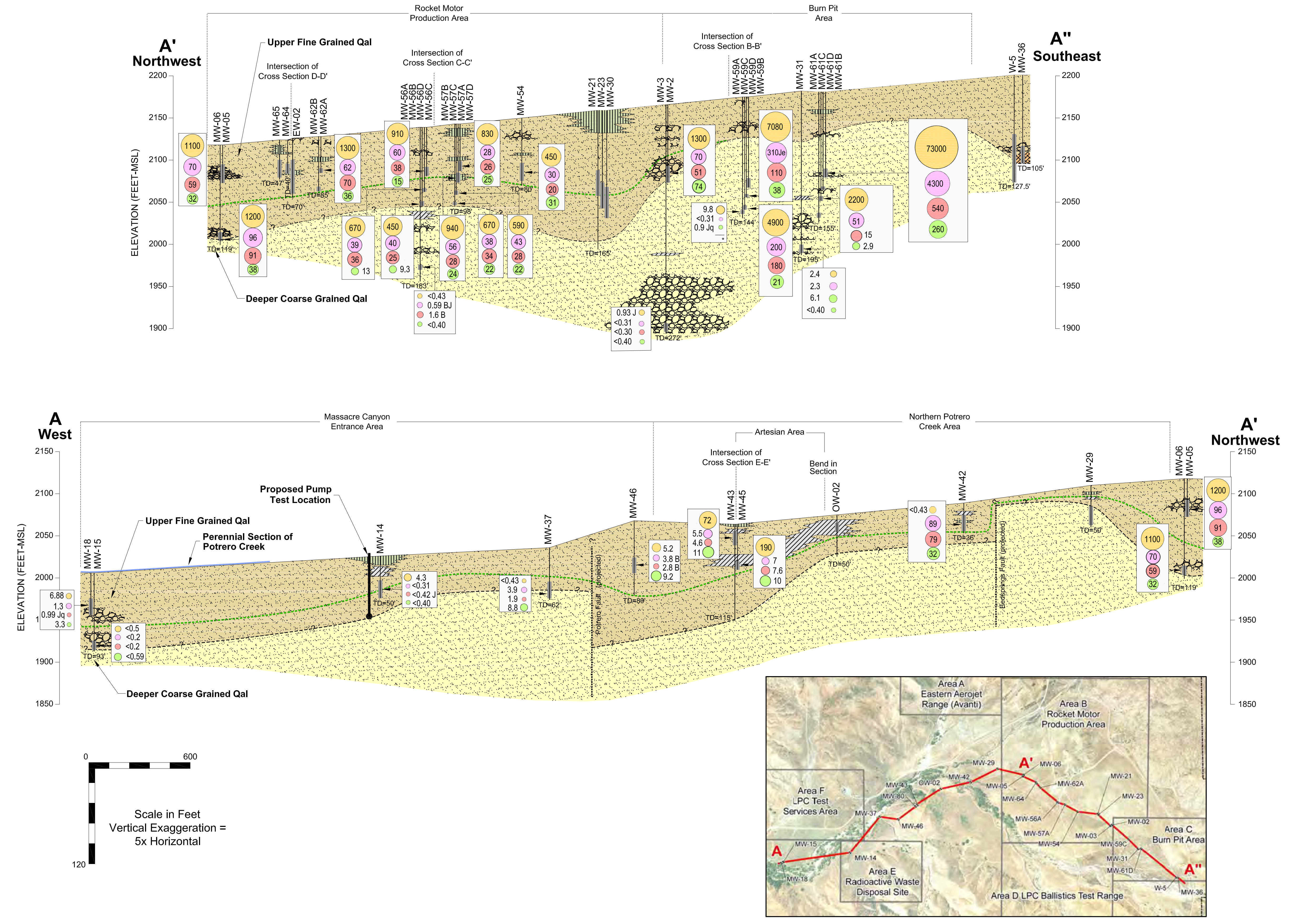
The Potrero Canyon Unit groundwater conceptual model was summarized in the groundwater numerical flow model report (Tetra Tech, 2010e) and the groundwater numerical transport model report (Tetra Tech, 201lb). Key elements of the conceptual model include the following:

- Groundwater occurs in four primary units: shallow low permeability Quaternary alluvium, deep high permeability Quaternary alluvium/weathered Mount Eden, the competent Mount Eden Formation, and the granitic basement (Figures 5-1 and 5-2). The basement rocks provide a base for the shallow water bearing groundwater in the alluvium and weathered Mount Eden, since groundwater in the basement rocks is confined and only found in weathered or fracture zones;

- A small unconfined alluvial basin is found in Bedsprings Creek Valley near the confluence of Potrero and Bedsprings Creeks, with a 100-200 foot thick sequence of saturated recent alluvium located near the Bedsprings Fault. All alluvial groundwater eventually discharges either as evapotranspiration or into Potrero Creek as the saturated alluvium pinches out against the Mount Eden;

- Groundwater flow is generally consistent with the direction of surface water flow and topography, with flow to the northwest at a gradient of 0.002 through the Bedsprings Creek alluvium turning southwest through the Potrero Creek canyon at a gradient of 0.01 to 0.02 (Figure 5-3). There are downward vertical gradients in the alluvium in the southeast of the site where there is recharge, and there are upward vertical gradients in the

X:\GIS\LOCKHEED 25241-01-0601\X-SEC A CSM.DWG



Adapted from:
Faults from Hydrogeologic Investigations for Water Resources Development, Leighton and Associates, 1983.

LEGEND

Concentrations in µg/L

●	500	Perchlorate
●	200	1,1-DCE
●	200	TCE
●	50	1,4-Dioxane
—		No Analysis

▨ Clay
▥ Silt
▩ Sand and Gravel
▩ Sandstone with some gravelly layering
▩ Weathered Granite or Granitic Boulder
- - - Boundary Between Upper and Lower Qal Zones
- -?- - Inferred Contact
| Well
▮ Screened Interval
TD=60' Total Boring Depth (feet)

Notes: COPC concentrations shown from 2nd Quarter 2006 Groundwater Monitoring Event, unless noted.

* 2Q02 Groundwater Monitoring Event.

B - The sample result is less than 5 times (10 times for common organic laboratory contaminants) the blank contamination. The result qualified for blank contamination is considered not to have originated from the environmental sample, since cross-contamination is suspected.

e - A holding time violation occured.

J - Analyte was positively identified and the reults is usable; however, the analyte concentration reported is an estimated value.

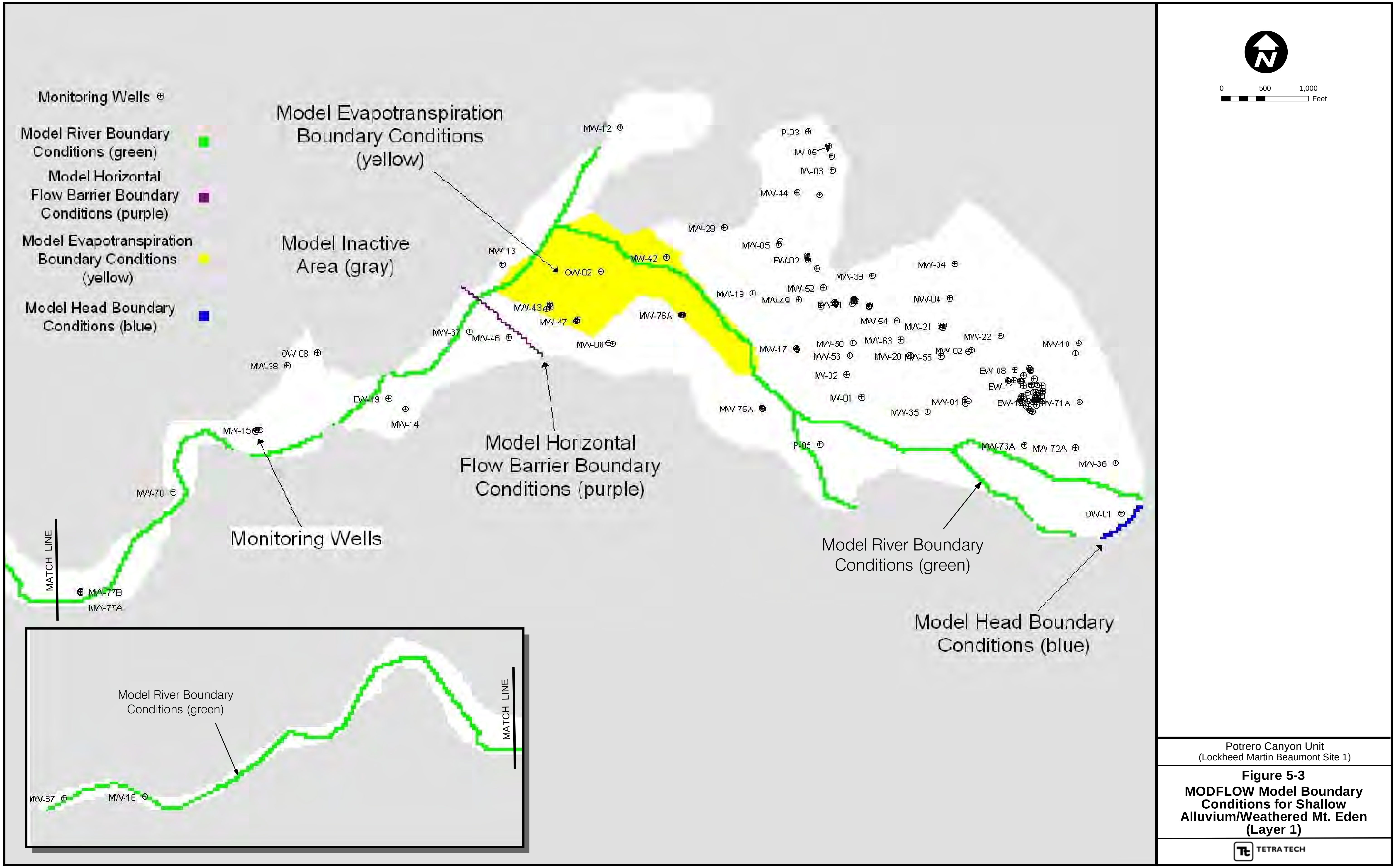
k - The analyte was found in the field blank.

Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 5-2
Geologic Cross Section A-A'-A"

TETRA TECH

X:\GIS\Lockheed 25421-01-0603\MODFLOW_Boundary.mxd



Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 5-3
MODFLOW Model Boundary Conditions for Shallow Alluvium/Weathered Mt. Eden (Layer 1)

TETRA TECH

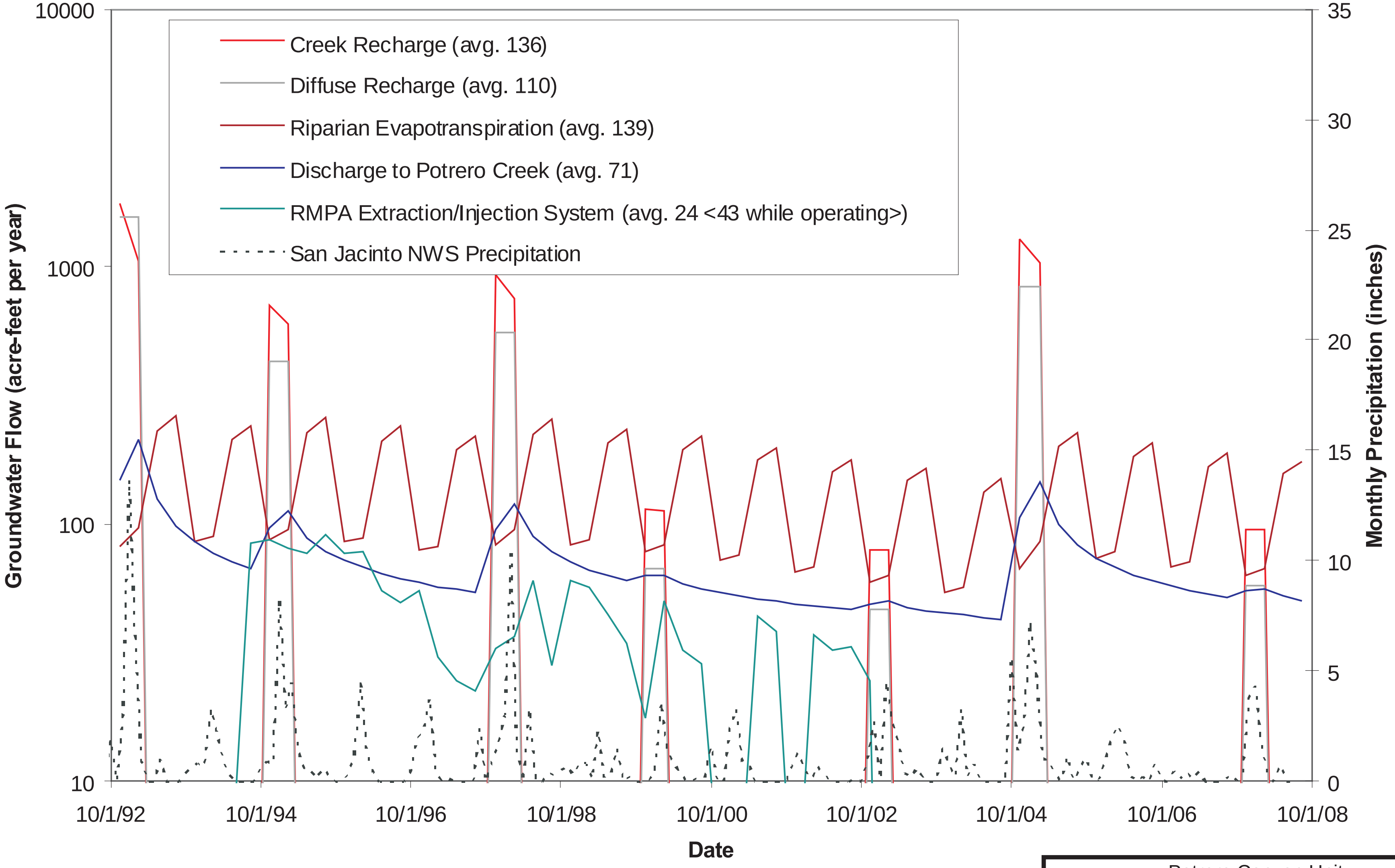
alluvium in the northwest and west of the site where there is discharge to the riparian area and to Potrero Creek. A small artesian zone occurs in the area with upward vertical gradients near the confluence of Bedsprings and Potrero Creeks;

- Hydrologic boundaries for the alluvium (Figure 5-4) are primarily no-flow conditions where the alluvium pinches out at the perimeter of the valley; a leakage boundary at the base of the alluvium; a flow recharge boundary along and under Bedsprings Creek; a flow discharge boundary along Potrero Creek; and partial flow barrier boundaries across Potrero Fault;

- Aquifer hydraulic conductivity values are from 1 to 30 feet per day for the alluvium. Hydraulic conductivity values vary with depth and have a geometric mean of 4 feet per day for the shallow alluvium; 22 feet per day for the deep alluvium; 0.1 foot per day for the competent Mount Eden Formation; and 0.01 foot per day for the granite. Hydraulic conductivity values also vary by area, with the highest values between the RMPA and BPA and low values below the RMPA. Aquifer transmissivity values are roughly 1,500 ft2 per day in the deep high permeability alluvium; 150 ft2 per day in the shallow low permeability alluvium; and 20 ft2 per day in the wells screened in the competent Mt Eden. Model transmissivity values are 20 ft2 per day in the BPA, 1,500 ft2 per day in the area between the RMPA and BPA, 100 to 500 ft2 per day in the lower RMPA, and 2,500 ft2 per day in middle Potrero Creek. A high model transmissivity in the area between the BPA and RMPA coincides with the flat gradients and thicker alluvium observed in this area;

- During the 1992-2008 period (Figure 5-5), total recharge to the alluvium is estimated to be 246 acre feet per year with 110 acre feet per year due to diffuse recharge over the valley floor and 136 acre feet due to recharge from creeks. During the 1992-2008 period, total discharge from the alluvium is estimated to be 218 acre feet per year with 139 acre-feet per year due to evapotranspiration from the riparian area, 71 acre feet per year due to discharge to Potrero Creek, and 8 acre feet per year due to leakage down into the Mt Eden. During the 1992-2008 period, aquifer storage also increased by 28 acre feet per year. The numerical groundwater flow model was calibrated for the period from Fall 1992 through Fall 2008, with a mean water level error of 1.4 feet, a standard deviation of error of 8.9 feet, and a relative error of 2.3 percent. In addition, the calibrated flow model (1) was used to simulate flowpaths at the site, which were in agreement with the observed morphology of the groundwater plume, providing additional support for the model calibration, and (2)

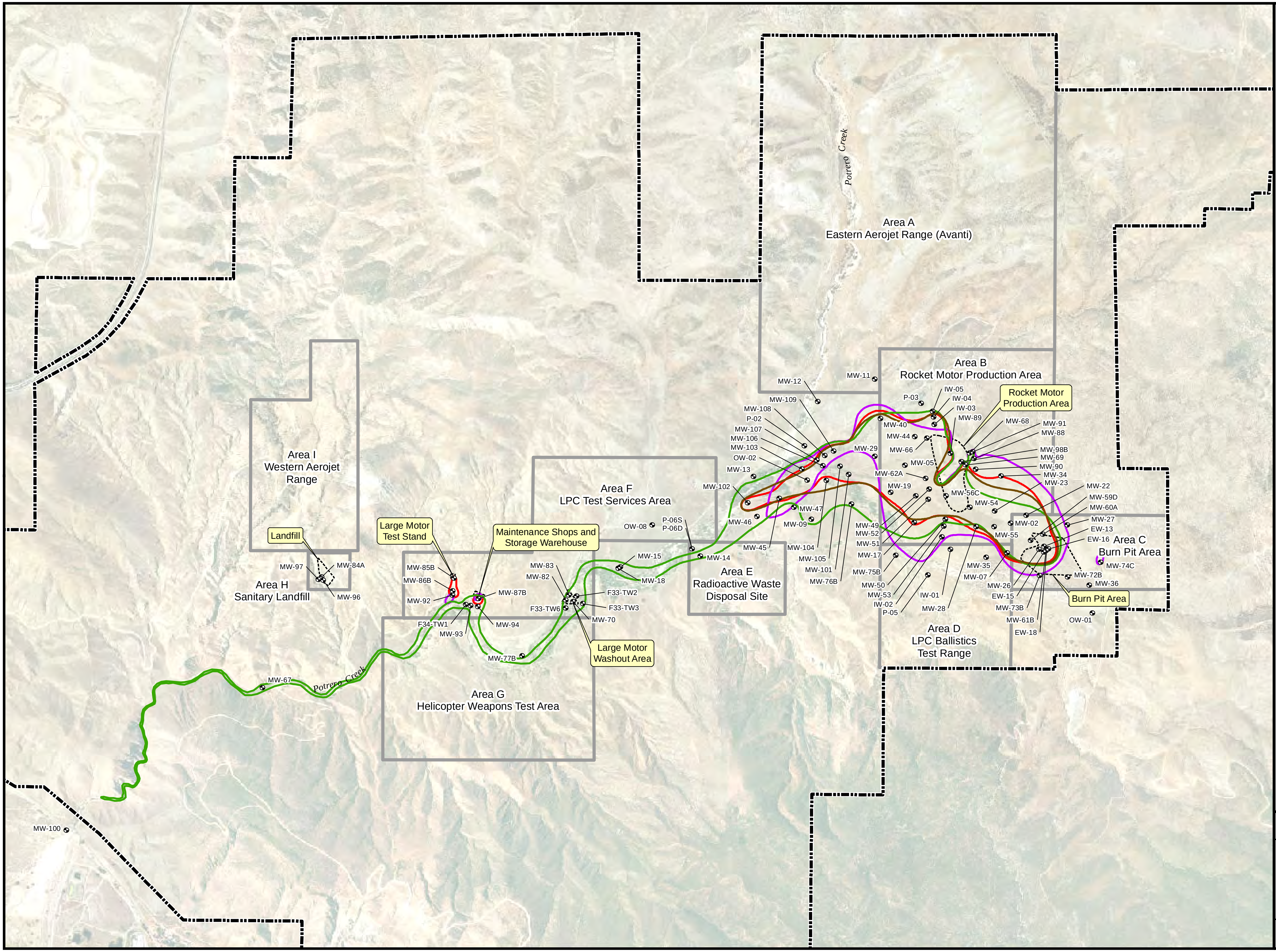
X:\GIS\Lockheed 25241-01-0601\GW Flow 1992-2008.cdr



Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 5-4
Groundwater Flow Predicted by the Model for 1992-2008 Transient Calibration

TETRA TECH



0 1,000 2,000
Feet

Adapted from: March 2007 aerial photograph.

Faults from structural analysis of Potrero Valley, *Lineament and Geologic Mapping Study, Tetra Tech, 2009.*

LEGEND

●	Well Location
〰	Perchlorate (6.0 µg/L) - Dashed where inferred
〰	1,4-Dioxane (1.0 µg/L) - Dashed where inferred
〰	Tricloroethene (5.0 µg/L) - Dashed where inferred
〰	1,1-DCE (6.0 µg/L) - Dashed where inferred
⬚	Potrero Canyon Unit Property Boundary (Lockheed Martin Beaumont Site 1)
⬚	Historical Operational Area Boundary

Notes: Beaumont Site 1 property boundary is approximate.

Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 5-5

Primary COPC Extents for Alluvium and Shallow Mount Eden Formation

TETRA TECH

X:\GIS\Lockheed 25421-01-0603\COPC Extents.mxd was validated for the time after shut-down of the RMPA system (2003 to present) when there were different hydrologic conditions than those in the prior 10 year period. Thus, the numerical flow model further confirmed the key hydraulic characteristics and water budget for the aquifer system, and was capable of simulating the large seasonal and inter-annual changes in aquifer storage observed in the groundwater monitoring data. The components of the water balance in the MODFLOW model also generally match the water budget calculations given in the site conceptual model, which are independent of the numerical groundwater model and based only upon measured data from the site groundwater monitoring program.

- Contaminants of Concern (COPCs) – The COPCs are perchlorate, 1,4-dioxane, 1,1-DCE, and TCE. There is generally one distinct plume at Potrero Canyon Unit that covers 278 acres (Figure 4-8). Perchlorate, 1,4-dioxane, 1,1-DCE, and TCE appear to be added to the plume by the flow of groundwater through a one (1) acre aquifer source area in the BPA. In addition, perchlorate appears to be added to the plume by the release of perchlorate from soil sources in the BPA, RMPA, and to a lesser extent at the Large Motor Washout Area. Additional source areas were identified west of the main valley and the Large Motor Washout Area during the Dynamic Site Investigation (Tetra Tech, 2009b). The soil source areas and any impacts to groundwater are fairly localized. These additional source areas include the Maintenance Shops and Storage Warehouse Area, the Large Motor Test Bay, and the Sanitary Landfill. Current COPC mass flux released from all sources is estimated as follows (Table 5.1-1): 19 pounds per year for 1,1-DCE; 9 pounds per year for TCE; 156 pounds per year for perchlorate; and 4 pounds per year for 1,4-dioxane. Current total COPC mass in the groundwater plume is estimated as follows: 500 pounds for 1,1-DCE; 350 pounds for TCE; 3,200 pounds for perchlorate; and 80 pounds for 1,4-dioxane. Current total COPC mass in soils is 1,800 pounds for perchlorate with no other COPCs present in soils. Statistical analysis of COPC time trends confirms the observation that the overall extent and magnitude of the plume is relatively unchanged over the 20-plus year monitoring period, though there had been a small reduction in plume mass near the RMPA groundwater extraction and treatment system when that system was active. The transport model was simulated for all four COCs (perchlortate, 1-4-dioxane, 1,1-DCE, and TCE) for the period from Fall 1992 through Fall 2008, and the relative error for the COCs concentration is 6.5 percent for perchlorate, 6.5 percent for 1,4-dioxane, 6.3 percent for 1,1-DCE, and 6.9 percent for TCE. The components of the COC mass and mass flux

Table 5.1-1 Transport Model COPC Mass and Mass Flux Summary

TRANSPORT MODEL PREDICTIONS								
	Perchlorate		1-4-Dioxane		1-1-DCE		TCE	
	Total Mass (pounds)	Mass Flux (pounds/year)	Total Mass (pounds)	Mass Flux (pounds/year)	Total Mass (pounds)	Mass Flux (pounds/year)	Total Mass (pounds)	Mass Flux (pounds/year)
Sources[1]	2,501	156*	62	3.9	303	19.0	144	9.0
Wells**	-423	-26	-5	-0.3	-95	-6.0	-109	-6.8
Creek	-15	-1	-2	-0.2	-4	-0.2	-5	-0.3
Evapotranspiration	-313	-20	-33	-2.1	-118	-7.4	-170	-10.6
Degradation	-2,139	-134	0	0	0	0	0	0
2009 Storage[2]	3,217	NA	81	NA	492	NA	355	NA

* 144 for BPA, 12 for RMPA, and < 1 for Large Motor Washout Area

CONCEPTUAL MODEL VALUES (from Section 3)								
	Perchlorate		1-4-Dioxane		1-1-DCE		TCE	
	Total Mass (pounds)	Mass Flux (pounds/year)	Total Mass (pounds)	Mass Flux (pounds/year)	Total Mass (pounds)	Mass Flux (pounds/year)	Total Mass (pounds)	Mass Flux (pounds/year)
Sources[1]	2,576	161	48	3.0	224	14.0	181	11.3
Wells**	-443	-28	-8	-0.5	-93	-5.8	-99	-6.2
Creek	-22	-1	-10	-0.6	-32	-2.0	-13	-0.8
Evapotranspiration	-640	-40	-128	-8.0	-288	-18.0	-304	-19.0
Degradation[3]	-1,008	-63	0	0	0	0	0	0
2009 Storage[2]	3,400	NA	100	NA	362	NA	314	NA

** For TCE and 1,1-DCE wells, represents net loss due to removal in treatment, but for perchlorate and 1,4-dioxane wells do not represent net loss since extraction is balanced by reinjection

[1] Sources include soil sources leaching COPCs from soils (only relevant for perchlorate) and groundwater sources releasing COPCs to underflow, as calculated in the Flow and Transport Model Report (Tetra Tech, 2010e)

[2] Storage is the mass dissolved in groundwater and adsorbed onto aquifer solids as calculated in the Flow and Transport Model Report (Tetra Tech, 2010d)

[3] Degradation is as calculated in Flow and Transport Model Report (Tetra Tech, 2010d). Note that for TCE, the earlier Site CSM in the modeling report did not include degradation, as the contaminant attenuation data was unavailable at that time. Based upon the new contaminant attenuation data, some TCE degradation appears likely, and is included in the updated CSM in Table 3, and this information will be used after completion of the proposed contaminant attenuation data collection to ultimately revise the Transport model.

budget also generally matches the conceptual model COC mass and mass flux budget, which are independent of the numerical groundwater model and derived from the site groundwater level and water quality data collected in the site monitoring program. Notable components of the transient mass flux budget include the following: (1) Total COC plume mass predicted for 2009 is within 6 percent of 2009 observed mass for perchlorate, 19 percent of 2009 observed mass for 1,4-dioxane, 48 percent of 2009 observed mass for 1,1-DCE, and 36 percent of observed 2009 mass for TCE; (2) COC mass and mass flux into the aquifer is within 14 percent of the mass and mass flux out of the aquifer due to loss to evapotranspiration, wells, streams, and biodegradation (perchlorate only) suggesting the plume is nearly at steady-state conditions as reflected in the plume mass being relatively constant over the 1992 through 2009 simulation period; (3) there is generally good comparison between the transport model mass and mass flux values estimated at the extraction well locations for TCE and 1,1,-DCE; (4) there is generally fair comparison between the MT3D transport model mass and mass flux values and those estimated in the conceptual model derived from site monitoring data; and (5) the perchlorate mass flux values from soil sources in the RMPA and BPA reasonably match those estimated using vadose zone transport models. Thus, the groundwater COC mass and mass flux budget for the calibrated transport model generally matches the conceptual model COC mass and mass flux budget.

- COPC Transport – The primary pathway for contaminant migration in groundwater appears to be the coarse-grained, high permeability alluvium/weathered Mount Eden that is primarily located at depth and in the center of valleys. The COPCs are generally restricted to the alluvium and weathered Mt. Eden. Groundwater velocity is typically 600 feet per year within the main plume area, such that transport times are approximately 12 years across the 7,200 foot long plume.

- COPC Fate Mechanisms – In the riparian area, all COPCs appear to be removed from the plume by evapotranspiration; in addition perchlorate is removed by biodegradation in the riparian area and a small amount of TCE is removed by biodegradation in localized methanogenic areas of the aquifer in the BPA source area, in the riparian area, and near the former injection wells. Generally, the plume at the site appears to be in a quasi- steady state conditions where COPCs are added to the plume in the BPA and RMPA source areas

> at rates approximately equal to the COPC removal rates from the plume in the riparian area. The lateral and vertical extent of the plume appears to be controlled by the build-up of plume mass and extent in the areas between the BPA and RMPA source areas, and the evapotranspiration and biodegradation sinks in the riparian area. There are several lines of empirical evidence outlined in the flow and transport modeling reports that show that there is significant perchlorate degradation occurring in the riparian area, including the disappearance of perchlorate from the plume; the drop in groundwater redox conditions from aerobic to perchlorate-reducing within this same area; and the results of the site bench scale tests (Section 3.5) showing perchlorate degradation in a batch reactor.

The reader is referred to the flow and transport model reports for more details and supporting information on the groundwater flow and transport conceptual model.

5.1.2 Summary of the Groundwater to Plant Uptake Study

A groundwater-to-plant uptake study was conducted between 2010 and 2011 in order to develop statistical models that could be used to predict concentrations of perchlorate and 1,4-dioxane in plant tissues based on concentrations measured in contaminated groundwater. A secondary goal of this study was to assess the potential for recycling of perchlorate and 1,4-dioxane from groundwater through riparian plants and subsequently to soil. A brief summary of the findings of this study are included in this report with the complete report provided in an appendix of the *Draft Human Health and Predictive Ecological Risk Assessment* (Tetra Tech, 2011c).

The primary focus of the groundwater-to-plant uptake study was on the translocation of perchlorate from groundwater to riparian plant tissue. Based on the greater abundance of riparian habitat and accessibility of the riparian area for sampling, the study was conducted primarily at the Potrero Canyon Unit site, with some supplemental sampling conducted at the Laborde Canyon site. Plants targeted for analysis in the groundwater-to-plant uptake study were riparian shrubs (willow, mulefat, and elderberry) and trees (cottonwood and sycamore).

The first phase of sampling was conducted to determine whether perchlorate and 1,4-dioxane uptake from groundwater to plants is occurring. Three plant tissue samples were collected around each of two existing monitoring wells (OW-2 and MW-43) and analyzed for perchlorate and 1,4-dioxane. Phase II of the sampling consisted of drilling primary direct-push soil borings and collecting grab groundwater samples from temporary monitoring wells installed at five of the selected locations. Based on the perchlorate and 1,4-dioxane results from the Phase II borings, five additional Phase III borings were drilled and sampled in an attempt to capture the range of perchlorate and 1,4-dioxane concentrations in the riparian zone. Upon completion of the Phase III sampling, the results were reviewed and used as the basis for selecting locations for seven permanent groundwater monitoring wells. These seven wells were located to provide as wide a range of groundwater concentrations for both perchlorate and 1,4-dioxane as possible. At each of the seven permanent groundwater monitoring well locations, three 1-m radius tissue and soil sampling locations were selected within a 10-m radius of the well. At each of these three sub-locations, fresh leaves from surrounding riparian plants and leaf litter samples were collected, and three hand auger borings were installed and sampled at depths of 0.5, 2, and 5 feet bgs. In general leaves from only a single species were collected as part of each plant tissue sample (Appendix A-2). Leaf litter samples generally corresponded with the associated plant tissue sample; however, leaf litter samples were more variable and may have consisted of multiple species.

Although perchlorate was detected in leaf tissue, leaf litter, and shallow soils samples collected for this study, the study found only a weak correlation between groundwater perchlorate concentrations and riparian plant tissue concentrations. The regression analysis explains approximately 32 percent of the variance in the plant tissue concentrations. As a result of the low explanatory power, the regression is not suitable for use in the predicative ecological risk assessment (PERA) to estimate perchlorate concentrations in plant tissue. The relationship between groundwater concentrations and leaf litter concentration is weaker than with plant tissue, likely due to degradation of the litter on the ground. No relationship was detected between groundwater perchlorate concentrations and soil perchlorate concentrations. The regression developed in this study represents site-specific conditions at the time that sampling occurred. Several factors, including the duration of exposure of riparian plants to groundwater, plant species, and potentially other sources may contribute to the high degree of variability in the regression.

1,4-Dioxane was not detected in plants or in surface soils. Therefore, the groundwater to plant uptake study does not provide evidence for 1,4-dioxane translocation from groundwater by riparian plants or recycling to soils. It cannot be determined whether 1,4-dioxane was taken up by plants and subsequently metabolized or volatilized from tissues, or whether it was not taken up.

5.1.3 Summary of Contaminant Attenuation CSM

A preliminary groundwater contaminant attenuation conceptual model was presented in the recent Technical Memorandum (Tetra Tech, 2010f), which outlined the recent field program discussed in Sections 3 and 4. The Contaminant Attenuation CSM included definitions of the site contaminant attenuation conditions, including the major species relevant to COPC natural attenuation processes.

The preliminary groundwater contaminant CSM is updated in the following section based upon the results of the recent field program discussed in Sections 3 and 4.

5.1.3.1 Key Contaminant Attenuation Species

Given that (1) the site plume extends from an upgradient groundwater recharge area where the aquifer is primarily oxic to a downgradient groundwater discharge area where the aquifer is primarily anoxic, and (2) the site plume primarily consists of perchlorate, 1,4-dioxane, 1,1-DCE, and TCE, the following aquifer water quality parameters are key species related to contaminant attenuation and the gradual transition of the plume from oxic to anoxic conditions: dissolved oxygen (DO), nitrate, manganese, iron, sulfate/sulfide, hydrogen, methane, organic carbon, cis-1,2-DCE, and vinyl chloride. Also, oxidation-reduction potential (ORP) is an indicator of the oxic to anoxic transition.

Maps presenting the spatial distribution of these key contaminant attenuation species are provided in Appendix A of the recent technical memorandum (Tetra Tech, 2010f). The new sampling results are discussed in Section 4.7 of this report. The redox state of the water quality data is defined by the dominant type of reduction/oxidation reaction, or redox process, using USGS software and threshold values (Jurgens et al., 2009), with the results given in Table 5.1-2 and plotted in Figure 4-8. Note that VFAs are often important organic carbon sources for perchlorate degradation, but the site data show only trace concentrations of VFAs in most areas.

Therefore, while VFAs are typically important for perchlorate degradation, VFAs data does not appear to be particularly helpful to the perchlorate CSM at Potrero Canyon Unit.

5.1.3.2 Temporal Trend Analysis of COPCs

As presented in Section 4.5, results of the temporal trend analysis for the monitoring period between 1986 and 2011 indicate that the plume appears to be in a quasi- steady state as previously

Table 5.1-2

Redox Assingment for Beaumont Site 1 Groundwater Samples

	Redox Variables	*Dissolved O_2*	*NO_3^- (as Nitrogen)*	*Mn^{2+}*	*Fe^{2+}*	*SO_4^{2-}*	*Sulfide (sum of H_2S, HS^-, S^{2-})*	***Redox Assignment***			*Fe^{2+}/ Sulfide, ratio*
	Units	millig/L	millig/L	microg/L	microg/L	millig/L	millig/L				
Sample ID	Threshold values	**0.5**	**0.5**	**50**	**100**	**0.5**	**none**	Num of Params	General Redox Category	Redox Process	
EW-13		0.68	0.11	17	70	5.2	0.01	6	Oxic	O2	
EW-15		0.31	0.11	210	1910	7.8	0.02	6	Anoxic	Fe(III)	95.50
F33-TW2		0.31	0.11	470	1900	51	0.01	6	Anoxic	Fe(III)	190.00
F33-TW3		0.24	0.11	500	270	57		5	Anoxic	Fe(III)/SO4	
F33-TW6		0.24	0.11	250	300	72		5	Anoxic	Fe(III)/SO4	
F33-TW7		0.33	0.11	650	1100	54	0.02	6	Anoxic	Fe(III)	55.00
F34-TW1		0.18	0.11	56	340	110	0.36	6	Mixed(anoxic)	Fe(III)-SO4	0.94
IW-04		0.34	0.12	660	3300	0.75	0.01	6	Anoxic	Fe(III)	330.00
MW-01		4.9	2.4	1.2	20	19	0.01	6	Oxic	O2	
MW-02		6.83	11	1.2	30	7.6		5	Oxic	O2	
MW-03		0.35	0.11	1.2	30	12	0.01	6	Suboxic	Suboxic	
MW-05		0.4	7.2	2.5	10	11	0.03	6	Anoxic	NO3	
MW-06		0.25	0.11	140	570	8.6	0.1	6	Mixed(anoxic)	Fe(III)-SO4	5.70
MW-07		7.15	2.7	2.5		7	0.02	5	O2 >= 0.5 mg/L	Unknown	
MW-08		1.07	0.11	160	80	9.5		5	Mixed(oxic-anoxic)	O2-Mn(IV)	
MW-09		0.23	0.11	43	80	19		5	Suboxic	Suboxic	
MW-100		0.61	0.11	1.2	60	300	0.01	6	Oxic	O2	
MW-101		0.19	0.11	120	170	29	0.02	6	Mixed(anoxic)	Fe(III)-SO4	8.50
MW-102		0.25	0.11	190	44	16	0.01	6	Anoxic	Mn(IV)	
MW-11		1.9	12	2.5	20	66	0.01	6	Oxic	O2	
MW-12		0.91	0.11	2600	1410	450		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4	
MW-13		0.25	0.11	280	20	77		5	Anoxic	Mn(IV)	
MW-14		2.69	0.5	2.5		24	0.01	5	O2 >= 0.5 mg/L	Unknown	
MW-15		0.19	0.11	110	20	40	0.02	6	Anoxic	Mn(IV)	
MW-17		0.56	3.8	3.3		7		4	O2 >= 0.5 mg/L	Unknown	
MW-18		0.44	0.27	150	12	44		5	Anoxic	Mn(IV)	
MW-19		0.96	0.11	2.8	60	7.4		5	Oxic	O2	
MW-22		6.27	11	2.5	50	6.6	0.01	6	Oxic	O2	
MW-23		5.61	14	2.5	80	7.4	0.02	6	Oxic	O2	
MW-26		7.87	14	1.2	80	10		5	Oxic	O2	
MW-27		0.35	0.58	290	1400	1.9	0.09	6	Mixed(anoxic)	NO3-Fe(III)	15.56
MW-28		1.88	2.4	2.5	30	13	0.05	6	Oxic	O2	
MW-29		0.34	0.11	18	10	29		5	Suboxic	Suboxic	
MW-31		0.27	0.11	1.2		16		4	O2 < 0.5 mg/L	Unknown	
MW-32		0.07	0.11	1.2	10	16	0.01	6	Suboxic	Suboxic	

Defined using USGS method by Jurgens et al., 2009

Table 5.1-2
Redox Assingment for Beaumont Site 1 Groundwater Samples

Sample ID	*Redox Variables*	*Dissolved O_2*	*NO_3^- (as Nitrogen)*	*Mn^{2+}*	*Fe^{2+}*	*SO_4^{2-}*	*Sulfide (sum of H_2S, HS^-, S^{2-})*	***Redox Assignment***			*Fe^{2+}/ Sulfide, ratio*
	Units	millig/L	millig/L	microg/L	microg/L	millig/L	millig/L				
	Threshold values	**0.5**	**0.5**	**50**	**100**	**0.5**	**none**	Num of Params	General Redox Category	Redox Process	
MW-34		1.32	19	2.5		20	0.01	5	O2 >= 0.5 mg/L	Unknown	
MW-35		7.19	1.3	1.2		4.3		4	O2 >= 0.5 mg/L	Unknown	
MW-36		7.88	6.5	1.2	60	8	0.02	6	Oxic	O2	
MW-40		0.56	5.8	2.5		18	0.01	5	O2 >= 0.5 mg/L	Unknown	
MW-43		0.23	0.94	4.1	300	11		5	Mixed(anoxic)	NO3-Fe(III)/SO4	
MW-45		1.47	1.6	1.2		9.2		4	O2 >= 0.5 mg/L	Unknown	
MW-46		0.81	0.14	23		12	0.02	5	O2 >= 0.5 mg/L	Unknown	
MW-48		0.23	0.11	180	1490	0.37		5	Anoxic	CH4gen	
MW-49		0.72	4.3	1.2	60	6		5	Oxic	O2	
MW-53		6.18	2.2	2.5	50	4.7	0.01	6	Oxic	O2	
MW-54		3.03	11	2.5	70	9.2	0.01	6	Oxic	O2	
MW-55		8.16	9.8	1.2	40	6.9		5	Oxic	O2	
MW-56A		0.15	0.11	1.7	70	12	0.01	6	Suboxic	Suboxic	
MW-56B		0.27	10	7.8	50	9.6		5	Anoxic	NO3	
MW-56C		2.46	9.3	1.2	70	8.6	0.01	6	Oxic	O2	
MW-59A		1.16	0.63	1.2	60	9.2	0.02	6	Oxic	O2	
MW-59B		6.7	14	1.8	10	9.8	0.01	6	Oxic	O2	
MW-59D		7.24	15	1.2	40	9.5		5	Oxic	O2	
MW-60A		4.27	9	1.2	50	8.2	0.01	6	Oxic	O2	
MW-60B		1.98	3.7	1.2	80	9.7	0.01	6	Oxic	O2	
MW-61A		1.84	2.3	16	380	14	0.8	6	Mixed(oxic-anoxic)	O2-Fe(III)-SO4	0.48
MW-61B		3.98	21	1.2	50	22		5	Oxic	O2	
MW-61C		1.8	0.11	1.2		12	0.01	5	O2 >= 0.5 mg/L	Unknown	
MW-62A		3.55	16	2.5	30	12	0.01	6	Oxic	O2	
MW-66		0.51	6.7	94	70	12	0.02	6	Mixed(oxic-anoxic)	O2-Mn(IV)	
MW-67		0.15	0.11	220	210	100	0.01	6	Anoxic	Fe(III)	21.00
MW-68		5.67	5	2.5	50	45	0.01	6	Oxic	O2	
MW-69		4.05	11	1.2	40	20		5	Oxic	O2	
MW-70		0.24	0.11	1.2	12	55	0.02	6	Suboxic	Suboxic	
MW-71A		1.32	0.11	5.4	80	19	0.01	6	Oxic	O2	
MW-71C		2.86	2	1.2	30	10		5	Oxic	O2	
MW-72A		0.23	0.11	4.1	110	31	0.02	6	Mixed(anoxic)	Fe(III)-SO4	5.50
MW-72B		2.93	2.5	3	100	42		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4	
MW-72C		3.59	3.9	1.2		10		4	O2 >= 0.5 mg/L	Unknown	
MW-73A		1.96	1.1	1.2	40	16		5	Oxic	O2	

Defined using USGS method by Jurgens et al., 2009

Table 5.1-2

Redox Assingment for Beaumont Site 1 Groundwater Samples

	Redox Variables	*Dissolved O_2*	*NO_3^- (as Nitrogen)*	*Mn^{2+}*	*Fe^{2+}*	*SO_4^{2-}*	*Sulfide (sum of H_2S, HS^-, S^{2-})*	***Redox Assignment***			*Fe^{2+} / Sulfide, ratio*
	Units	millig/L	millig/L	microg/L	microg/L	millig/L	millig/L				
Sample ID	Threshold values	**0.5**	**0.5**	**50**	**100**	**0.5**	**none**	Num of Params	General Redox Category	Redox Process	
MW-73B		2.51	0.97	1.2		110		4	O2 >= 0.5 mg/L	Unknown	
MW-73C		4.55	3.5	1.2	30	18	0.01	6	Oxic	O2	
MW-74A		2.51	0.11	1.2		18		4	O2 >= 0.5 mg/L	Unknown	
MW-74B		0.35	2.1	210	110	220	0.8	6	Mixed(anoxic)	NO3-SO4	0.14
MW-74C		3.59	16	1.2	20	11	0.01	6	Oxic	O2	
MW-75A		0.27	0.11	1.2	70	20	0.01	6	Suboxic	Suboxic	
MW-75B		3.09	3.1	1.2	50	8.7	0.01	6	Oxic	O2	
MW-75C		0.15	0.29	250	10	14	0.02	6	Anoxic	Mn(IV)	
MW-76A		0.28	0.11	1.2		28	0.03	5	O2 < 0.5 mg/L	Unknown	
MW-76B		0.23	0.11	11	200	8.6	0.02	6	Mixed(anoxic)	Fe(III)-SO4	10.00
MW-76C		0.15	0.11	52	190	21	0.01	6	Anoxic	Fe(III)	19.00
MW-77A		0.1	0.11	2.9		280	0.75	5	O2 < 0.5 mg/L	Unknown	
MW-77B		0.38	0.11	1.2		180	0.01	5	O2 < 0.5 mg/L	Unknown	
MW-78		0.33	1.9	1.2	50	7.3	0.32	6	Anoxic	NO3	
MW-79A		2.48	0.11	3.4		20	0.09	5	O2 >= 0.5 mg/L	Unknown	
MW-79C		2.16	5.7	1.2	50	10		5	Oxic	O2	
MW-80		0.99	0.11	5.4	30	14	0.14	6	Oxic	O2	
MW-81		0.69	0.11	1.2	10	37	0.03	6	Oxic	O2	
MW-82		0.35	0.11	41	21	73	0.01	6	Suboxic	Suboxic	
MW-83		1.11	0.11	1.2	12	58		5	Oxic	O2	
MW-84A		0.47	0.11	44	110	66	0.11	6	Mixed(anoxic)	Fe(III)-SO4	1.00
MW-84B		0.59	0.11	16	50	170	0.29	6	Oxic	O2	
MW-85A		0.13	0.11	4.8	40	93	0.17	6	Suboxic	Suboxic	
MW-85B		0.12	0.11	2.7	10	97	0.02	6	Suboxic	Suboxic	
MW-86A		0.16	0.11	1.2	40	110	0.05	6	Suboxic	Suboxic	
MW-86B		0.29	0.11	120	1380	110		5	Anoxic	Fe(III)/SO4	
MW-87A		0.14	0.11	1.2	20	110	0.03	6	Suboxic	Suboxic	
MW-87B		2.37	25	1.2	40	130		5	Oxic	O2	
MW-88		4.36	10	1.7		50		4	O2 >= 0.5 mg/L	Unknown	
MW-89		0.53	11	59	40	36		5	Mixed(oxic-anoxic)	O2-Mn(IV)	
MW-90		0.73	0.95	1.2	30	13	0.01	6	Oxic	O2	
MW-91		3.72	5.7	5.1	60	45		5	Oxic	O2	
MW-92		5.46	11	5	110	85	0.13	6	Mixed(oxic-anoxic)	O2-Fe(III)-SO4	0.85
MW-93		0.54	3.6	6.1	30	120	0.01	6	Oxic	O2	
MW-94		0.6	0.11	4.5	120	81	0.04	6	Mixed(oxic-anoxic)	O2-Fe(III)-SO4	3.00

Defined using USGS method by Jurgens et al., 2009

Table 5.1-2

Redox Assingment for Beaumont Site 1 Groundwater Samples

	Redox Variables	*Dissolved O_2*	*NO_3^- (as Nitrogen)*	*Mn^{2+}*	*Fe^{2+}*	*SO_4^{2-}*	*Sulfide (sum of H_2S, HS^-, S^{2-})*	***Redox Assignment***			*Fe^{2+}/ Sulfide, ratio*
	Units	millig/L	millig/L	microg/L	microg/L	millig/L	millig/L				
Sample ID	Threshold values	**0.5**	**0.5**	**50**	**100**	**0.5**	**none**	Num of Params	General Redox Category	Redox Process	
MW-95		0.76	0.11	1.2	30	110		5	Oxic	O2	
MW-96		0.73	0.11	9.2	20	110	0.06	6	Oxic	O2	
MW-97		0.41	0.11	10	50	76	0.1	6	Suboxic	Suboxic	
MW-98A		0.08	0.11	1.2	100	7.1	0.1	6	Mixed(anoxic)	Fe(III)-SO4	1.00
MW-98B		3.42	15	1.2	70	20		5	Oxic	O2	
MW-99		0.69	0.11	1.2	1230	24		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4	
OW-01		0.53	0.14	480	40	620		5	Mixed(oxic-anoxic)	O2-Mn(IV)	
OW-02		2.46	3.1	1.2	50	6.9	0.01	6	Oxic	O2	
OW-08		4.42	3.7	1.2	50	230		5	Oxic	O2	
P-02		0.59	0.11	1300	10	250		5	Mixed(oxic-anoxic)	O2-Mn(IV)	
P-03		0.67	0.11	370	670	240	0.03	6	Mixed(oxic-anoxic)	O2-Fe(III)	22.33
P-05		5.19	3.4	2.5	30	7		5	Oxic	O2	
P-06D		0.23	0.11	2.9	50	23		5	Suboxic	Suboxic	
P-06S		0.92	0.18	87	40	110	0.01	6	Mixed(oxic-anoxic)	O2-Mn(IV)	
EW-16		0.61	1.7	78	4500	7.7	0.04	6	Mixed(oxic-anoxic)	O2-Fe(III)	112.50
EW-18		1.03	5.1	200	4000	12	0.03	6	Mixed(oxic-anoxic)	O2-Fe(III)	133.33
IW-01		0.07	0.11	390	85000	2.4	0.51	6	Anoxic	Fe(III)	166.67
IW-02		0.27	0.11	360	19000	1.9	0.05	6	Anoxic	Fe(III)	380.00
IW-03		0.28	0.11	420	19000	1.2	0.13	6	Anoxic	Fe(III)	146.15
IW-05		0.3	0.53	260	11000	4.9	0.1	6	Mixed(anoxic)	NO3-Fe(III)	110.00
MW-106		0.24	0.11	310	5.5	110		5	Anoxic	Mn(IV)	
MW-109		0.26	3.2	320	28	20		5	Mixed(anoxic)	NO3-Mn(IV)	
MW-44		0.54	12	0.25	180	16		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4	
MW-50		7.14	4.1	0.58	270	6.3	0.02	6	Mixed(oxic-anoxic)	O2-Fe(III)	13.50
MW-51		3.56	5.6	1.3	340	7	0.01	6	Mixed(oxic-anoxic)	O2-Fe(III)	34.00
MW-52		3.98	8.1	0.24	270	8.1		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4	
MW-70		2.77	0.11	0.24	6.3	74		5	Oxic	O2	

Defined using USGS method by Jurgens et al., 2009

reported in the groundwater transport modeling report (Tetra Tech, 2010e). Contaminants are added to the plume in the BPA and RMPA source areas at rates that are approximately equal to the contaminant removal rates in the riparian area. The riparian area appears to have a significant impact on the extent of the plume with evapotranspiration being the primary attenuation process for all contaminants with additional perchlorate also being removed through biodegradation due to the reducing aquifer conditions. The temporal trends and plume stability provide another line of evidence that contaminant attenuation is playing a key role in controlling/managing the extent and magnitude of the groundwater plumes at the site and is an important aspect of the contaminant attenuation CSM.

5.1.3.3 Water Quality Distribution and Redox Conditions

The various maps depicting the distribution of site water quality parameters indicate that redox conditions vary across the site. The redox conditions in the upgradient recharge areas are primarily oxic near the BPA where the redox process is oxygen. The redox conditions then gradually transition in the downgradient discharge areas to primarily anoxic, flowing first into a narrow strip where the redox process is nitrate, followed by a transition to an area where the redox process is manganese and perchlorate, followed by a shift towards an iron redox level in the riparian area just aboave the confluence of Bedsprings and Potrero creeks. These redox levels are further supported by the hydrogen data (values from 0.2 to 5 nM), sulfide data (values generally much less than 0.1 mg/L), and ORP data (values near 100 mV in the upgradient oxic areas lowering to -100 to 0 mV in the downgradient anoxic areas). Note that the USGS software does not include the use of methane, hydrogen, and perchlorate data that were available at Potrero Canyon Unit, so some of the site observations may have minor deviations from the USGS derived redox scheme (Table 5.1-2) based upon this additional site data. Other significant features of the site redox conditions are as follows:

- Sulfate depletion and methane production is generally small, and therefore are generally not important redox processes. Very little sulfide is present, further supporting the argument that sulfate reduction is not widespread or significant. However, there are exceptions in a few small areas where limited methane generation is observed, such as near well EW-13 in the BPA; the former injection wells; the lower riparian area well MW-102; and the the Large Motor Washout Area area. In these four sulfate depletion and methane production areas, ORP levels drop low enough to allow for solvent degradation as noted by the TCE degradation by-products cis-1,2-DCE and vinyl chloride. However, in the majority of the plume, the redox levels are too high for solvent degradation as evidenced by the fact that sulfate is only near depletion (less than 1 mg/L) and methane is only significantly generated (greater than 1 mg/L) in three areas near the former injection well IW-02; near the former injection well IW-04; and near well MW-48 in the lower riparian area. In contrast to TCE, redox levels in most areas downgradient of the RMPA and BPA appear low enough for perchlorate use as an electron acceptor, as evidenced by the depletion of nitrate and the formation of manganese IV, and perchlorate degradation appears widespread in the riparian area.

- Iron II does not appear in significant concentrations except near the former injection wells even though the redox levels are low enough for this to occur, since perchlorate and iron processes occur at similar ORP levels. This is attributed to either (1) limited amounts of iron III accessible in the aquifer solid phase, or (2) another electron acceptor inhibiting the use of iron.

- There are some significant deviations from these general redox trends, including the following:

  - A 20 acre area of oxic redox conditions in the lower riparian area near wells MW-45/43, MW-08/09, MW-47/48, and OW-02. In this area, DO, nitrate, and perchlorate concentrations are relatively high and manganese is relatively low, indicating oxygen is the dominant redox process. This oxic redox area in the lower riparian zone is also the location where artesian conditions occur in all of the deeper aforementioned wells, and the deeper artesian zone in all these wells shows higher redox levels than the shallow zone. Thus, the presence of the oxic redox area in the lower riparian zone is attributed to the upward flow of deeper more oxic groundwater, although the proximity of the nearby Potrero Creek and Bedsprings Creek Fault zones is noted and this may also play a role in the formation of this oxic zone.

  - A 5 acre area of mixed anoxic redox conditions in the riparian area near the plant uptake area wells MW-106 and MW-109, where there are slightly higher redox levels (manganese reducing) than redox levels in nearby wells. These higher redox conditions may be the cause of the higher perchlorate concentrations in this area, and perchlorate reduction may not be occurring to the extent it is in other nearby wells, perhaps delineating a pathway for perchlorate through the riparian area. At another location in the riparian area near MW-45/43, MW-08/09, MW-47/48, and OW-02 (discussed in the preceding paragraph), the reducing conditions in the shallow aquifer are disrupted by the upward flow of oxic, artesian groundwater from the deep aquifer. This same mechanism may be the cause of the disruption in the shallow aquifer reducing conditions near MW-106 and MW-109, but there are no deep wells installed in this area to confirm or refute this hypothesis.

  - A 10 acre zone in the Middle Potrero Creek area near P-06S and OW-08 where the aquifer redox conditions returns briefly to oxic, which is also supported by the seasonal water level variations in wells in this area that are indicative of recharge and the recharge rates estimated in the calibrated groundwater flow model.

  - A 2.5 acre area near the northeast injection wells IW-03, IW-04, and IW-05 and a 5 acre near the southwest injection wells IW-01 and IW-02 where there are low DO concentrations, low nitrate concentrations, elevated manganese concentrations, highly elevated iron concentrations, depressed sulfate concentrations, and high methane concentrations at two locations (IW-02 and IW-04). Thus, there are lower redox conditions near the two former injection sites than those present in the aquifer surrounding the two former injection sites.

- **Vertical Redox Trends** – The data generally show a decrease in redox conditions with depth in the upgradient recharge areas and an increase in redox conditions with depth in the downgradient discharge areas. One important deviation is noted in the BPA, where data indicate the shallower zone has more reducing conditions while the deeper zone has more oxic conditions; this is attributed to the anthropogenic influence from the known BPA COPC source area at this location.

- **General Minerals** – General minerals data generally show TDS increases between the upgradient recharge areas and the downgradient discharge areas. There is also a trend from a sodium-bicarbonate water type in the upgradient recharge areas to a sodium/calcium-bicarbonate water type in the downgradient discharge areas.

Electron Acceptor, Organic Carbon, and COPC Mass – The mass and mass flux of electron acceptors, organic carbon, and various COPCs are summarized in Table 5.1-3, the recent groundwater transport model report (Tetra Tech, 2010e), and the recent contaminant attenuation technical memorandum (Tetra Tech, 2010f). In terms of mass present, the dominant dissolved species are sulfate, nitrate, DO, DOC, and perchlorate. In terms of mass of carbon used as a substrate in redox processes, the dominant electron acceptor species are DO, nitrate, and perchlorate. In terms of contaminant mass present, the dominant species are perchlorate, 1-1-DCE, TCE, and 1,4-dioxane, respectively. Note that manganese does high and the manganese substrate stoichiometric coefficient is quite low. The mass of organic carbon directly measured as DOC in groundwater is only 10,000 pounds, however, the soil solid phase organic carbon data indicates a much larger carbon

Table 5.1-3 Mass and Mass Flux Summary, Beaumont Potrero Canyon Unit

		Inflows/Outflows (Pounds/year)								
Species	Inflow-Recharge	Inflow-Groundwater Sources	Generation from Reactions	Outflow ET	Outflow Stream	Reaction Loss	Substrate Stoichiometric Coefficient* (gm carbon substrate/gm electron acceptor)	Substrate Utilization Rate (pounds carbon per year)	Storage Mass (pounds)	Comment
Electron Acceptors										
Dissolved Oxygen	4,350	0	0	-113	-60	-4,177	0.33	1,378	16,000	Loss due to substrate reactions
Nitrate	2,800	0	0	-42	-20	-2,738	0.21	575	23,000	Loss due to substrate reactions
Manganese	0	0	38	-19	-19	0	0.09	4	360	Generation due to substrate reactions with solid phase
Perchlorate	62	95	0	-20	-1	-130	0.20	26	3,200	Loss due to substrate reactions (inflow due to soils sources, generation due to groundwater sources)
Iron	0	0	17	-11	-6	0	0.05	1	1,500	Generation due to substrate reactions with solid phase
Sulfate	9,800	0	11,270	-11,000	-10,000	-70	0.21	15	185,000	Generation due to TDS increases as groundwater moves from low TDS recharge area to high TDS discharge area; loss separated from generation using sulfide data showing low concentrations
Methane	0	0	2	-1	-1	0	1.28	3	75	Generation due to methanogenic substrate reactions
							SUM	2,001		
Substrate										
Dissolved Organic Carbon	1,000	0	1,701[1]	-300	-400	-2,001			10,000	Generation as TOC leaches from solid phase; loss due to reactions with electron acceptors
Solid Phase Organic Carbon									45,000,000	Estimated from high TOC in organic rich layers in riparian area
Other COPCs										
TCE	0	9	0	-11	-1	-1			350	Loss to cis-1,2-DCE
1,1-DCE	0	19	0	-7	-1	~0			500	

		Inflows/Outflows (Pounds/year)								
Species	Inflow-Recharge	Inflow-Groundwater Sources	Generation from Reactions	Outflow ET	Outflow Stream	Reaction Loss	Substrate Stoichiometric Coefficient* (gm carbon substrate/gm electron acceptor)	Substrate Utilization Rate (pounds carbon per year)	Storage Mass (pounds)	Comment
cis-1,2-DCE	0	0	1	-1	0	-0.1			5	Gain from TCE and Loss to vinyl chloride
Vinyl Chloride	0	0	0.1	-0.1	0	~0			1	Potential loss to CO2, H20, and CL
Dioxane	0	*4*	0	-2	-1	~0			80	

Notes:
* Modified from EPA, 1998
* Modified from EPA, 1998

1 For DOC, generation is via leaching from aquifer solid phase aquifer solid phase
Values for COPCs (Perchlorate, 1,4-dioxane, TCE, and 1,1-DCE) taken from the Flow and Transport Model Report (Tetra Tech, 2011d)

pool on the order of 45 million pounds (see Section 4.6) is present in the aquifer solids in the riparian area that potentially could release on the order of a million pounds of organic carbon. The methodology and results of the mass flux budget are discussed in more detail below.

- **Electron Acceptor, Organic Carbon, and COPC Source Areas** – Source areas and inflows of the various electron acceptors, organic carbon, and COPCs are as follows:

  – <u>Dissolved Oxygen</u> – Dissolved oxygen is added to groundwater at a rate of 4,350 pounds per year through the oxygenated diffuse recharge and stream recharge that occurs at the site. The main recharge flows are in the central and upper portions of Bedsprings Creek valley, although other recharge does occur throughout the area. This main recharge area in the central and upper portions of Bedsprings Creek valley is characterized by high DO concentrations of 5 to 8 mg/L, very near saturation concentrations. DO is not generated in significant quantities.

  – <u>Nitrate</u> - Nitrate is added to groundwater at a rate of 2,800 pounds per year through recharge. Nitrate is presumably influenced by former cattle ranching or the site activities. The main recharge area is characterized by nitrate concentrations of up to 10 mg/L; a small area with high nitrate also is found at the BPA, presumably a result of BPA activities. Nitrate is not generated in significant quantities.

  – <u>Manganese</u> - Manganese is not added to groundwater in significant quantities through recharge. Manganese is generated at a rate of 38 pounds per year by reduction of insoluble manganese IV present in the aquifer solid phase to soluble manganese II.

  – <u>Perchlorate</u> - Perchlorate is added to groundwater at a rate of 62 pounds per year through diffuse recharge that occurs through perchlorate soil sources primarily in the BPA and RMPA. Perchlorate is also generated at a rate of 95 pounds per year by flow of clean groundwater through an aquifer source area present in the BPA.

  – <u>Iron</u> - Iron is not added to groundwater in significant quantities through recharge. Iron is generated at a rate of 17 pounds per year by reduction of insoluble iron III present in the aquifer solid phase to soluble iron II.

  – <u>Sulfate</u> - Sulfate is added to groundwater at a rate of 9,800 pounds per year through recharge. The main recharge area is characterized by concentrations of 10 mg/L. Sulfate is added to groundwater at a rate of 11,270 pounds per year from interactions with the aquifer solid phase as groundwater moves downgradient and TDS increases. This addition of sulfate is supported by the increase in sulfate concentrations and mass flux between the upgradient and downgradient areas.

  – <u>Methane</u> – Methane is not added to groundwater in significant quantities through recharge. Methane is generated in a few isolated areas at a very small rate of 2 pounds per year by reduction of organic carbon present in the aquifer.

  – <u>Organic Carbon</u> – DOC is added to groundwater at a rate of 1,000 pounds per year through recharge. The main recharge area is characterized by concentrations of 1 to 2 mg/L. DOC is likely added to groundwater from interactions with the aquifer solid phase as groundwater moves downgradient, but since DOC is depleted due to reactions with DO, nitrate, manganese, and perchlorate, it currently is only possible to indirectly estimate DOC generation rates. A DOC generation rate of 1,700 pounds per year is indirectly estimated by considering the electron acceptor demand for DOC and the other net DOC fluxes (see discussion below).

- <u>Other COPCs</u> – The other COCs and COPCs (TCE, 1,1-DCE, 1,4-dioxane, cis-1,2-DCE, and vinyl chloride) are not added to groundwater through recharge, as there are no soil sources for these analytes. TCE, 1,1-DCE, and 1,4-dioxane are generated at rates of 9, 19, and 4 pounds per year, respectively, by the flow of clean groundwater through an aquifer source area present in the BPA. Vinyl chloride and cis-1,2-DCE are generated at small rates of 0.2 and 1 pounds per year, respectively, as daughter products of TCE degradation in the low methanogenic redox areas near the Large Motor Washout Area, the BPA, IW-04, and the riparian area. Note that the vinyl chloride and cis-1,2-DCE generation rates were estimated based upon the vinyl chloride and cis-1,2-DCE contour maps and the site water budget as given in Table 5.1-3, which may not precisely match generation rates based the stoichiometry of the TCE degradation reaction.

- **Electron Acceptor, Organic Carbon, and COPC Sink Areas –** Sink areas and outflows of the various electron acceptors, organic carbon, and COPCs are as follows:

  - <u>Dissolved Oxygen</u> – Dissolved oxygen discharges from the aquifer due to groundwater evapotranspiration and stream discharge at rates of 113 and 60 pounds per year, respectively. The main discharge flows are in the riparian area in the lower portions of Bedsprings Creek valley, and in the portion of Potrero Creek below well MW-18. This main discharge area is characterized by low DO concentrations of 0.3 mg/L. DO is also removed at rates of 4,177 pounds per year due to reactions with a substrate, presumed to be some form of organic carbon. This removal of DO is supported by the decline in DO concentrations and mass flux between the upgradient and downgradient areas.

  - <u>Nitrate</u> - Nitrate discharges from the aquifer due to groundwater evapotranspiration and stream discharge at rates of 42 and 20 pounds per year, respectively. The main discharge area is characterized by nitrate concentrations below 0.11 mg/L. Nitrate is also removed at rates of 2,738 pounds per year due to reaction with a substrate, presumed to be some form of organic carbon. This removal of nitrate is supported by the decline in nitrate concentrations and mass flux between the upgradient and downgradient areas.

  - <u>Manganese</u> - Manganese discharges from the aquifer due to groundwater evapotranspiration and stream discharge at rates of 19 and 19 pounds per year, respectively. The main discharge area is characterized by manganese concentrations of 0.05 to 1 mg/L. Manganese is not lost in significant quantities from the groundwater dissolved phase due to reactions.

  - <u>Perchlorate</u> - Perchlorate discharges from the aquifer due to groundwater evapotranspiration and stream discharge at rates of 20 and 1 pounds per year, respectively. The main discharge area is characterized by low perchlorate concentrations of 0.001 to 0.005 mg/L, except at the high redox area near wells OW-02/MW-45 and also possibly near the plant uptake wells MW-106 and MW-109. Perchlorate is also removed at rates of 130 pounds per year due to reactions and processes within the aquifer. This removal of perchlorate is supported by the decline in perchlorate concentrations and mass flux between the upgradient and downgradient areas. The processes that remove perchlorate include evapotranspiration; reactions within the aquifer with a substrate, presumed to be some form of organic carbon; salt filtration within the root zone (ITRC, 2005); and rhizodegradation within the root zone as part of the phytoremediation process (ITRC, 2007). The rhizodegradation process actually results in the complete destruction of perchlorate (ITRC, 2007), while the salt filtration process within the root zone can remove perchlorate from water prior to uptake by the plants (ITRC, 2005). However, currently available data does not allow distinguishing between these processes, so for the purposes of this CSM the destructive rhizodegradation process and salt filtration process is lumped together with physical removal processes such as evapotranspiration.

- <u>Iron</u> - Iron discharges from the aquifer due to groundwater evapotranspiration and stream discharge at rates of 11 and 6 pounds per year, respectively. The main discharge area is characterized by iron concentrations of 0.02 to 0.3 mg/L. Iron is not lost in significant quantities from the groundwater dissolved phase due to reactions.

- <u>Sulfate</u> - Sulfate discharges from the aquifer due to groundwater evapotranspiration and stream discharge at rates of 11,000 and 10,000 pounds per year, respectively. The main discharge area is characterized by high sulfate concentrations of 30 to 50 mg/L. Sulfate is also removed at rates of 70 pounds per year due to reaction with a substrate, presumed to be some form of organic carbon. This low removal of sulfate is supported by the low sulfide concentrations in groundwater.

- <u>Methane</u> – Methane discharges from the aquifer due to groundwater evapotranspiration and stream discharge at very low rates of 1 pound per year for each mechanism. The main discharge area is characterized by low methane concentrations of 0.001 to 0.1 mg/L.

- <u>Organic Carbon</u> – DOC discharges from the aquifer due to groundwater evapotranspiration and stream discharge at rates of 300 and 400 pounds per year, respectively. The main discharge area is characterized by DOC concentrations of 1 to 2 mg/L. DOC is also likely removed at rates of 2,000 pounds per year due to reaction with electron acceptors including DO, nitrate, manganese, and perchlorate, but this removal rate is inferred from the mass balance of the other species rather than directly calculated based upon DOC data.

- <u>Other COPCs</u> – The other COCs and COPCs (TCE, 1,1-DCE, 1,4-dioxane, cis-1,2-DCE, and vinyl chloride) discharge from the aquifer due to groundwater evapotranspiration at rates of <0.1 to 11 pounds per year, and due to stream discharge at very low rates of 0 to 1 pounds per year. The main discharge area is characterized by low concentrations of TCE, 1-1-DCE, and 1,4-dioxane relative to other plume areas, but the concentrations of cis-1,2-DCE, and vinyl chloride are somewhat higher relative to other plume areas since these analytes are generated by the degradation of TCE in the discharge area.

- **Net Budget** – Generally, the mass inflow rates for the electron acceptors and DOC in Table 5.1-3 are approximately equal to the mass outflow rates, as a steady-state budget was assumed at this preliminary stage in this study. The mass inflow/outflow rates are also approximately 0.1 to 0.05 of the total plume mass, implying approximately a 10 to 20 year residence time in the plume. This 10 to 20 year residence time in the plume is generally consistent with the 12 year transport time across the plume and the historical site conditions. Note that the mass inflow and outflow rates for TCE, 1,1-DCE, perchlorate, and 1,4-dioxane do not necessarily balance, as these rates were estimated in the recent groundwater flow and transport model study that allowed for transient budgets (Tetra Tech, 2010c).

- **Demand for TOC** - Demand for organic carbon due to redox reactions far exceeds DOC supply, suggesting DOC must be leaching from solid phase TOC to maintain the redox reactions. The 2,000 pounds per year of carbon substrate demand and an estimated 50 year plume life results in organic carbon requirements on the order of 100,000 pounds to sustain current redox conditions, which is on the order of 0.2 percent of the approximately 45 million pounds of organic carbon present in the aquifer solids. Therefore, if the leachable portion of organic carbon exceeds 0.2 percent of the total, then there should be sufficient organic carbon present to sustain current redox conditions. Since studies typically show that the water soluble portion of total organic matter is on the order of a few percent (Herbert and Bertsch, 1995; and Ma et al., 2010), there should be sufficient water soluble organic matter (1 million pounds) to sustain site redox conditions for a long time into the future. Note that the Ex-Situ Perchlorate Biodegradation Test Results indicate that a significant fraction of organic carbon appears to be biodegradable, supporting the use of these literature-reported values.

The groundwater CSM and mass flux budget does contain significant uncertainties; for example, it is apparent that there is significant variability in the data, and localized changes from the general trends. This groundwater mass flux budget is intended to serve as a guide for use in the upcoming feasibility study.

5.2 LABORDE CANYON CONTAMINANT ATTENUATION CSM

Summary of Laborde Canyon Flow and COC Transport CSM

The Laborde Canyon groundwater conceptual model was recently updated in the recent groundwater numerical flow and transport model report (Tetra Tech, 2011b). Key elements of the conceptual model include the following:

- Groundwater occurs in two primary units: the shallow weathered San Timoteo formation (wSTF) and the deeper competent San Timoteo formation (STF). The high perchlorate concentration areas of the plume are generally limited to the wSTF, except in the Test Bay Canyon and WDA source areas where high perchlorate concentration extend up to 100 feet into the competent San Timoteo formation in the areas directly beneath the sources. Outside the Test Bay Canyon and WDA source areas, plume concentrations are moderate to low and generally limited to a narrow 400 feet wide plume in the wSTF;

- Groundwater flow is generally consistent with the direction of surface water flow and topography, with flow to the south at a gradient of 0.03 through Laborde Canyon (Figure 5-6). The gradient does not vary much along the length of Laborde Canyon, suggesting that aquifer transmissivity is either constant or changing in proportion to the underflow rate;

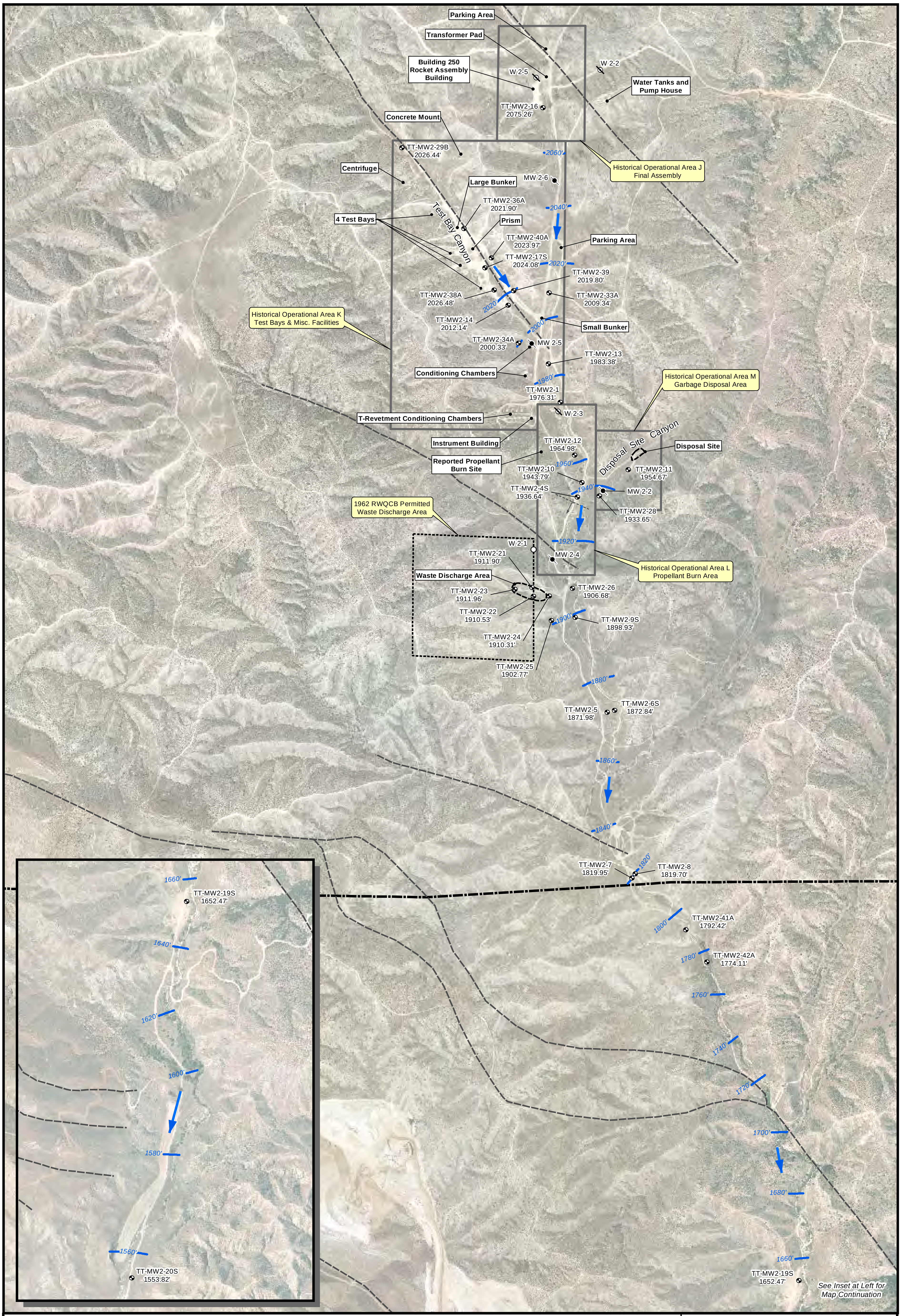
- Vertical gradients are generally downward in the upper reaches of Laborde Canyon where there is recharge, and generally upward in the riparian corridor south of the property boundary where there is discharge. There does not appear to be significant recharge or discharge to the Laborde Canyon ephemeral drainage channel. Small seasonal water table fluctuations occur in the recharge areas in Test Bay Canyon, near the WDA, and near the southern site boundary. Generally, no significant seasonal water table fluctuations occur outside of these recharge areas;

- Aquifer hydraulic conductivity values average approximately 0.16 feet per day in the wSTF, and 0.04 feet per day in the STF. Aquifer transmissivity values average approximately 10 feet2 per day in the wSTF and 1 ft2/day for individual water-bearing zones within the STF. Groundwater velocity values are estimated to average about 20 to 90 feet per year in the weathered San Timoteo using a geometric mean hydraulic conductivity value of 0.16 feet per day, a gradient of 0.03, and an effective porosity of 0.02 to 0.10. These data generally show that the age of the plume is relatively consistent with the plume extent and the velocity estimates;

- The wSTF aquifer thins to the east and west towards the margins of Laborde Canyon, where competent STF is exposed in the canyon walls. This observation limits the width of the wSTF aquifer to the approximately 400-foot width of Laborde Canyon;

- Total recharge in the wSTF is estimated to be 2.7 acre feet per year, with all recharge due to diffuse recharge over the valley floor. Total discharge in the wSTF is estimated to be 2.5

X:\GIS\Lockheed 25421-01-0603\GW_Elev_Q111.mxd



LEGEND

- ⊕ Monitoring Well Location with Groundwater Elevation (feet msl)
- ⊘ Destroyed Production Well Location
- ● Destroyed Monitoring Well Location
- ○ Reported Production Well Location
- Groundwater Elevation Contour
- Groundwater Flow Direction
- Fault, Accurately Located Showing Dip
- Fault, Approximately Located
- RWQCB Permitted Waste Discharge Area
- Historical Operational Area Boundary
- Laborde Canyon Property Boundary (Lockheed Martin Beaumont Site 2)

0 500 1,000 Feet

N

Adapted from: April 2007 aerial photograph

Faults from the, *Site 2 Lineament Study, Tetra Tech, 2009*

Notes: Laborde Canyon property boundary (Lockheed Martin Beaumont Site 2) from Hillwig-Goodrow survey, May 2004

Laborde Canyon
(Lockheed Martin Beaumont Site 2)

Figure 5-6

Groundwater Contours for First Groundwater - First Quarter 2011

TETRA TECH

acre feet per year due to evapotranspiration in the offsite riparian area. There is also a small amount of underflow further down Laborde Canyon, to the south of the offsite riparian corridor;

- Perchlorate appears to be added to the plume by the flow of groundwater through aquifer source areas in Test Bay Canyon and the WDA, and by the release of perchlorate from soil sources in Test Bay Canyon and the WDA (Figure 5-7). The current perchlorate mass flux (Table 5.2-1) released from all sources is estimated to be in the range of 24 and 250 pounds per year; the large range for perchlorate mass influx reflects the considerable uncertainty in this model parameter. Current total perchlorate mass in the groundwater plume is estimated to be approximately 3,500 pounds. Current total perchlorate mass in soils is estimated to be approximately 1,000 pounds. Minor amounts of other compounds (1,4-dioxane, TCE, RDX, and methylene chloride) are also present in a few small areas. The extent and mass of these contaminants, particularly RDX and methylene chloride, are very small relative to perchlorate.

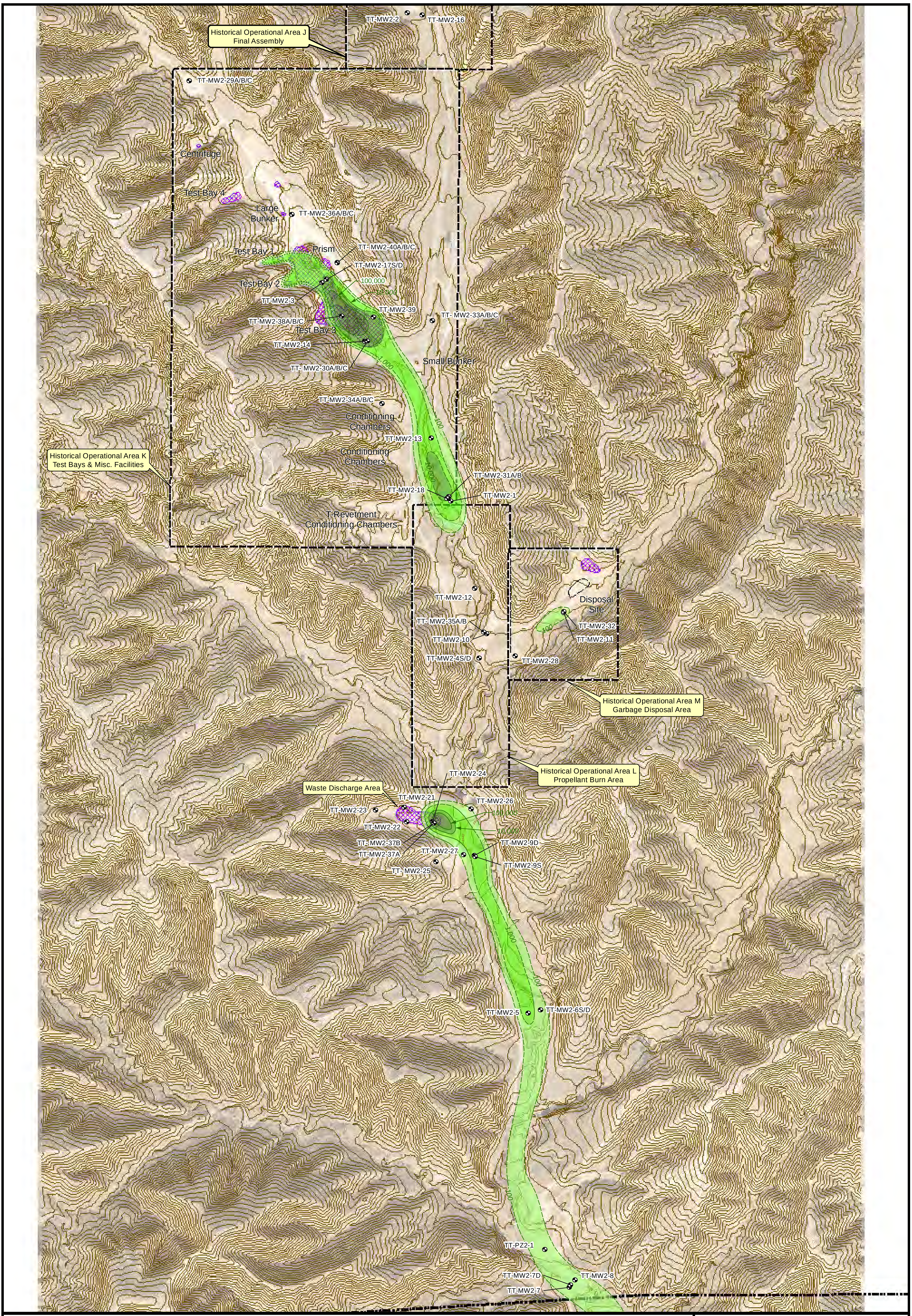
Due to the nature of the site conditions and the limited amount of groundwater monitoring data for the site, there is considerable uncertainty in the CSM. For example, while the very low recharge rates are supported by the site data, it is recognized that because there is limited data available for the site, this parameter is highly uncertain.

Summary of Contaminant Attenuation CSM

A preliminary groundwater contaminant attenuation conceptual model was presented in a recent Technical Memorandum (TM) (Tetra Tech, 2011a), which outlined the recent field program discussed in Sections 3 and 4. The Contaminant Attenuation CSM included definitions of the site contaminant attenuation conditions, including the major species relevant to COC natural attenuation processes.

The preliminary groundwater contaminant CSM is updated in the following section based upon the results of the recent field program discussed in Sections 3 and 4. Due to the limited additional data collected for Laborde Canyon (soils data for TOC; microbiological sampling; and the plant density survey), there are only minor changes in the CSM from the prior TM (Tetra Tech, 2011a). A summary of the contaminant attenuation conceptual model is as follows:

X:\GIS\Lockheed 25421-01-0603\Perch_Source_S2.mxd



LEGEND

Perchlorate in Groundwater

🟩	100 µg/L
🟩	1,000 µg/L
🟩	10,000 µg/L
🟩	100,000 µg/L

Perchlorate Soil Source

▨	>100 µg/kg

Perchlorate Isoconcentration Line

Isoconcentration Segment Inferred

Isoconcentration Segment Based on 2008 Grab Sample Data

● Monitoring Well Location

Ground Surface Elevation Contour
(10-foot interval - feet msl)

Historic Operational Area Boundary

0 300 600
Feet

Note:

µg/L - Micrograms per liter.

Laborde Canyon
(Lockheed Martin Beaumont Site 2)

Figure 5-7

Perchlorate Source Areas and Groundwater Impacts

TETRA TECH

Table 5.2-1 Laborde Canyon Flow and Transport Model Perchlorate Mass and Mass Flux Summary for the 2006 through 2010 Period

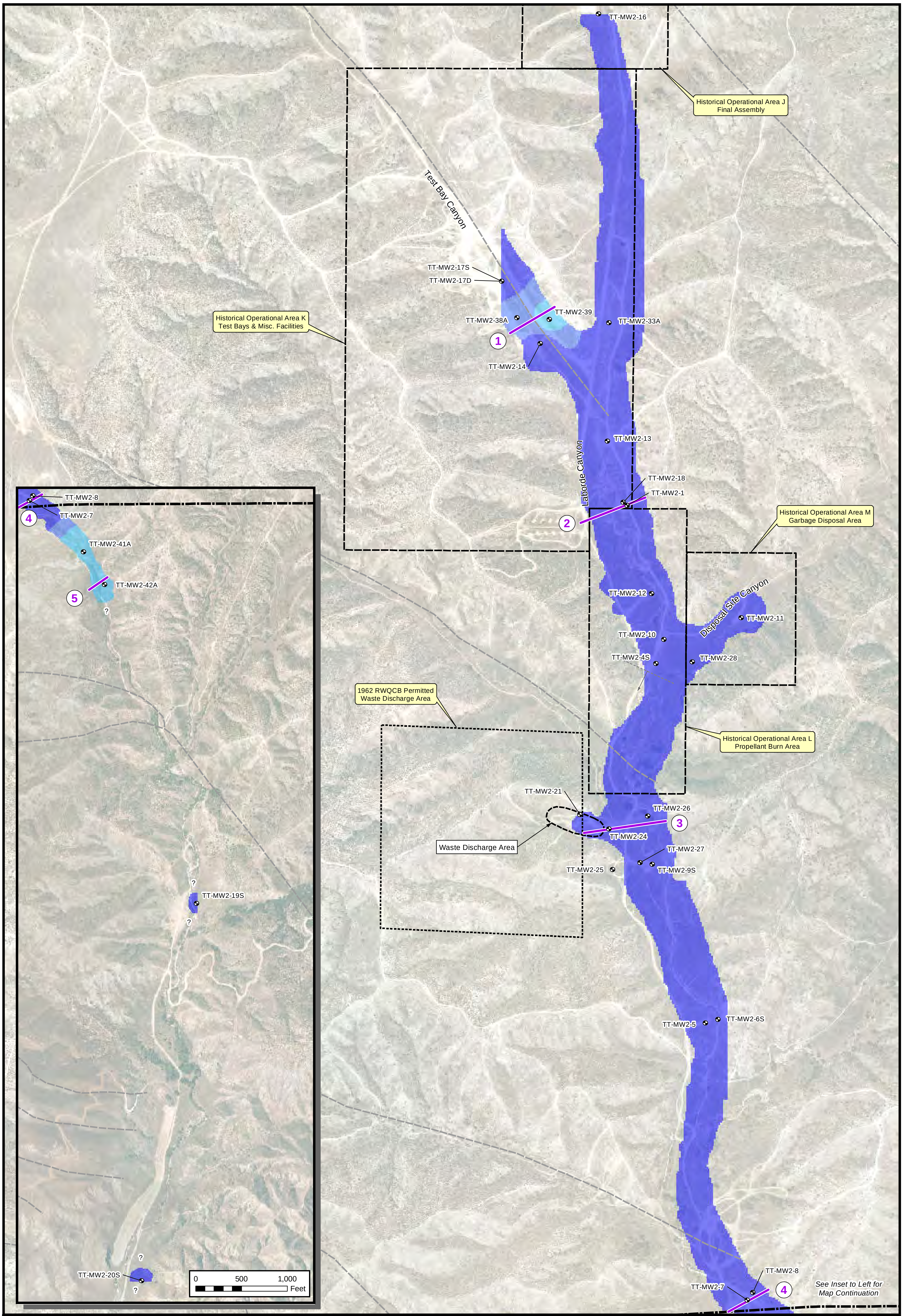
TRANSPORT MODEL PREDICTIONS		
	Total Mass (pounds)	Mass Flux (pounds/year)
Sources	987	246.9
Wells	0	0
Creek	0	0
Evapotranspiration	-0.67	-0.17
Underflow downgradient	1.09E-05	2.74E-06
Degradation	0	0
2010 Plume Mass	3,372	NA
CONCEPTUAL MODEL VALUES		
	Perchlorate	
	Total Mass (pounds)	Mass Flux (pounds/year)
Sources	990	247
Wells	0	0
Creek	0	0
Evapotranspiration	-4	-1
Underflow downgradient	0.00E+00	0.00E+00
Degradation	0	0
2010 Plume Mass	4,395	NA

- Key Contaminant Attenuation Species – Given that (1) the site plume extends from an upgradient groundwater recharge area where the aquifer is primarily oxic to a downgradient groundwater discharge area where the aquifer is bordering on mildly anoxic, and (2) the site plume primarily consists of perchlorate, 1,4-dioxane, and TCE, the following aquifer water quality parameters are key species related to contaminant attenuation and the gradual transition of the plume from oxic to anoxic conditions: dissolved oxygen (DO), nitrate, dissolved manganese, dissolved iron, sulfate/sulfide, hydrogen, methane, organic carbon, cis-1,2-DCE, and vinyl chloride. Oxidation-reduction potential (ORP) is also an indicator of the oxic to anoxic transition. Maps presenting the spatial distribution of these parameters are provided in Appendix A of the TM (Tetra Tech, 2011a). The overall redox state of groundwater was defined using water quality data to identify the dominant types of redox process occurring in the wSTF aquifer, using USGS software and threshold values (Jurgens et al., 2009). The results of this evaluation is summarized in Table 5.2-2 and plotted in Figure 5-8. Note that volatile fatty acids (VFAs) are often important organic carbon sources for contaminant degradation, but the site data show only trace concentrations of VFAs in most areas, the exception being wells

Table 5.2-2 Redox Assignment for Beaumont Laborde Canyon Groundwater Samples

	Redox Variables	*Dissolved O_2*	*NO_3^- (as Nitrogen)*	*Mn^{2+}*	*Fe^{2+}*	*SO_4^{2-}*	*Sulfide (sum of H_2S, HS^-, S^{2-})*	***Redox Assignment***			
	Units	millig/L	millig/L	microg/L	microg/L	millig/L	millig/L				*Fe^{2+}/ Sulfide, ratio*
Sample ID	Threshold values	**0.5**	**0.5**	**50**	**100**	**0.5**	**none**	Num of Params	General Redox Category	Redox Process	
TT-MW2-1	Clear Redox Assignments	5.09	7.30	1.20	23.33	31.00	0.00	6	Oxic	O2	
TT-MW2-10		2.40	0.11	2.50	30.00	75.00	0.00	6	Oxic	O2	
TT-MW2-11		3.56	16.00	2.50	60.00	62.00	0.00	6	Oxic	O2	
TT-MW2-12		2.47	0.11	1.20	16.67	53.00	0.02	6	Oxic	O2	
TT-MW2-13		6.54	7.90	1.20	0.00	42.00		5	Oxic	O2	
TT-MW2-14	Assign Redox Categories and Processes	4.04	14.00	1.20	33.33	170.00	0.00	6	Oxic	O2	
TT-MW2-16		5.45	27.00	1.20	50.00	30.00	0.01	6	Oxic	O2	
TT-MW2-17D		0.50	8.70	25.00	40.00	54.00	0.01	6	Oxic	O2	
TT-MW2-17S		1.51	27.00	1.80	0.00	25.00	0.00	6	Oxic	O2	
TT-MW2-18		1.34	0.75	2.50	10.00	44.00	0.00	6	Oxic	O2	
TT-MW2-19S		2.27	4.80	2.50	50.00	100.00	0.01	6	Oxic	O2	
TT-MW2-20D		0.38	0.11	1.20	80.00	170.00	0.04	6	Suboxic	Suboxic	
TT-MW2-20S		3.13	0.11	1.20	50.00	210.00	0.00	6	Oxic	O2	
TT-MW2-21		0.75	0.11	2.50	10.00	43.00	0.01	6	Oxic	O2	
TT-MW2-22		0.41	0.11	4.90	80.00	15.00	0.00	6	Suboxic	Suboxic	
TT-MW2-23		0.45	0.11	2.50	93.33	26.00	0.10	6	Suboxic	Suboxic	
TT-MW2-24		0.66	55.00	3.30	36.67	95.00	0.01	6	Oxic	O2	
TT-MW2-25		0.74	0.11	11.00	10.00	26.00	0.00	6	Oxic	O2	
TT-MW2-26		1.05	3.60	39.00	30.00	88.00	0.00	6	Oxic	O2	
TT-MW2-27		0.99	0.11	36.00	240.00	76.00	0.00	6	Mixed(oxic-anoxic)	O2	
TT-MW2-28		1.29	0.29	49.00	40.00	79.00	0.02	6	Oxic	O2	
TT-MW2-33A		0.65	0.17	40.00	70.00	20.00	0.01	6	Oxic	O2	
TT-MW2-38A		1.07	15.00	8.90	150.00	39.00	0.01	6	Mixed(oxic-anoxic)	O2-Fe(III)	15.00
TT-MW2-39		0.85	23.00	27.00	110.00	65.00	0.02	6	Mixed(oxic-anoxic)	O2-Fe(III)-SO4	5.50
TT-MW2-41A		1.07	0.11	4.60	110.00	97.00	0.11	6	Mixed(oxic-anoxic)	O2-Fe(III)-SO4	1.00
TT-MW2-42A		0.91	0.11	77.00	270.00	33.00	0.06	6	Mixed(oxic-anoxic)	O2-Fe(III)-SO4	4.50
TT-MW2-4S		3.57	0.80	2.50	20.00	49.00	0.00	6	Oxic	O2	
TT-MW2-5		4.67	10.00	1.20	80.00	140.00	0.01	6	Oxic	O2	
TT-MW2-6S		3.21	8.20	2.50	0.00	120.00	0.00	6	Oxic	O2	
TT-MW2-7		2.38	6.20	1.20	46.67	190.00	0.00	6	Oxic	O2	
TT-MW2-7D		0.39	0.11	1.20	10.00	20.00	0.16	6	Suboxic	Suboxic	
TT-MW2-8		3.01	7.20	1.20	40.00	180.00	0.00	6	Oxic	O2	
TT-MW2-9S		1.82	12.00	2.50	46.67	130.00	0.00	6	Oxic	O2	

X:\GIS\Lockheed 25421-01-0603\REDOX_S2.mxd



- ● Well Location
- ① Line Segment Used to Determine Underflow Rate
- Fault, Accurately Located Showing Dip
- Fault, Approximately Located
- Waste Discharge Area
- RWQCB Permitted Waste Discharge Area
- Historical Operational Area Boundary
- Laborde Canyon Property Boundary (Lockheed Martin Beaumont Site 2)

Redox Conditions in Groundwater

Increasingly Reduced

- 🟥 Methanogenesis
- 🟧 Ferrous Iron - Sulfate ($Fe(II)$ - SO_4) Reduction
- 🟨 Ferrous Iron - Fe(II) Reduction
- 🟨 Manganese (Mn) Reduction
- 🟩 Mixed Nitrate - Ferrous Iron - Sulfate (NO_3- Fe(II)-SO_4) Reduction
- 🟦 Nitrate - (NO_3) Reduction

Mixed

- 🟦 Dissolved Oxygen - Ferrous Iron - Sulfate (O_2-Fe(II) - SO_4)
- 🟦 Dissolved Oxygen - Ferrous Iron O_2-Fe(II)

Oxic

- 🟪 Dissolved Oxygen (O_2)

N

0 300 600 Feet

Adapted from:
April 2007 aerial photograph.
Faults from the *Site 2 Lineament Study, Tetra Tech, 2009.*

Note:
Beaumont Site 2 property boundary from Hillwig-Goodrow survey, May 2004.

Values based on data collected from June 2010 to July 2010.

Laborde Canyon
(Lockheed Martin Beaumont Site 2)

Figure 5-8

Redox Conditions

TETRA TECH

TT-MW2-23 and TT-MW2-24 in the WDA. Therefore, while VFAs are typically important for contaminant degradation, VFAs do not appear to be important to perchlorate degradation at Laborde Canyon, except potentially in wells TT-MW2-23 and TT-MW2-24.

- Water Quality Distribution and Redox Conditions – The various maps depicting the spatial distribution of water quality parameters in the wSTF indicate that redox conditions are relatively uniform across the site, with the only variations being in a portion of Test Bay Canyon, near the WDA, and in the offsite riparian corridor. The redox conditions across most of the site, which is primarily a recharge area, are mainly oxic where the dominant redox process is oxygen reduction. The exceptions onsite are in wells TT-MW2-38A and TT-MW2-39 in Test Bay Canyon, where DO concentrations are low, nitrate concentrations are relatively high, dissolved iron and manganese concentrations are somewhat elevated, methane is not generated significantly, and sulfate and perchlorate do not appear to be depleted. Redox conditions in Test Bay Canyon may be best characterized as nitrate to iron reducing, although due to the limited data there is uncertainty in the exact redox condition. The redox conditions also shift to mixed oxic-anoxic in the offsite riparian corridor, as supported by low levels of manganese and iron generation; depletion of nitrate; and low to moderate levels of DO. The overall site redox levels are generally supported by the ORP data, which show values near 100 mV except lower toward offsite riparian corridor where values are near 0 mV and in the WDA where values are below 0 mV). Dissolved hydrogen concentrations, which range from 1.9 to 7.6 nM with one outlier value of 64 nM, are suggestive of highly reduced (sulfate-reducing to methanogenic) conditions, which are not supported by the generally low sulfide and methane concentrations in groundwater. Note that the USGS software does not include the use of methane, hydrogen, and perchlorate data that were available at Laborde Canyon, so some of the site observations may have minor deviations from the USGS-derived redox scheme (Table 5.2-2) based upon this additional site data. Other significant features of the site redox conditions are as follows:

    - Sulfate depletion is not apparent at any locations and methane concentrations are small; therefore, sulfate reduction and methanogenesis are generally not important redox processes. Very little sulfide also is present, further supporting the argument that sulfate reduction is not widespread or significant. While there is one exception (well TT-MW-7D near the southern site boundary) where sulfate is partially depleted and methane is generated, in the majority of the plume, the redox levels are too high for either perchlorate or chlorinated solvent degradation. The degradation byproducts of TCE (cis-1,2-DCE and vinyl chloride) are also not significantly present at the site, further supporting the lack of significant TCE degradation.

- Vertical Redox Trends – The data show a general decrease in oxidation state with depth, with more reducing conditions observed in the STF than in the shallow wSTF.

- General Minerals – There is a general trend for higher chloride concentrations in the more highly perchlorate-contaminated wells, which could be an indication of past perchlorate degradation in this area. However, it is noted that if the chloride was entirely a byproduct of perchlorate biodegradation, mass balance requires that the sum of chloride and perchlorate (expressed in molar units) be approximately constant along the length of the plume. This is not the case for the Test Bay Canyon and WDA plumes, both of which have relatively high perchlorate and chloride concentrations in the source area and lower concentrations downgradient. It is further noted that mass balance would also require unrealistically large amounts of perchlorate biodegradation to account for the relatively high chloride concentrations observed in the source areas. The observed distribution of chloride thus appears to be more consistent with a source of chloride at or near the primary perchlorate source areas, rather than perchlorate biodegradation. Rocket motor testing or fuel incineration, both of which may produce chloride salts as byproducts, are processes which could account for the chloride observed in Test Bay Canyon and the WDA. General minerals data generally show TDS increases between the upgradient and downgradient areas.

- Time Trends – The available data is insufficient to quantitatively assess time trends in redox conditions. Data on time trends of COPCs are given in Section 4.5.

  Electron Acceptor, Organic Carbon, and COPC Mass – The mass and mass flux of electron acceptors, organic carbon, and various COPCs are summarized in Table 5.2-3, and in the groundwater flow and transport model report (Tetra Tech, 2011b). In terms of mass present, the dominant dissolved species are sulfate, nitrate, perchlorate, DO, and DOC. In terms of mass flux, the dominant species are sulfate, perchlorate, nitrate, DO, and DOC. In terms of mass of carbon used as a substrate in redox processes, the dominant electron acceptor species are nitrate and DO. In terms of contaminant mass present, the dominant species is perchlorate. Note that manganese does not contribute much to carbon substrate depletion, as the manganese concentrations are very low and the manganese substrate stoichiometric coefficient is quite small. The mass of organic carbon directly measured as DOC in groundwater is only 2,238 pounds; the probable origin of the

Table 5.2-3 Laborde Canyon Mass and Mass Flux Summary

		Inflows/Outflows (Pounds/year)							Underflow Rate (pounds/year)						
Species	Inflow Recharge	Inflow-Groundwater Sources	Generation from Reactions	Outflow ET	Outflow Stream	Reaction Loss	Substrate Stoichiometric Coefficient[1]	Substrate Utilization Rate (pounds of carbon per year)	Test Bay Canyon (Line 1)	Mid-Laborde Canyon (Line 2)	WDA (Line 3)	Southern Site Boundary (Line 4)	Offsite Riparian Corridor (Line 5)	Storage Mass (pounds)	Comment
Electron Acceptors															
Dissolved O_2	37	0	0	-7	0	-30	0.33	9.8	5.1	39.1	10.8	31.4	5.2	2,984	Loss due to substrate reactions
Nitrate	59	0	0	-1	0	-58	0.21	12.1	35	27	154	50	1	5,968	Loss due to substrate reactions
Manganese	0.00	0.00	0.27	-0.27	0	0.0	0.09	0.02	0.05	0.01	0.16	0.01	0.18	4.5	Generation due to substrate reactions with solid phase
Perchlorate	24	up to 226	0	0	0	0	0.20	0	276	26	263	2	0	3,500	Uncertainty in inflow rate due to short monitoring period
Iron	0	0	1.02	-1.02	0	0	0.05	0.05	0.34	0.11	0.45	0.37	0.62	8.3	Generation due to substrate reactions with solid phase
Sulfate	366	0	~ 35 to 835	~ -400 to -1,200	0	-1	0.21	0.2	129	137	1,022	1,363	114	111,905	Generation due to TDS increases as groundwater moves from low TDS recharge area to high TDS discharge area; loss separated from generation using sulfide data showing low concentrations; large uncertainty in riparian area discharge
Methane	0	0	0.01	-0.01	0	0	1.28	0.02	-	-	-	-	-	2.4	Generation due to methanogenic substrate reactions
Substrate															
Dissolved Organic Carbon	7	0	23	-8	0	-22	-	-	1.9	5.6	30.3	11.9	3.6	2,238	Generation as TOC leaches from solid phase; loss due to reactions with electron acceptors
Solid Phase Organic Carbon	-	-	-	-	-	-	-	-	-	-	-	-	-	14,000,000	

Notes:

1. Stoichiometric coefficient in units of grams of substrate/gram of electron donor; modified from USEPA, 1998.
2. The COC values (perchlorate) were defined using a transient budget from the recent transport model
3. For DOC, generation is via leaching from the aquifer solid phase
4. A steady-state budget was assumed for all species except perchlorate

dissolved organic carbon is a geologic source that has been in place for thousands of years. However, the soil solid phase organic carbon data indicates a much larger carbon pool (on the order of 14 million pounds) may be present in the aquifer, which could potentially release on the order of one half million pounds of organic carbon. The organic carbon mass on the order of 14 million pounds was estimated for the saturated zone soils using the aquifer bulk volume and fraction organic carbon data, where a bulk average fraction organic carbon value of 1,000 mg/kg was used based upon the fraction organic carbon values measured at the site. The methodology and results of the mass flux budget are discussed in more detail below.

- Electron Acceptor, Organic Carbon, and COPC Source Areas – Source areas and inflows of the various electron acceptors, organic carbon, and perchlorate are as follows:

  - DO – DO is added to groundwater at a rate of 37 pounds per year through the oxygenated diffuse recharge that occurs at the site. The main recharge flows are in Test Bay Canyon, although other recharge does occur throughout the entire site. This main recharge area is characterized by DO concentrations of 2 to 5 mg/L. DO is not generated in significant quantities.

  - Nitrate - Nitrate (as N) is added to groundwater at a rate of 59 pounds per year through recharge. The highest nitrate concentrations are in the perchlorate source areas. Nitrate therefore appears to be influenced by former site activities. The main recharge area is characterized by nitrate (as N) concentrations of 1 to 10 mg/L although small areas with high nitrate (as N) concentrations of 15 to 50 mg/L are found at the WDA and Test Bay Canyon, again presumably a result of site activities. Nitrate is not generated in significant quantities.

  - Manganese - Manganese is not added to groundwater in significant quantities through recharge. Manganese is generated at a rate of 0.27 pounds per year by reduction of insoluble Mn(IV) present in the aquifer solid phase to soluble Mn(II).

  - Perchlorate - Perchlorate is added to groundwater at a rate of between 24 and 250 pounds per year through diffuse recharge that occurs through perchlorate soil sources and the flow of clean groundwater through possible aquifer source areas present in Test Bay Canyon and the WDA; the large range for perchlorate mass influx reflects the considerable uncertainty in this model parameter.

  - Iron - Iron is not added to groundwater in significant quantities through recharge. Iron is generated at a rate of 1 pound per year by reduction of insoluble Fe(III) present in the aquifer solid phase to soluble Fe(II).

  - Sulfate - Sulfate is added to groundwater at a rate of 366 pounds per year through recharge. The main recharge area is characterized by concentrations of 50 mg/L. Sulfate is added to groundwater at a rate of up to 1,000 pounds per year from interactions with the aquifer solid phase as groundwater moves downgradient and TDS increases. The addition of sulfate is supported by the increase in sulfate concentrations and mass flux between the upgradient and downgradient areas, although the decline in sulfate concentrations within the offsite riparian area is not well understood.

- Methane – Methane is not added to groundwater in significant quantities through recharge. Methane is generated in a few isolated areas at a very small rate of 0.01 pounds per year by reduction of carbon dioxide present in the aquifer.

- Organic Carbon – DOC is added to groundwater at a rate of 7 pounds per year through recharge. The main recharge area is characterized by concentrations of 1 mg/L. DOC is likely added to groundwater from interactions with the aquifer solid phase as groundwater moves downgradient, but since DOC is depleted due to reactions with primarily DO and nitrate, it currently is only possible to indirectly estimate DOC generation rates. A DOC generation rate of 23 pounds per year is indirectly estimated by considering the electron acceptor demand for DOC and the other net DOC fluxes (see discussion below).

- Electron Acceptor, Organic Carbon, and COPC Sink Areas – Sink areas and outflows of the various electron acceptors, organic carbon, and COPCs are as follows:

  - DO – DO discharges from the aquifer due to groundwater evapotranspiration at rates of 7 pounds per year. The main discharge flows are in the offsite riparian corridor south of the property boundary. This main discharge area is characterized by DO concentrations of 1 mg/L. DO is also removed at rates of 30 pounds per year due to reactions with a substrate, presumed to be some form of organic carbon. This removal of DO is weakly supported by the decline in DO concentrations and mass flux between the upgradient and downgradient areas.

  - Nitrate - Nitrate discharges from the aquifer due to groundwater evapotranspiration at rates of 1 pound per year. The main discharge area is characterized by nitrate concentrations below 0.11 mg/L. Nitrate is also removed at rates of 58 pounds per year due to reaction with a substrate, presumed to be some form of organic carbon. This removal of nitrate is weakly supported by the decline in nitrate concentrations and mass flux between the upgradient and downgradient areas.

  - Manganese - Manganese discharges from the aquifer due to groundwater evapotranspiration at rates of 0.27 pounds per year. The main discharge area is characterized by manganese concentrations of 0.005 to 0.08 mg/L. Manganese is not lost in significant quantities from the groundwater dissolved phase due to reactions.

  - Iron - Iron discharges from the aquifer due to groundwater evapotranspiration at rates of 1 pound per year. The main discharge area is characterized by iron concentrations of 0.11 to 0.27 mg/L. Iron is not lost in significant quantities from the groundwater dissolved phase due to reactions.

  - Sulfate - Sulfate discharges from the aquifer due to groundwater evapotranspiration at rates of 400 to 1,200 pounds per year. The main discharge area is characterized by high sulfate concentrations of 33 to 97 mg/L. Sulfate is also removed at low rates of 1 pound per year due to reaction with a substrate, presumed to be some form of organic carbon.

This low removal of sulfate is supported by the low sulfide concentrations in groundwater. Note that while the WDA and Test Bays do have sulfate concentrations that are somewhat lower than other downgradient areas of the site, they are consistent with the WDA and Test Bays being recharge areas located in a side canyon off the main Laborde Canyon and the sulfate concentrations reported in other upgradient recharge areas (for example, wells TT-MW2-33A and TT-MW2-16), as opposed to being indicative of sulfate removal.

  - Methane – Methane discharges from the aquifer due to groundwater evapotranspiration at very low rates of 0.01 pounds per year. The main discharge area is characterized by low methane concentrations of 0.001 to 0.004 mg/L.

  - Organic Carbon – DOC discharges from the aquifer due to groundwater evapotranspiration at rates of 8 pounds per year. The main discharge area is characterized by DOC concentrations of 0.6 to 1.9 mg/L. DOC is also likely removed at rates of 22 pounds per year due to reaction with electron acceptors, primarily DO and nitrate, but this removal rate is inferred from the mass balance of the other species rather than directly calculated based upon DOC data.

  - Perchlorate - Perchlorate currently does not discharge from the aquifer since concentrations are below the detection limit. Perchlorate also is not significantly removed due to reactions with a substrate since the redox levels do not appear to be low enough to support perchlorate reduction in the main plume area. The only area where redox levels appear low enough to potentially support perchlorate reduction is the offsite riparian corridor; however, perchlorate levels are very low flowing into this area, suggesting that perchlorate reduction rates are low if reduction is occurring at all. Note that the processes that remove perchlorate include evapotranspiration; reactions within the aquifer with a substrate, presumed to be some form of organic carbon; salt filtration within the root zone (ITRC, 2005); and rhizodegradation within the root zone as part of the phytoremediation process (ITRC, 2007). The rhizodegradation process actually results in the complete destruction of perchlorate (ITRC, 2007), while the salt filtration process within the root zone can remove perchlorate from water prior to uptake by the plants (ITRC, 2005). However, currently available data does not allow distinguishing between these processes, so for the purposes of this CSM the destructive rhizodegradation process and salt filtration process is lumped together with physical removal processes such as evapotranspiration.

- Net Budget – Generally, the mass inflow rates for the electron acceptors and DOC in Table 5.2-3 are approximately equal to the mass outflow rates, as a steady-state budget was assumed at this preliminary stage in this study. The mass inflow/outflow rates are also approximately 1 percent of the total plume mass, implying approximately a 100 year residence time in the plume. The 100 year residence time in the plume is generally consistent with the transport time across the plumes and the historical site conditions. Note that the mass inflow and outflow rates for perchlorate do not balance, as these rates were estimated in the recent groundwater flow and transport model study that allowed for a transient budget.

- Demand for TOC - Demand for organic carbon due to redox reactions far exceeds DOC supply, suggesting DOC must be leaching from solid phase TOC to maintain the redox reactions. The 23 pounds per year of carbon substrate demand and an estimated 50 year plume life results in organic carbon requirements on the order of 1,150 pounds to sustain current redox conditions, which is less than 0.01 percent of the approximately 14 million pounds of organic carbon present in the aquifer solids. Therefore, if the leachable portion of organic carbon exceeds 0.01 percent of the total, then there should be sufficient organic carbon present to sustain current redox conditions for at least 50 more years. Since studies typically show that the water soluble portion of total organic matter is on the order of a few percent (Herbert and Bertsch, 1995; and Ma et al., 2010), there should be sufficient water soluble organic matter (one half million pounds) to sustain site redox conditions for a long time into the future. Note that the Ex-Situ Perchlorate Biodegradation Test Results indicate that a significant fraction of organic carbon appears to be biodegradable, supporting the use of these literature-reported values.

The groundwater CSM and mass flux budget does contain significant uncertainties; for example, it is apparent that there is significant variability in the data, and localized changes from the general trends. This groundwater mass flux budget is intended to serve as a guide for future data collection efforts, and use in the upcoming site FS.

5.3 CONTAMINANT ATTENUATION CAPACITY OF AQUIFER

5.3.1 Potrero Canyon Unit

The Potrero Canyon Unit investigation has identified two primary mechanisms by which contaminants are attenuated in the Site groundwater plume: discharge by evapotranspiration and degradation due to reducing conditions in the riparian area. In addition, there is a smaller amount of degradation at the primary source area in the BPA and near the former RMPA system injection wells.

Based upon both the site modeling work and the recently completed field investigations, including the riparian area plant survey, evapotranspiration is estimated to discharge approximately 130 acre-feet per year of groundwater from the plume via plant uptake. Given that the plume underflow rate into the riparian area is approximately 185 acre-feet per year, this mechanism alone appears to remove approximately 70 percent of the Potrero Canyon Unit groundwater plume volume. Evapotranspiration also removes approximately 40 pounds per year of contaminants from the plume. Given that the plume mass flux rate into the riparian area is approximately 187.9 to 189 pounds per year, this mechanism appears to remove approximately 22 percent of the Potrero Canyon Unit groundwater plume mass flux. The fraction of plume mass flux removed by evapotranspiration (22 percent) is lower than the fraction of plume volume removed by evapotranspiration (70 percent) because a large fraction of the plume mass is removed by degradation prior to evapotranspiration uptake (see below).

Based upon both the site modeling work and the recently completed field investigation, contaminant degradation in the riparian area is estimated to remove 135 pounds per year from the Potrero Canyon Unit plume. Given that the plume mass flux rate into the riparian area is 185 pounds per year, this mechanism alone appears to remove 72 percent of the Potrero Canyon Unit groundwater plume mass. In addition, contaminant degradation in the former injection well area and the BPA is estimated to remove 1 pound per year from the Potrero Canyon Unit plume (approximately 0.5 percent). The TOC data collected in this investigation indicates that there is enough organic carbon in the riparian area to support continued contaminant degradation for several hundreds of years into the future. For example, using the 1 million pounds of bioavailable organic carbon estimated for the aquifer solids in the riparian area (45 million pounds of total organic carbon with the bioavailable fraction being on the order of a few percent; Herbert and Bertsch, 1995; and Ma et al., 2010), this organic carbon has the potential to last 500 years given the current aquifer organic carbon utilization rate of 2,000 pounds per year. Given the current perchlorate degradation rate of 135 pounds per year, this would equate to 67,500 pounds of perchlorate, which is far more than the total perchlorate that is projected to be available from the Potrero Canyon Unit plume. Thus, the contaminant attenuation potential of the aquifer would appear to exceed to available contaminant supply. However, this contaminant attenuation capacity is not immediately available, as time and aquifer reactions are required to release this organic carbon into the aqueous phase where the contaminants reside and degradation occurs, such that the maximum sustainable release rate of the organic carbon is not known but available site data and modeling results suggest releases rate are at least 2,000 pounds per year.

It is also important to note that the evapotranspiration and degradation mechanisms are coupled. For example, if perchlorate degradation declined in the riparian area there would be a commensurate increase in perchlorate discharge by evapotranspiration, and any attempt to assign attenuation capacity to one mechanism must also reference the impacts of the other. Based upon current conditions where approximately 130 pounds per year of contaminants are removed from the plume by degradation, then evapotranspiration is estimated to remove 40 pounds per year of contaminants in the riparian area. However, a decrease in the degradation removal rate would also result in a commensurate increase in contaminant discharge by evapotranspiration. Since 70 percent of the plume volume is removed by riparian area evapotranspiration, a one (1) pound decrease in the degradation rate would result in a 0.7 pound increase in the evapotranspiration removal rate.

The plume contaminant mass flux removal rate due to both evapotranspiration and degradation is 175 pounds per year, which accounts for approximately 95 percent of the plume contaminant mass flux of 185 pounds per year. In addition to the contaminant mass flux removal rate of 175 pounds per year due to evapotranspiration and degradation, approximately 1.7 to 4.4 pounds per year is estimated to be removed by discharge of contaminants to Potrero Creek at very low concentrations, and approximately 0.4 pounds per year is estimated to be removed by leakage of contaminants into the Mt Eden aquifer at very low concentrations.

The remaining difference of a few pounds per year between the total attenuation rate and the total underflow rate is attributed to the inherent difficulty in trying to approximate steady state mass flux rates from a transient groundwater system that is actually modeled in a transient groundwater transport model. For example, the available site data indicates the groundwater system is approximately in steady-state where estimated influxes equal estimate outfluxes, however, there is some uncertainty in both the influx and outflux estimates, such that a small imbalance in steady-state conditions may exist but not be detected given the uncertainty inherent in the numbers. Actually, some site data would seem to suggest current influx may be slightly smaller than current outflux (as well as past historical influx), however, the transport model calibration is not reliable enough to reliably make this conclusion.

5.3.2 Laborde Canyon

The Laborde Canyon investigation has not identified any significant mechanisms by which contaminants are currently being significantly attenuated within the Site groundwater plume. Within the overall Laborde Canyon area, there are two potential attenuation mechanisms in the Offsite riparian area south of the site boundary: discharge by evapotranspiration and degradation. However, since the plume has not yet migrated into the Offsite riparian area, there are currently no active attenuation mechanisms within the Laborde Canyon plume.

Offsite Riparian Area Attenuation Potential

Based upon both the site modeling work and the recently completed field investigation including the riparian area plant survey, evapotranspiration is estimated to discharge approximately 2.5 acre-feet per year of groundwater from the Offsite riparian area via plant uptake. This potentially could consume some of the underflow in the Laborde Canyon plume. However, since there is considerable uncertainty in the water budget and plume underflow rate, the significance of the 2.5 acre-feet per year of groundwater lost to evapotranspiration in the Offsite riparian with respect to the overall plume underflow rate is difficult to estimate.

Based upon both the site modeling work and the recently completed field investigations, the Offsite riparian area has redox conditions that may be low enough to support future perchlorate degradation, should the plume migrate into the Offsite Riparian area at some point in the future. However, unlike the Potrero Canyon Unit riparian where redox conditions are clearly anoxic and the redox process is manganese to iron reducing, the Laborde Canyon riparian area has mixed oxic-anoxic redox conditions where the redox process is oxygen to iron reducing. Thus, at the Laborde Canyon riparian area it is not entirely clear whether perchlorate will degrade, since oxygen could interfere with perchlorate reduction. Thus, until the plume migrates into this area and the potential for degradation of perchlorate can be quantitatively assessed, it is currently not possible to estimate whether and at what rates perchlorate may be degraded in this area.

SECTION 6 CONCLUSIONS AND RECOMMENDATIONS

This section presents a summary of the primary conclusions and recommendations of the contaminant attenuation evaluation study.

6.1 CONCLUSIONS

Potrero Canyon Unit

Primary Attenuation Mechanisms

This investigation has identified two primary mechanisms by which contaminants are attenuated in the Potrero Canyon Unit groundwater plume: (1) discharge by evapotranspiration, and (2) degradation due to reducing conditions in the riparian area. In addition, a more limited amount of degradation also occurs due to smaller scale reducing conditions in the BPA, near the former RMPA extraction/injection system injection wells, and at the Large Motor Washout Area.

Evapotranspiration

Evapotranspiration in the riparian area is estimated to discharge approximately 130 acre-feet per year of groundwater from the plume via plant uptake. This finding is supported by several independent lines of evidence, including site monitoring investigations showing diurnal water level trends that are consistent with the evapotranspiration mechanism; the site CSM dating back to a 1986 water supply investigation that identifies evapotranspiration as a significant component of the Bedsprings Creek aquifer water budget; the recently calibrated site groundwater flow and transport models; and the recently completed field investigations, which included a riparian area plant survey that found the quantity of high water use vegetation that exists within the riparian would require evapotranspiration from groundwater at rates on the order of 177 acre-feet per year.

Evapotranspiration of groundwater at a rate of 130 acre-feet per year removes approximately 70 percent of the Potrero Canyon Unit groundwater plume volumetric flow of 185 acre-feet per year. In addition, evapotranspiration also removes approximately 40 pounds per year of contaminants from the plume or approximately 22 percent of the Potrero Canyon Unit groundwater plume mass flux of 187.9 to 189 pounds per year. The percent of plume mass removed by evapotranspiration (22 percent) is smaller than the percent of plume volumetric flow removed by evapotranspiration (70 percent) due to the removal of plume mass via degradation prior to evapotranspiration withdrawal (see below).

Degradation

Contaminant degradation in the riparian area is estimated to remove 135 pounds per year of contaminants from the Potrero Canyon Unit plume, or 72 percent of the groundwater plume mass flux of 187.9 to 189 pounds per year. In addition, contaminant degradation in the former injection well area, the BPA, and the Large Motor Washout Area is estimated to remove another 1 to 2 pounds per year from the plume (approximately 0.5 to 1 percent). This finding is supported by several independent lines of evidence, including site monitoring over a 20-plus year monitoring period that show essentially no expansion of the site plume into the area below the riparian zone where degradation is occurring; the site CSM including geochemical signatures consistent with perchlorate degradation; the recently calibrated site groundwater flow and transport models; and the recently completed field and laboratory investigations which included a bench scale test showing degradation of site groundwater using a bioreactor constructed from site groundwater and site sediments.

The TOC data collected in this investigation indicates that there is enough organic carbon in the riparian area to support continued contaminant degradation for several hundreds of years into the future, with the potential to degrade tens of thousands of pounds of contaminants, far in excess of the amount of contaminants that may potentially be released from the site in the future. Thus, the aquifer conditions appear capable of sustaining contaminant degradation for the foreseeable future.

Other Attenuation Mechanisms

The plume contaminant mass flux removal rate due to both evapotranspiration and degradation is 175 pounds per year, which accounts for approximately 95 percent of the plume contaminant mass flux of 185 pounds per year. In addition, discharge of contaminants at very low concentration levels to Potrero Creek is estimated to remove approximately 1.7 to 4.4 pounds per year, and discharge of contaminants at very low concentration levels to the deeper Mt. Eden aquifer is estimated remove approximately 0.4 pounds per year. The remaining difference of a few pounds per year between the total attenuation rate and the total underflow rate is attributed to the slightly transient as opposed to steady state nature of the groundwater system, as well as inherent uncertainty in the influx and outflux estimates.

Potential Role of Contaminant Attenuation in Site Cleanup Strategy

Since natural contaminant attenuation processes appear to currently remove a substantial portion of the current plume contaminant mass flux, natural contaminant attenuation processes will play a significant role in the overall cleanup strategy for the site. This topic will be addressed further in the upcoming site feasibility study.

Laborde Canyon

Primary Attenuation Mechanisms

The Laborde Canyon investigation has not identified any significant mechanisms by which contaminants are currently being significantly attenuated within the Site groundwater plume. Within the overall Laborde Canyon area, there are two potential attenuation mechanisms in the Offsite riparian area south of the site boundary: discharge by evapotranspiration and degradation. However, since the plume has not yet migrated into the Offsite riparian area, there are currently no active attenuation mechanisms within the Laborde Canyon plume.

Evapotranspiration

Evapotranspiration in the riparian area is estimated to discharge approximately 2.5 acre-feet per year of groundwater from the plume via plant uptake. This finding is supported by several independent lines of evidence, including site monitoring investigations showing diurnal water level trends that are consistent with the evapotranspiration mechanism; the site CSM; the recently calibrated site groundwater flow and transport models; and the recently completed field investigations, which included a riparian area plant survey that found the quantity of high water use vegetation that exists within the riparian would require evapotranspiration from groundwater at rates of 11 acre-feet per year. Since there is considerable uncertainty in the Laborde Canyon water budget and plume underflow rate, the significance of the 2.5 acre-feet per year of groundwater lost to evapotranspiration in the Offsite riparian with respect to the overall plume underflow rate is difficult to estimate.

Degradation

The Offsite riparian area has redox conditions that are mixed oxic-anoxic, which may be low enough to support future perchlorate degradation, but which also may interfere with perchlorate reduction. Thus potential for future perchlorate degradation within the riparian area is uncertain.

Potential Role of Contaminant Attenuation in Site Cleanup Strategy

Since natural contaminant attenuation processes do not currently appear to remove a substantial portion of the current plume contaminant mass flux, natural contaminant attenuation processes may play a limited role in the overall cleanup strategy for the sites. This topic will be addressed further in the upcoming site feasibility study.

6.2 RECOMMENDATIONS

Potrero Canyon Unit

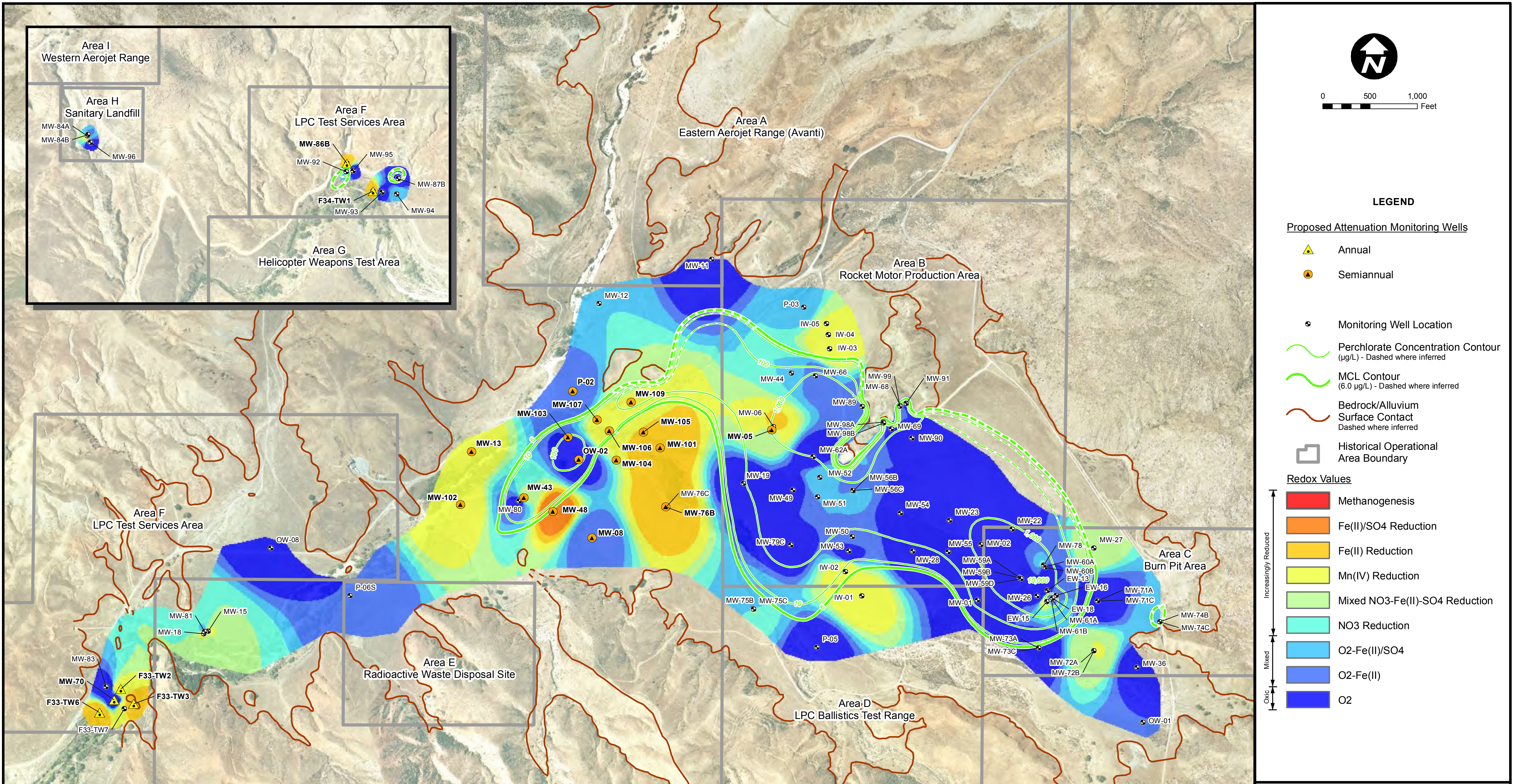
Contaminant Attenuation Sampling

Due to the active contaminant degradation that is occurring in the riparian area and on a smaller scale at the Large Motor Washout Area (F-33), the Maintenance Shops and Warehouse Area (F-34), and the Test Bays (F-39), it is recommended that groundwater wells in these areas be sampled for contaminant attenuation parameters to monitor contaminant degradation progress and the aquifer redox conditions (Figure 6-1). Since significant contaminant attenuation is taking place in the riparian area, which will play a key role in the sitewide plume remedies evaluated in the forthcoming feasibility study, semiannual monitoring of these 16 wells for contaminant attenuation parameters is recommended for the first year and annual thereafter. At the Large Motor Washout Area, the Maintenance Shops and Warehouse Area, and the Test Bays, annual monitoring of contaminant attenuation parameters is recommended for a total of 6 wells. Given the relatively small groundwater impacts and degradation activity at these three features, annual monitoring is sufficient to evaluate contaminant attenuation as one of the possible groundwater remedies for these features. Based on the results of the qPCR analyses for this study, no further qPCR analyses are recommended since PRBs have been positively detected in two different areas of the site. Therefore, further confirmation of their presence at the site is not needed especially since there are other lines of evidence that can detect or monitor perchlorate degradation which are less problematic. Based on the previous contaminant attenuation results for the site, the following parameters should be analyzed for contaminant attenuation; alkalinity, nitrate, sulfate, sulfide, chloride, DOC, VFAs, hydrogen, iron, ferrous iron, dissolved manganese, and methane/ethane/ethane.

Laborde Canyon

No additional Laborde Canyon contaminant attenuation fieldwork is recommended at this time.

X:\GIS\Lockheed 2541-01-0603\REDOX_PERC.mxd



Potrero Canyon Unit
(Lockheed Martin Beaumont Site 1)

Figure 6-1

Proposed Contaminant Attenuation Monitoring Wells

TETRA TECH

SECTION 7 REFERENCES

1. ASTM, 1996. Guide for Application for Groundwater Flow Model to a Site Specific Problem (D 5447-93); Guide for Determining Boundary Conditions in Groundwater Flow Modeling (D 5609-94); Guide for Comparing Groundwater Flow Model Simulations to Site Specific Information (D 5490-93); and others given in *ASTM Standards on Analysis of Hydrologic Parameters and Groundwater Modeling*, ASTM Publication Number 03-418096-38, ASTM, West Conshohocken, PA, 1996.

2. Anderson, M.P. and W.W. Woessner, 1992. Applied Groundwater Modeling Simulation of Flow and Advective Transport. Academic Press, Inc.

3. Baird, K. J. and T Maddock, 2005. Simulating riparian evapotranspiration: a new methodology and application for groundwater models, Journal of Hydrology, Volume 312, Issues 1-4, 10 October 2005, Pages 176-190.

4. California Irrigation Management Information System (CIMIS), 2011. Evapotranspiration data reported for Riverside, California at the California Irrigation Management System (CIMIS) Station, California Department of Water Resources, online at http://wwwcimis.water.ca.gov/cimis/welcome.jsp (accessed October 11, 2011)

5. Swades K. Chaudhuri, Susan M. O'Connor, Ruth L. Gustavson, Laurie A. Achenbach, and John D. Coates. “Environmental Factors that control Microbial Perchlorate Reduction.” Journal of Applied and Environmental Microbiology. p 4425-4430. 68(9). September 2002.

6. Elzinga, Caryl L., Daniel W. Salzer, and John W.Willoughby, 1998. Measuring and Monitoring Plant Populations, BLM Technical Reference 1730-1, BLM/RS/ST-98/005+1730, July 1998.

7. Herbert, B.E., and ,P.M. Bertsch, 1995 Characterization of dissolved and colloidal organic matter in soil solution: a review. In: W.W. McFee, Kelly, J.M., (eds). Carbon Forms and Functions in Forest Soils. Madison, WI: Soil Science Society of America, pp: 63-68.

8. Hoddenbach, G. 1987. Tamarix control. Tamarisk control in southwestern United States. Cooperative National Park Resources Studies Unit, Special Report No. 9: 116-125

9. Mamie Nozawa-Inoue, Kate M. Scow, and Dennis E. Rolston. “Reduction of Perchlorate and Nitrate by Microbial Communities in Vadose Zone Soil.” Journal of Environmental Microbiology. P 3928-3934. Vol. 71, No.7. July 2005.

10. ITRC (Interstate Technology & Regulatory Council), 2005. Perchlorate: Overview of Issues, Status, and Remedial Options. PERCHLORATE-1. Washington, D.C.: Interstate Technology & Regulatory Council, Perchlorate Team.

11. ITRC, 2007. Remediation Technologies for Perchlorate Contamination in Water and Soil. PERC-2. Washington, D.C.: Interstate Technology & Regulatory Council, Perchlorate Team

12. ITRC, 2009. Phytotechnology Technical and Regulatory Guidance and Decision Trees, Revised. PHYTO-3. Washington, D.C.: Interstate Technology & Regulatory Council, Phytotechnologies Team

13. Jurgens, B.C., McMahon, P.B., Chapelle, F.H., and Eberts, S.M., 2009 An Excel® workbook for identifying redox processes in ground water: U.S. Geological Survey Open-File Report 2009–1004 8 p. Available at http://pubs.usgs.gov/of/2009/1004/

14. M. Tony Lieberman and Bob C. Borden. "Natural Attenuation of Perchlorate in Groundwater. – Processes, Tools, and Monitoring Report. A Protocol Report." ESTCP Report. August, 2008.

15. Bruce E. Logan. " A Review of Chlorate- and Perchlorate-Respiring Microorganisms." Bioremediation Journal 2(2): p 69-79. 1998.

16. Bruce E. Logan, Husen Zhang, Peter Mulvaney, Michael G. Milner, Ian. M. Head, and Richard F. Unz. "Kinetics of Perchlorate- and Chlorate-Respiring Bacteria." Journal of Applied and Environmental Microbiology, p 2499-2506. Vol. 67, No.6. June, 2001.

17. Bruce E. Logan, A.R. Biven, S.R. Olsen, and R. Patnaik. "Growth kinetics of mixed cultures under chlorate-reducing conditions." Journal of Environmental Engineering. 124. p 1008-1011. 1998.

18. Ma, X. Z., L. J. Chen, Z. H. Chen, Z.J. Wu1, L.L. Zhang, and Y.L. Zhang, 2010 Soil Glycosidase Activities And Water Soluble Organic Carbon Under Different Land Use Types, R.C. Suelo Nutr. Veg. 10(2): 93 - 101 (2010)

19. Metcalf & Eddy. Textbook of Wastewater Engineering. Third Edition. McGraw-Hill, Inc. 1991.

20. Owens, M. K., G. M. Moore. 2007. Saltcedar water use: realistic and unrealistic expectation. Rangeland Ecology and Management 60:553-557.

21. Robinson, T. W, 1958. Phreatophytes, U.S. Geological Survey, Water Supply Paper 1423, 1958

22. Tetra Tech, Inc. 2009a. First Quarter 2008 and Second Quarter 2008 Semiannual Groundwater Monitoring Report, Lockheed Martin Corporation, Beaumont Site 1, Beaumont, California, April 2009.

23. Tetra Tech, Inc. 2009b. Dynamic Site Investigation Report, Historical Operational Areas B, C, F, G, and H, Beaumont Site 1, Lockheed Martin Corporation, Beaumont, California, July 2009.

24. Tetra Tech, Inc. 2009d. Waste Management Plan, Lockheed Martin Corporation, Beaumont Sites 1 & 2, Beaumont, California, November 2009.

25. Tetra Tech, Inc., 2010a. Dynamic Site Investigation and Summary Remedial Investigation Report, Lockheed Martin Corporation, Beaumont Site 2, Beaumont, California, April 2010.

26. Tetra Tech, Inc. 2010b. Transient Groundwater Model Report, Numerical Flow Model Development, Lockheed Martin Corporation, Beaumont Site 1, Beaumont, California, January 2010.

27. Tetra Tech, Inc., 2010c. Summary Remedial Investigation Report, Lockheed Martin Corporation, Beaumont Site 1, November 2010.

28. Tetra Tech, Inc., 2010d. Programmatic Sampling and Analysis Plan, Lockheed Martin Corporation, Beaumont Sites 1 & 2, Beaumont, California, September 2010.

29. Tetra Tech, Inc., 2010e. Numerical Groundwater Transport Model Development, Lockheed Martin Beaumont Site 1, Beaumont, California, October 2010.

30. Tetra Tech, Inc., 2010f. Beaumont Site 1 Preliminary Contaminant Attenuation Conceptual Model Technical Memorandum – (EESHRLP02381_R605), Technical Memorandum prepared for Ms. Denise Kato of LMC by Mr. Robert Johns, December 9, 2010.

31. Tetra Tech, Inc., 2011a. Beaumont Site 2 Preliminary Contaminant Attenuation Conceptual Model Technical Memorandum – (EESHRLP02382_R606), Technical Memorandum prepared for Ms. Denise Kato of LMC by Mr. Robert Johns, January 5, 2011.

32. Tetra Tech, Inc., 2011b. Contaminant Flow and Transport Modeling Report, Beaumont Site 2, Lockheed Martin Corporation, Beaumont, California, July 2011.

33. Tetra Tech, Inc., 2011c. Human Health and Predictive Ecological Risk Assessment, Potrero Canyon Unit (Lockheed Martin Beaumont Site 1), Beaumont, California, October 20, 2011

34. Tetra Tech, Inc., 2011d. Numerical Groundwater Transport Model Development, Lockheed Martin Beaumont Site 1, Beaumont, California, July 2011.

35. USDA (US Department of Agriculture), 2011. PLANTS Profile, Plants Database, available at: http://plants.usda.gov/java/, accessed February 16, 2011.

36. US Environmental Protection Agency (EPA), 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water, Office of Research and Development, EPA/600/R-98/128, September 1998.

37. US Environmental Protection Agency (EPA), 2007 Monitored Natural Attenuation of Inorganic Contaminants in Ground Water, Volume 1 - Technical Basis for Assessment, Office of Research and Development National Risk Management Research Laboratory, Ada, Oklahoma, EPA/600/R-07/139, October 2007.

38. WRCC (Western Regional Climate Center), 2011. Pan Evaporation Data for Beaumont, CA from the Desert Research Institute, available at: http://www.wrcc.dri.edu/htmlfiles/westevap.final.html, accessed February 22, 2011.

39. White, W.N. 1932 A method of estimating groundwater supplies based on discharge from plants and evaporation from the soil: Results of investigations in Escalante Valley, Utah. United States Geological Survey Water Supply Paper 659, 1932

40. Wullschleger, S. D., F. C. Meinzer and R. A. Vertessy. 1998. A review of whole-plant water use studies in trees, Tree Physiology 18, 499—512, 1998 Heron Publishing, Victoria, Canada.

41. Jianlin Xu, Yanguang Song, Booki Min, Lisa Steinberg, and Bruce E. Logan. " Microbial Degradation of Perchlorate: Principles and Applications." Environmental Engineering Science. Volume 20, Number 5, 2003.