Revised

Transient Groundwater Model Report, Numerical Flow Model Development Lockheed Martin Corporation, Beaumont Site 1 Beaumont, California

Prepared for:

LOCKHEED MARTIN

TETRA TECH

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

TC# 23521-0701 / January 2010

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LOCKHEED MARTIN

January 20, 2009

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

Subject: Submittal of Revised *Transient Groundwater Model Report, Numerical Flow Model Development, Beaumont Site 1, Lockheed Martin Corporation, Beaumont, California*

Dear Mr. Zogaib:

Enclosed please find a hard copy of the body of the report, *Transient Groundwater Model Report, Numerical Flow Model Development, Beaumont Site 1, Lockheed Martin Corporation, Beaumont, California*, revised in accordance with agreed-on responses to DTSC comments. Also enclosed are two copies of a CD containing the entire report.

If you have any questions regarding this submittal or the status of site activities, please contact me at 408.756.9595 or denise.kato@lmco.com.

Sincerely,

Denise Kato

Denise Kato
Remediation Analyst Senior Staff

Enclosures

Copy with Enc:
Gene Matsushita, LMC (one hard copy, text: one electronic copy text & appendices)
John Eisenbeis, CDM (one electronic copy)
Thomas Villeneuve, Tetra Tech. Inc. (hard copy & electronic copy)

REVISED

Transient Groundwater Model Report
Numerical Flow Model Development
Beaumont Site 1
Lockheed Martin Corporation
Beaumont, California

January 2010
T#: 23521-0701

Prepared for:
Lockheed Martin Corporation
Burbank, California

Prepared by:
Tetra Tech, Inc.

Robert Johns, PhD
Environmental Engineer

William Muir
Deputy Program Manager, Geologist

Thomas J. Villeneuve, P.E.
Program Manager

RESPONSE TO COMMENTS, DATED OCTOBER 5, 2009,
TRANSIENT GROUNDWATER MODEL REPORT, NUMERICAL FLOW MODEL DEVELOPMENT, LOCKHEED MARTIN CORPORATION, BEAUMONT SITE 1, BEAUMONT, CALIFORNIA, DATED AUGUST 2009.

Comments from Dina Kourda, DTSC (dated September 14, 2009)		
Comment	**Response**	**Proposed Action**
Minor Comment: 1. Section 1.0, Page 1-1: "… three-quarters of a pore volume of the 400 µg/L Total VOCs plume targeted for cleanup?, or about one-quarter of a pore volume…" should be removed.	Agree – The "?" in the text will be removed as requested.	Delete the "?" in the last full sentence on page 1-1 in Section 1.0.
Specific Comments: 1. The signature page should be revised to include a Professional Geologist's wet stamp with expiration date. An appropriate sized Professional Geologist stamp (no less than 1-1/2 inches) should be included in the report according to page 17 of the Geologist and Geophysical Act with Rules and Regulations dated 2007 http://www.geology.ca.gov/laws/act.pdf.	The signature page will be revised to include a Professional Geologists wet stamp as requested.	Add a Professional Geologist stamp to the signature page as requested.
2. Figure 3-3: Cross-sections B-B' through E-E' should be included in the report as they are included on the A-A'-A" figure.	The reference to the other sections that bisect A-A'-A" were inadvertently left on the section included in the report. The purpose of the cross-section in the report is to illustrate the interpreted subsurface geology down the axis of the plume. Those other sections referenced are not necessary to the discussion and the reference will be removed from Figure 3-3 (section A-A'-A").	Delete the reference to sections B-B' through E-E' from Figure 3-3.
3. Table 3-1: Units should be included in the table.	Units will be added to the columns in the table as requested.	Add units to Table 3-1. Hydr Conduct (ft/day), Transmissivity (ft2/day), and Underflow (acre-feet per year)

RESPONSE TO COMMENTS, DATED OCTOBER 5, 2009,
TRANSIENT GROUNDWATER MODEL REPORT, NUMERICAL FLOW MODEL DEVELOPMENT,
LOCKHEED MARTIN CORPORATION, BEAUMONT SITE 1,
BEAUMONT, CALIFORNIA, DATED AUGUST 2009.

Comments from Dina Kourda, DTSC (dated September 14, 2009)		
Comment	**Response**	**Proposed Action**
4. Figure 4-8: The explanation should be reformatted so as it is legible.	The Figure has been reformatted to make the entire Figure more legible. Specifically, the dashed line and the explanation for it will be revised to make it more legible.	Reformat Figure 4-8 to make the Figure more legible as requested. Specifically, change the Legend text for “San Jacinto NWS Precipitation Station” so it is legible.
5. Section 8, Page 8-1: IRM should be defined.	The acronym “IRM” will be defined as requested.	The acronym IRM will be defined with Interim Remedial Measure in the Acronym List as requested.

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EXECUTIVE SUMMARY

This Groundwater Modeling Report was prepared by Tetra Tech, Inc. on behalf of Lockheed Martin Corporation and presents the results of groundwater flow modeling activities for Beaumont Site 1, Beaumont, California. A Conceptual Site Model (CSM), water budget, and numerical groundwater flow model were developed based upon the site historical groundwater monitoring, remedial operations data, and the November 2008 pumping test data collected from Middle Potrero Creek. Key aspects of the 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. The plume is generally limited to the alluvial units;
- During the 1992-2008 period, 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; and
- 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 steady-state and transient conditions, simulating the large seasonal and inter-annual changes in aquifer storage observed in the site monitoring data, further confirming the key hydraulic characteristics and water budget for the aquifer system.

The calibrated groundwater flow model was used to simulate the aquifer response and impacts on the site groundwater plume for various site groundwater remedial alternatives, including operation of a potential IRM at Middle Potrero Creek and an expanded RMPA extraction/injection system. The model predictions indicated the following:

- Groundwater extraction at Middle Potrero Creek at rate of 44 gpm (71 acre-feet year) could completely capture any plume groundwater flowing down Potrero Creek alluvium and cut-off any potential discharge of contaminants into Potrero Creek. The extraction well installed as part of pumping test, EW-19, appears to be sufficient for this system. The need for groundwater extraction at Middle Potrero Creek will be evaluated in the Feasibility Study (FS);
- Installation and operation of an extraction/injection system at rate of 91 gpm (147 acre-feet year) should completely capture all groundwater flowing through the plume above the extraction wells. Three extraction wells (existing wells EW-1 and EW-2 and new well EW-20) and seven re?-injection wells (existing wells IW-1 to IW-5 and new wells IW-6 and IW-7) and 8 new monitoring wells are needed for this system. If the expanded RMPA extraction/injection system is installed, it is anticipated that the system would need to be operated for a period of 23 years before the plume is remediated in the RMPA/BPA area. To accommodate uncertainty in site conditions and the possible need for higher extraction rates during wet periods, the nominal recommended design rate for the expanded RMPA treatment system is 125 to 150 gpm; and

- If the IRM-Middle Potrero Creek extraction system and/or the RMPA extraction/injection system were operated, the operation(s) would be unlikely to significantly impact groundwater levels evapotranspiration rates, or the vegetation in the riparian zone. In fact, groundwater remediation of the plume is likely to be supplemented by phytoremediation in the riparian zone Current estimates indicate that 70 percent of the groundwater plume is intercepted by evapotranspiration in the riparian area.

Therefore, this report recommends using the groundwater model in the upcoming site FS to aid in the evaluation of site remedial options..

1.0 INTRODUCTION

This Groundwater Modeling Report (Report) was prepared by Tetra Tech, Inc. (Tetra Tech) on behalf of Lockheed Martin Corporation (LMC) and presents the results of groundwater flow modeling activities for the Beaumont Site 1 (Site). The Site is located southwest of the City of Beaumont, Riverside County, California (Figure 1-1).

The objectives of this Report are to:

- Present the most current Conceptual Site Model (CSM) and water budget;
- Document the development and calibration of a Site groundwater model;
- Analyze potential site groundwater remedial alternatives using the calibrated model; and
- Evaluate potential Site groundwater remedial options and monitoring plans based upon the model predictions, and use the model to assess alternatives developed in the upcoming Site Feasibility Study (FS).

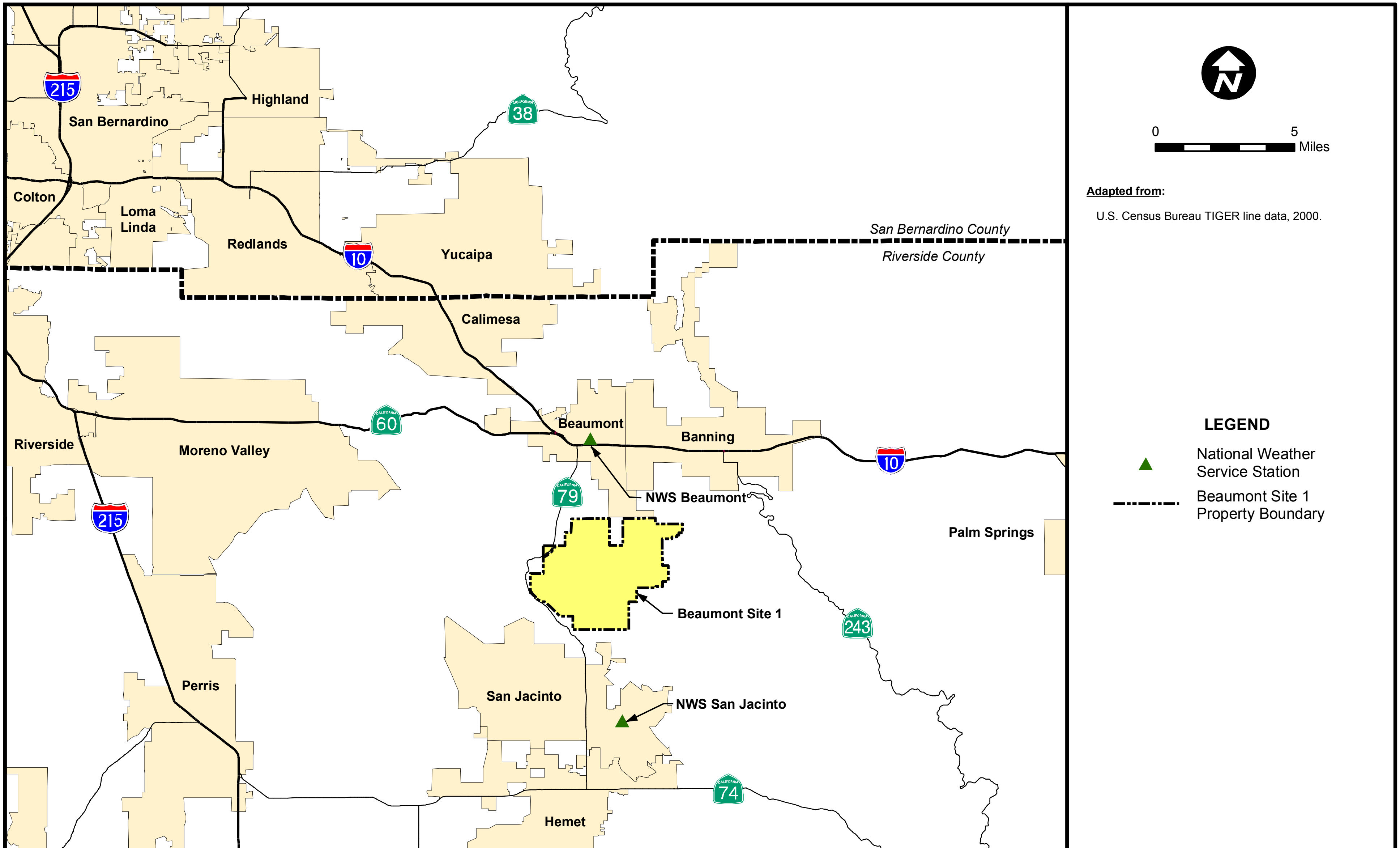
This Report also includes background on the Site and prior groundwater modeling activities.

1.1 SITE BACKGROUND

The Site is a 9,117-acre parcel located south of Beaumont, California. 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 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. A Site historical operational areas and features map is presented as Figure 1-2. Each historical operational area was used for various activities associated with rocket motor assembly, testing, and propellant incineration. Significant groundwater contamination was found in Site investigations in the Rocket Motor Production Area (RMPA) and the BPA (see plumes depicted in Figures 3-7 and C-12).

Two groundwater remediation systems were historically installed and operated at the Site: the RMPA Groundwater Extraction and Injection System (see Figure 5-4) 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 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



Beaumont Site 1

Figure 1-1
Regional Location of Beaumont Site 1

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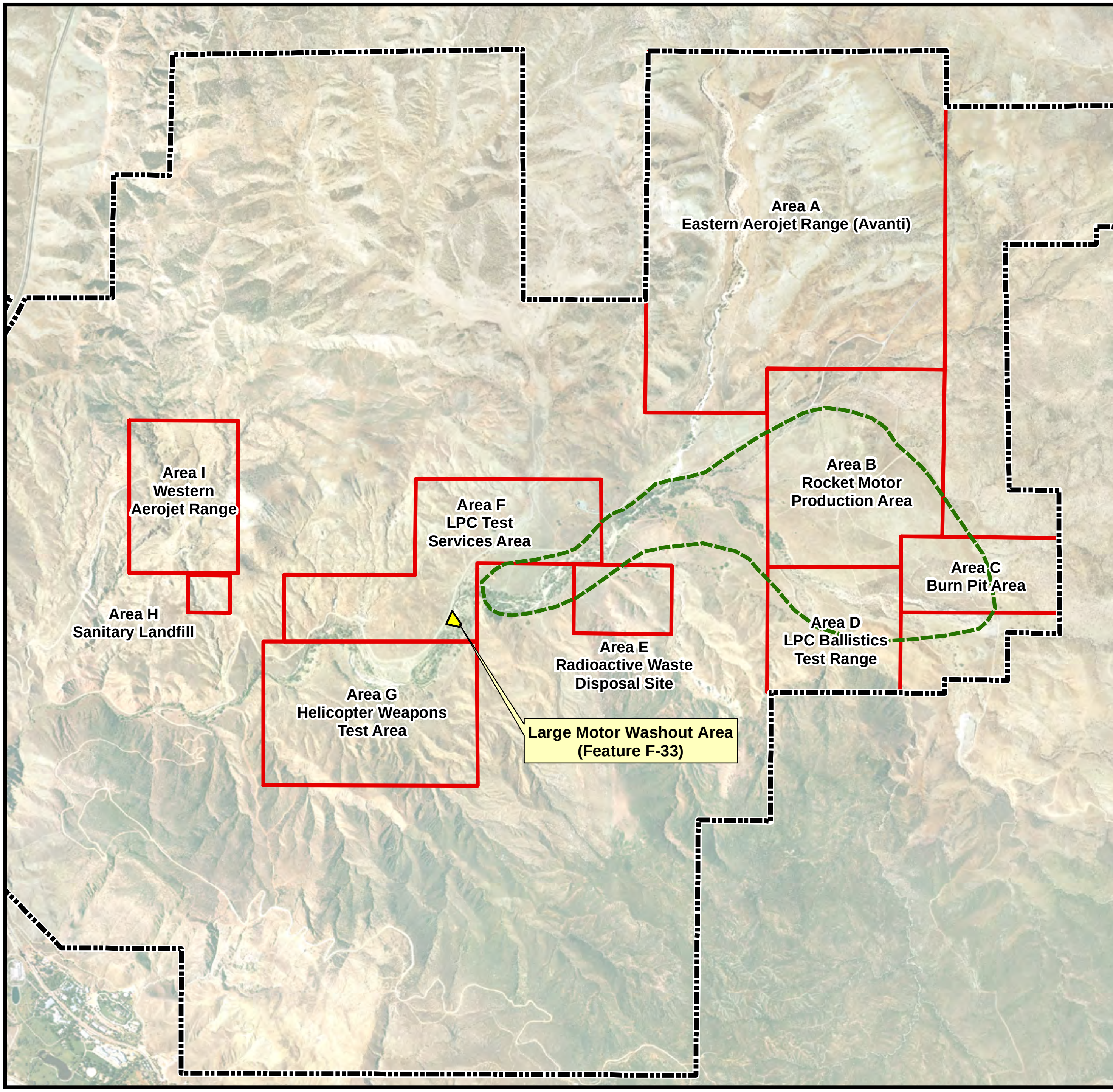
X:\GIS\Lockheed 22288-0606\region.mxd

X:\GIS\Lockheed 22288-0606\Site.mxd



Beaumont Site 1

Figure 1-2

Site 1 Historical Operational Areas and Features Map

TETRA TECH

operated at the BPA from August 1994 through July 1998 to treat soils and very shallow groundwater in low permeability bedrock of the Mt Eden formation, 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 quarterly basis from 1990 through 2008 to monitor the site 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 the most current site conceptual model in the site groundwater monitoring semi-annual reports.

1.2 PREVIOUS GROUNDWATER MODELING ACTIVITIES

A three-dimensional finite element groundwater flow model was developed for the site in 1993 (Radian, 1993b). The model included the Quarternary alluvium and a 20 foot thick weathered Mt Eden formation in the Potrero and Bedsprings Valleys, and was calibrated for steady-state conditions using 1992 water levels. Documentation on the water budget and hydraulic parameters for the model is limited, with the diffuse recharge reported to be at a rate of 1.7 inches per year and evapotranspiration reported to be at a rate of 3.65 feet per year. This modeling effort indicated that 60 gpm would be needed to maintain hydraulic control over the 1,130 feet wide target zone, which was the 400 ug/L Total VOCs isopleth within the RMPA. The model files for this 1993 finite element groundwater flow model were not available for review and use in this study

1.3 CURRENT GROUNDWATER MODELING ACTIVITIES

The objective of this study is to develop a transient numerical groundwater flow model for the Site and to use the calibrated model to evaluate groundwater remedial alternatives. More detailed objectives of the modeling task include the following:

- Quantifying the site conceptual model and water budget;
- Developing a calibrated transient numerical groundwater flow model; and
- Utilizing the calibrated groundwater model to evaluate remedial actions at the site.

Specific issues to be addressed using the model include (1) estimating the pumping rate and number of wells required to intercept the leading edge of the plume in middle Potrero Creek Valley, (2) estimating the pumping rate and number of wells required to fully contain the plume in the RMPA in Bedsprings Creek Valley, and (3) estimating the impact of evapotranspiration in the riparian area near the confluence of Bedsprings and Potrero Creeks, which appears to be providing phytoremediation of the plume.

The approach for development of the model includes the following:

- Compiling and assembling data regarding historic well pumping, well coordinates, well construction, groundwater levels, lithology, hydraulic conductivity, storativity, porosity, groundwater inflow and outflow, precipitation, recharge, evapotranspiration, surface water flow, and groundwater quality;
- Developing a conceptual hydrogeologic model of the Potrero Creek and Bedsprings Creek areas through evaluation and analysis of the available information. This effort included definition of hydrostratigraphic units, boundary conditions, direction of groundwater flow, and preparation of a groundwater budget;
- Constructing a groundwater flow model of the area using MODFLOW2000 (Harbaugh et al., 2000);
- Calibrating the flow model to steady state conditions for the October 1992 time period and transient conditions for the period October 1992 through October 2008;
- Evaluating alternative remedial options to intercept the leading edge of the plume in middle Potrero Creek and fully contain the plume in the RMPA; and
- Documenting the study findings in this Report.

The model was developed based upon modeling guidance given in ASTM reports (ASTM, 1996) and groundwater modeling guides (Anderson and Woessner, 1992). Section 2 summarizes the data used in this study. Section 3 presents the groundwater conceptual model. Section 4 presents the groundwater flow model design and calibration. Section 5 presents the groundwater flow model predictions for various remedial alternatives. Section 6 presents the project summary, conclusions and recommendations.

2.0 DATA COLLECTION

This project task involved compiling and assembling relevant data to support development of the conceptual and numerical models. Existing well information was a key aspect of the data assembled for the model, including information on location coordinates, lithologic logs, water levels, pumping rates, construction, depths and perforation intervals. Other information sought and considered relevant was surface geology, stream flow discharge, and land use.

2.1 SOURCES

The primary source of data used in this study is the database developed for the Site groundwater monitoring program (Tetra Tech, Inc., 2008 and 2009a), which includes the following data:

- Groundwater levels from 1990 through present;
- Groundwater and surface water quality data from 1992 through present;
- Well construction data;
- Streamflow data for various times and locations during 2008;
- Applicable GIS coverage for the ground surface and aquifer;
- Well screened interval hydraulic conductivity data derived from specific capacity measurements; and
- Soil gas and quality data.

Groundwater extraction and injection data were taken from remedial operations reports (Radian Corporation, 1990) and the Site five-year report (Earth Tech, Inc., 2000). Well pumping and slug test data were taken from the site hydrogeologic study (Radian Corporation, 1992c), which along with the 1983 water supply investigation (Leighton and Associates, Inc. 1983) was also used to define various elements of the conceptual model and water budget as discussed in Section 3.

In addition, a groundwater pumping test was conducted during November 2008 in middle Potrero Creek. Key results of the November 2008 pumping test indicate that the aquifer transmissivity is 2,455 ft^2/day, and the average underflow rate down the canyon was estimated using underflow calculations to be 74 acre-feet per year (46 gpm) (Tetra Tech, 2009b). This underflow rate is further supported by the stream baseflow measurements conducted in the site groundwater monitoring program (Tetra Tech, 2009a), which found baseflow in middle Potrero Creek at the beginning of the dry season was on the order of 70 to 100 acre-feet per year. The valley floor was also topographically surveyed utilizing current state plane coordinates and vertical datum, at accuracy sufficient to allow its use for modeling purposes.

2.2 ANALYSIS

The database incorporates information and respective sources of the information for all known wells in the model area. Information gathered was organized to develop components of the water budget, aquifer layers, and geometry.

Since high rate aquifer test data was lacking in the highly permeable zones of the alluvium in some areas, specific capacity information was converted to aquifer transmissivity by analytical methods (Heath, 1987) to supplement the well test data given in the Hydrogeologic Study (Radian Corporation, 1992) and the recent November 2008 pumping test (Tetra Tech, Inc., 2009b). The two high rate aquifer pumping tests (MW-30 and EX-19) conducted in the deep high permeability zone provide the best estimate of the full aquifer thickness transmissivity value (1,500 to 2,455 ft^2/day). These and other interpretations are addressed in more detail in the Conceptual Model discussion in Section 3.

2.3 DATA GAPS

Although there are uncertainties in some aspects of the conceptual model as discussed in Section 3, this is typical for hydrogeologic studies, and there do not appear to be any data gaps that would preclude proceeding with the development of a numerical flow model or the design of remediation systems. The most recent site investigations for the middle Potrero Creek pump test have provided valuable data to update the conceptual and construct a numerical model of groundwater flow at the site.

3.0 CONCEPTUAL MODEL

Various elements of the groundwater conceptual model are given in several earlier site reports (Leighton and Associates, Inc., 1983; Radian, 1992c, 1993b, and 1995; Earth Tech, 2000; and Tetra Tech, 2007a, 2007c, and 2008). The reader is referred to these reports for more details and supporting information on the historical development of the groundwater conceptual model.

Section 3 uses the additional characterization and remedial operations data that has been more recently collected to update the conceptual model so it is consistent with the available site data and the requirements for the numerical flow modeling task. The updated conceptual model includes the definition of the aquifer hydrostratigraphic framework and the sources of recharge and discharge. Section 4 extends this groundwater conceptual model to a numerical groundwater flow model.

Figures 3-1 through 3-7 and those in Appendix A (A-1 through A-9) show cross-sections and contour maps to support and illustrate the following text description of the conceptual model. The reader is also referred to prior site reports (Leighton and Associates, Inc., 1983; Radian Corporation, 1992c, 1993b, and 1995; Earth Tech Inc., 2000; and Tetra Tech Inc., 2007a, 2007c, 2008, 2009a, and 2009b) for additional supporting information on the groundwater conceptual model. For example, Figure 3-3 presents the primary cross-section across the site (A-A'-A'') depicting the various site hydrostratigraphic units, but recent groundwater monitoring reports (Tetra Tech, 2008) also gives many other site cross-sections that were used in developing the conceptual model given in this report. The conceptual model of the study area was formulated based on interpretations of all of the assembled reports and information, and only a concise summary of those reports and data are given in Sections 3.1 through 3.7.

3.1 GEOLOGIC FRAMEWORK

The Site is located in the northeastern foothills of the San Jacinto Mountains (Figures 3-1 and 3-2). The Potrero valley extends from San Gorgonio Pass to the San Jacinto Valley and decreases approximately 1,000 feet in elevation from north to south. Southwest of Potrero valley, the topographic gradient of the valley steepens toward Massacre Canyon and flattens out when it reaches the San Jacinto Valley. The Site is situated between the San Andreas Fault System located to the north and the San Jacinto Fault System located to the south, with numerous smaller faults such as the Bedsprings, Goetz, and Potrero Faults that are associated with movement along these major fault systems. The Potrero valley is located along an elongated graben that is bounded by the Potrero Creek and Bedsprings Creek Faults. Although faulting is known to displace the Tertiary sediments, no evidence is available to support the offset of the alluvium (Leighton and Associates, Inc., 1983). Geologic units (Figure 3-1) from oldest to youngest include: the Mesozoic to Paleozoic granitic/metasedimentary basement complex rocks; sedimentary deposits of the

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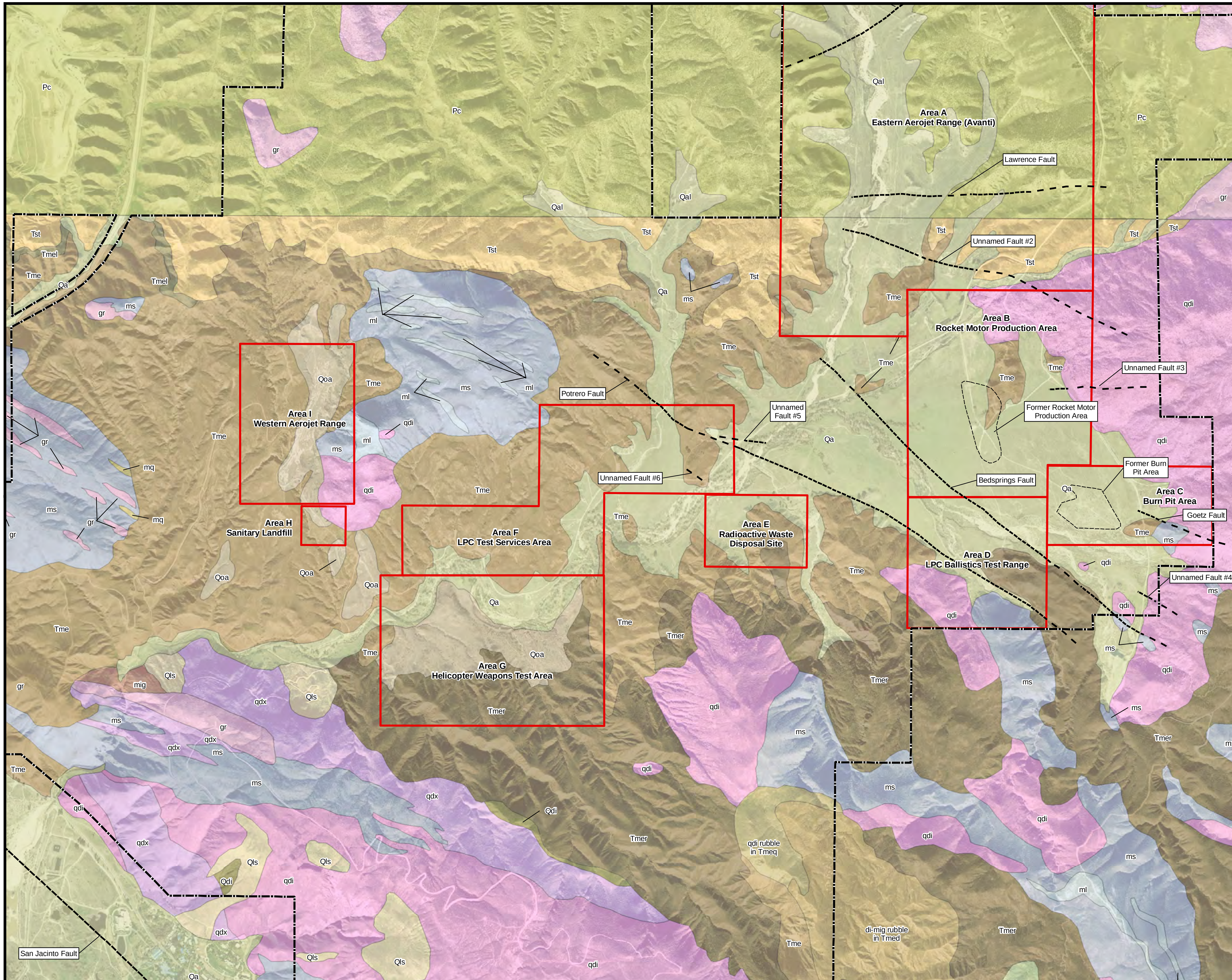

0 1,000 2,000
Feet

LEGEND

Approximate Location of Buried Fault

Approximate Location of Inferred Fault

Burn Pit and Rocket Motor Production Area

Beaumont Site 1 Property Boundary

Historical Operational Unit Boundary

Geology from Dibblee, 2003

SURFICIAL SEDIMENTS

Alluvial sediments, unconsolidated, undissected

Qa — Alluvial sand and clay of valley areas, covered by gray soil, includes stream channel gravel and sand in mountain area

LANDSLIDE DEBRIS

Qls — Landslide of rock rubble

OLDER SURFICIAL SEDIMENTS

Dissected older alluvial deposits, slightly indurated, undeformed, late Pleistocene age

Qoa — Alluvial gravel and sand of low terrace remnants Qog Alluvial gravel and sand of high terrace remnants

SAN TIMOTEO FORMATION

(of Frick, 1921), only lowest part exposed at north border in this quadrangle, weakly lithified; age, Pliocene

Tst — Sandstone, light gray to tan, arkosic, includes thin layers and interbeds of gray cobble - pebbled conglomerate of mostly granitic detritus

MOUNT EDEN FORMATION

(of Fraser, 1931), moderately lithified, derived from basement rocks of San Jacinto Mountains; age upper Miocene

Tme — Sandstone, light orange - red, bedded, arkosic, includes thin layers of reddish claystone and lenses of pebble - cobble conglomerate, gray, of unsorted boulders and cobbles of granitic rocks (qdi), lower part west of Massacre Canyon includes much pebble-cobble conglomerate

Tmer — Conglomerate - fanglomerate, reddish gray-brown of poorly to unsorted sub-granitic (qdi and qdx) detritus in sandy matrix, vaguely bedded

PLUTONIC ROCKS

Medium grained holocrystalline granitic rocks of San Jacinto Mountains, part of Peninsular Range batholith, of Cretaceous age

gr — Granite of Mount Eden (of Morton and Matti, 2001, granite to quartz monzonite, eucocratic, graywhite, hard, massive, of quartz, potassic feldspar and sadie plagioclase feldspar in nearly equal amounts, and less than 5% mica, mostly muscovite; intrusive as large pod into unit xqd at Massacre Canyon and as small pods in ms to northwest

qdi — Quartz diorite, ranges to granodiorite, leucocratic light gray, composed of about 1/3 quartz, 1/2 sadie plagioclase feldspar, less than 1/4 potassic feldspar, and 5-10% biotite, minor hornblende, massive to faintly gneissoid, contains few small dark gray discoid inclusions (xenoliths); most widespread rock of San Jacinto Mountains

qdx — Quartz diorite, gray, massive to gneissoid, composed of about 1/4 quartz, 1/2 sadie plagioclase feldspar, less than 1/4 potassic feldspar, 5-15% biotite and hornblende; contains few to abundant dark gray discoid inclusions (xenoliths) oriented parallel to gneissoid structure of rock; includes migmatized remnants of schist-gneiss (ms) in many places

METASEDIMENTARY ROCKS

Rocks crystallized at depth from deformed sedimentary rocks, mostly argillaceous, of Paleozoic? of Mesozoic? age

ml — Marble, white to light gray, fine-grained crystallized from limestone or dolomite

ms — Schist, dark gray, fine-grained, foliated, of mica (mostly biotite), feldspar and quartz, in some areas in part crystallized to fine grained gneiss

Geology from California Division of Mines and Geology, 1966

Qal — Alluvium

Pc — Undivided Pliocene nonmarine

gr — Mesozoic granitic rocks

ms — Pre-Cretaceous metasedimentary rocks

Note: Beaumont Site 1 property boundary is approximate.

Adapted from:

Geologic Map of the San Jacinto Quadrangle, Thomas W. Dibblee, Jr. 2003

Geologic Map of California - Santa Ana Sheet, California Division of Mines and Geology, 1966.

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

Beaumont Site 1

Figure 3-1

Regional Geology

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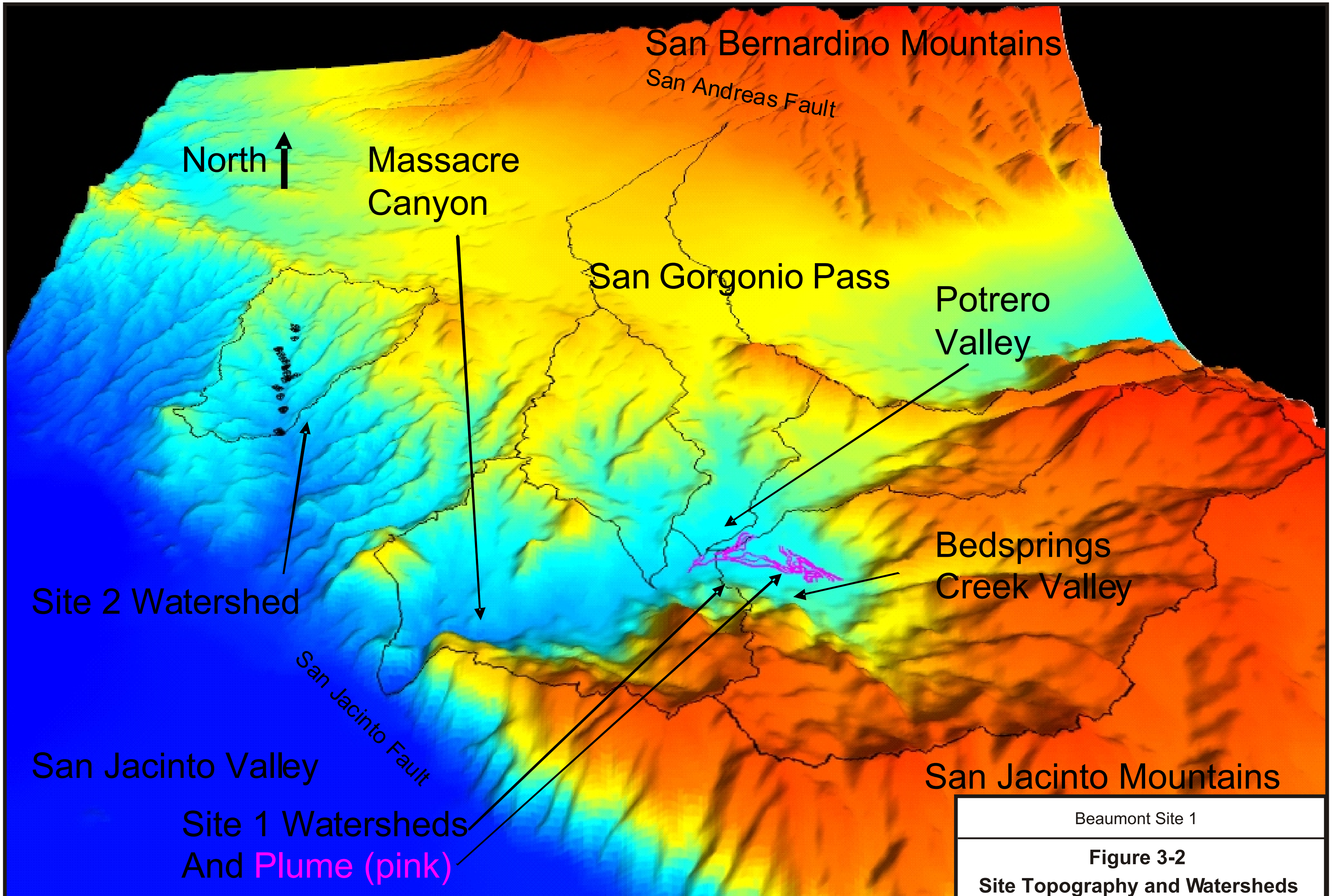

*Fault positions approximate.
Illustration not to scale.

Beaumont Site 1

Figure 3-2
Site Topography and Watersheds in the LMC Beaumont Sites 1 and 2 Areas

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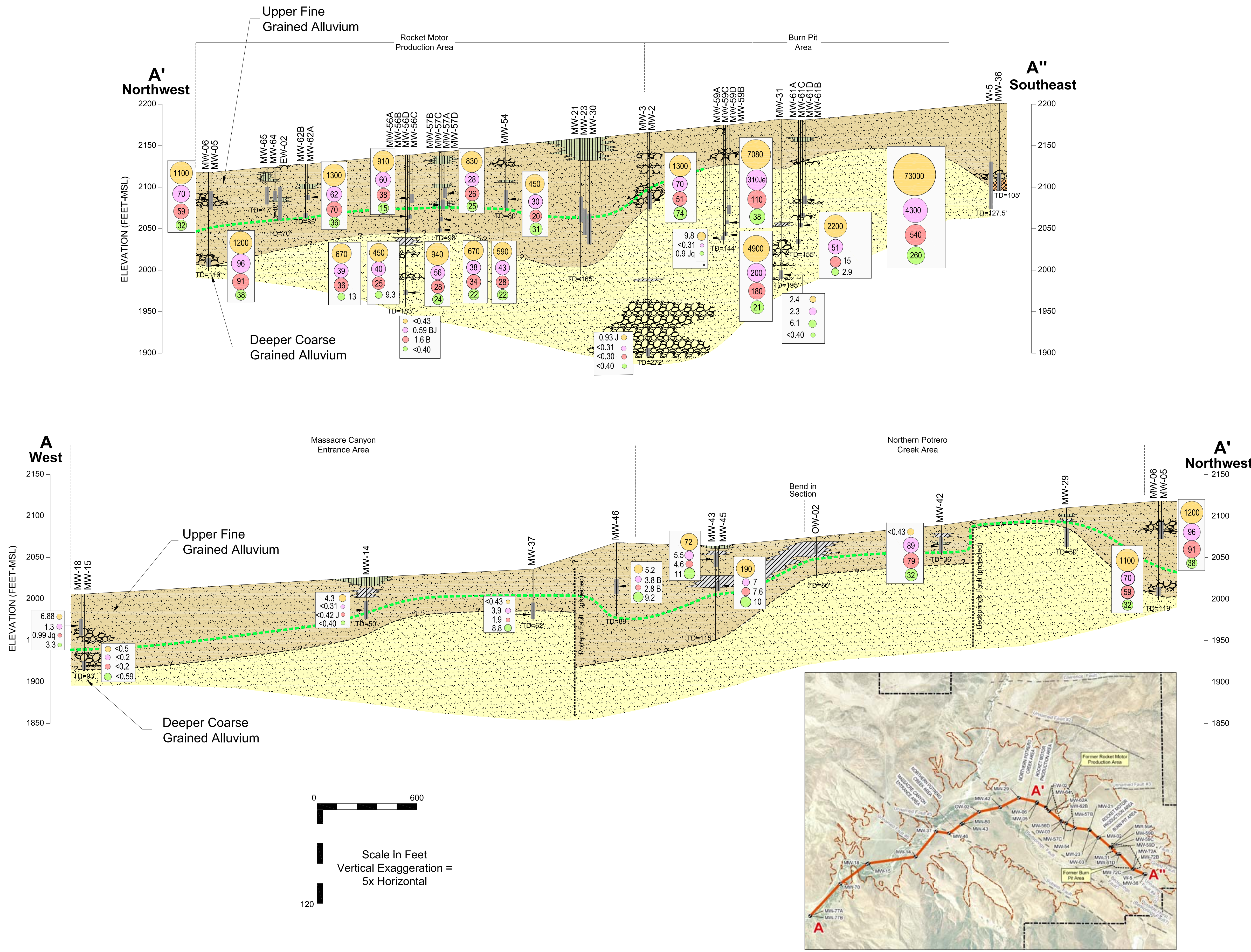


Adapted from:

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 Alluvium
- – – ? – – 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.

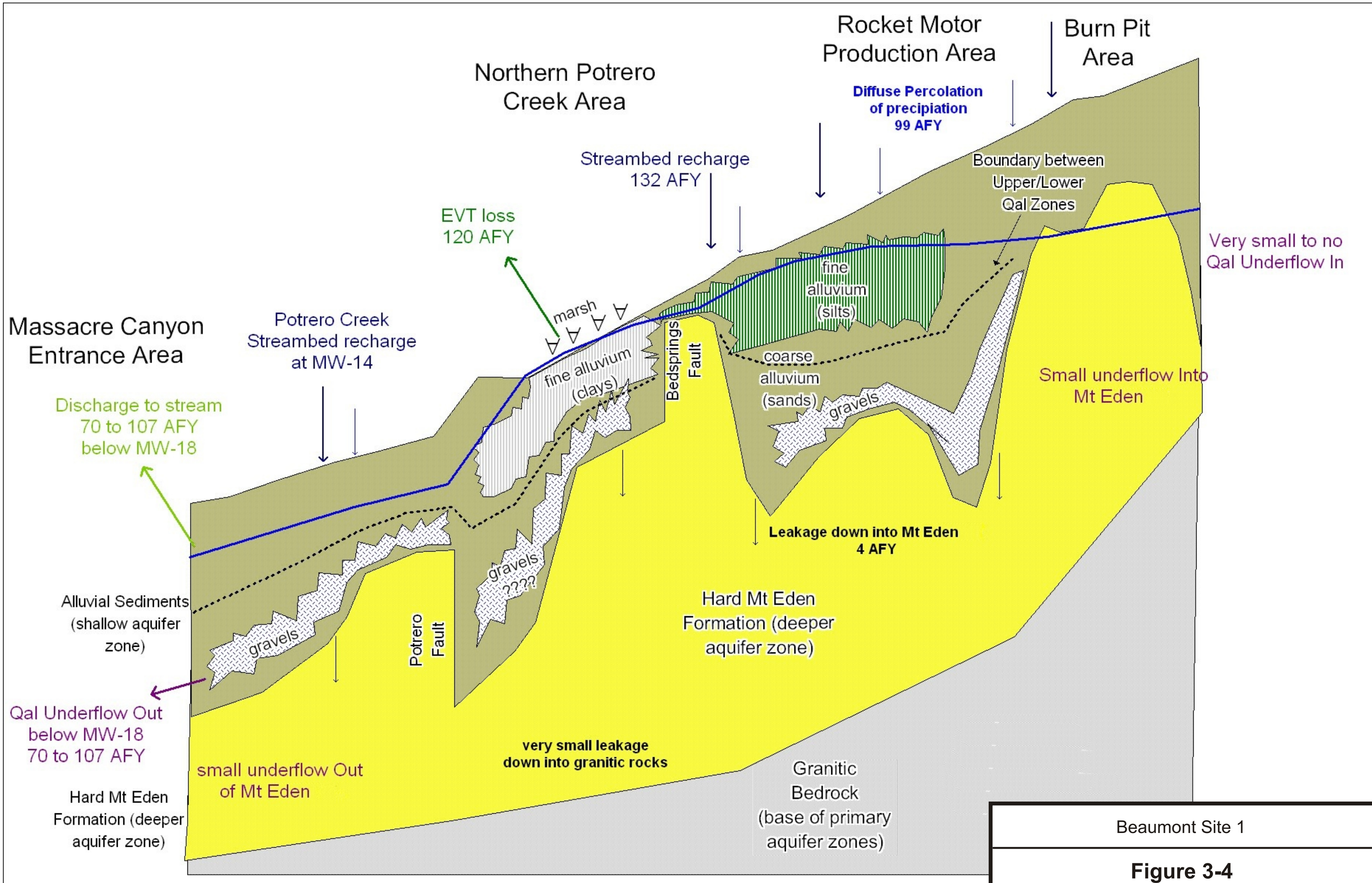
k - The analyte was found in the field blank.

Beaumont Site 1

Figure 3-3
Cross Section A-A'-A''

TETRA TECH

X:\GIS\22288-0606\FIG 3-4.CDR



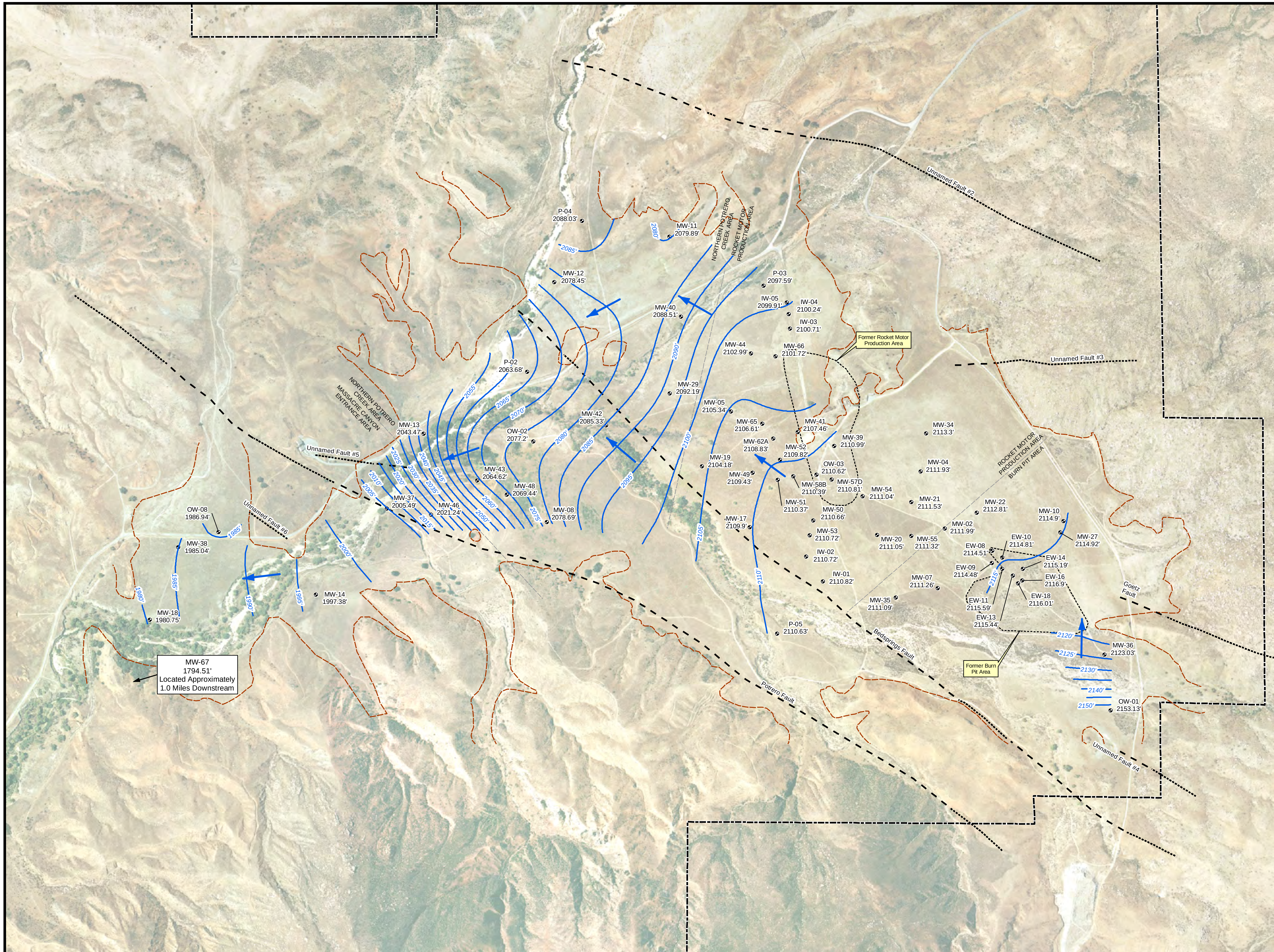
Beaumont Site 1

Figure 3-4

Updated Hydrostratigraphic Conceptual Model

TETRA TECH

Illustration not to scale.



0 500 1,000 Feet

Adapted from: March 2007 aerial photograph.

Published fault locations from Hydrogeologic Investigation for Water Resources Development, Leighton and Associates, 1983.

LEGEND

- Well Location
- Groundwater Flow Direction
- 2050' Groundwater Elevation Contour (mean sea level, dashed where inferred)
- Approximate Location of Fault
- Approximate Location of Buried Fault
- Beaumont Site 1 Property Boundary
- Mt. Eden/Alluvium Surface Contact

Notes: Beaumont Site 1 property boundary is approximate.
5-foot contour interval.

Beaumont Site 1

Figure 3-5
First Quarter (March) 2007 Groundwater Contours for Alluvium /Shallow Mt. Eden Formation

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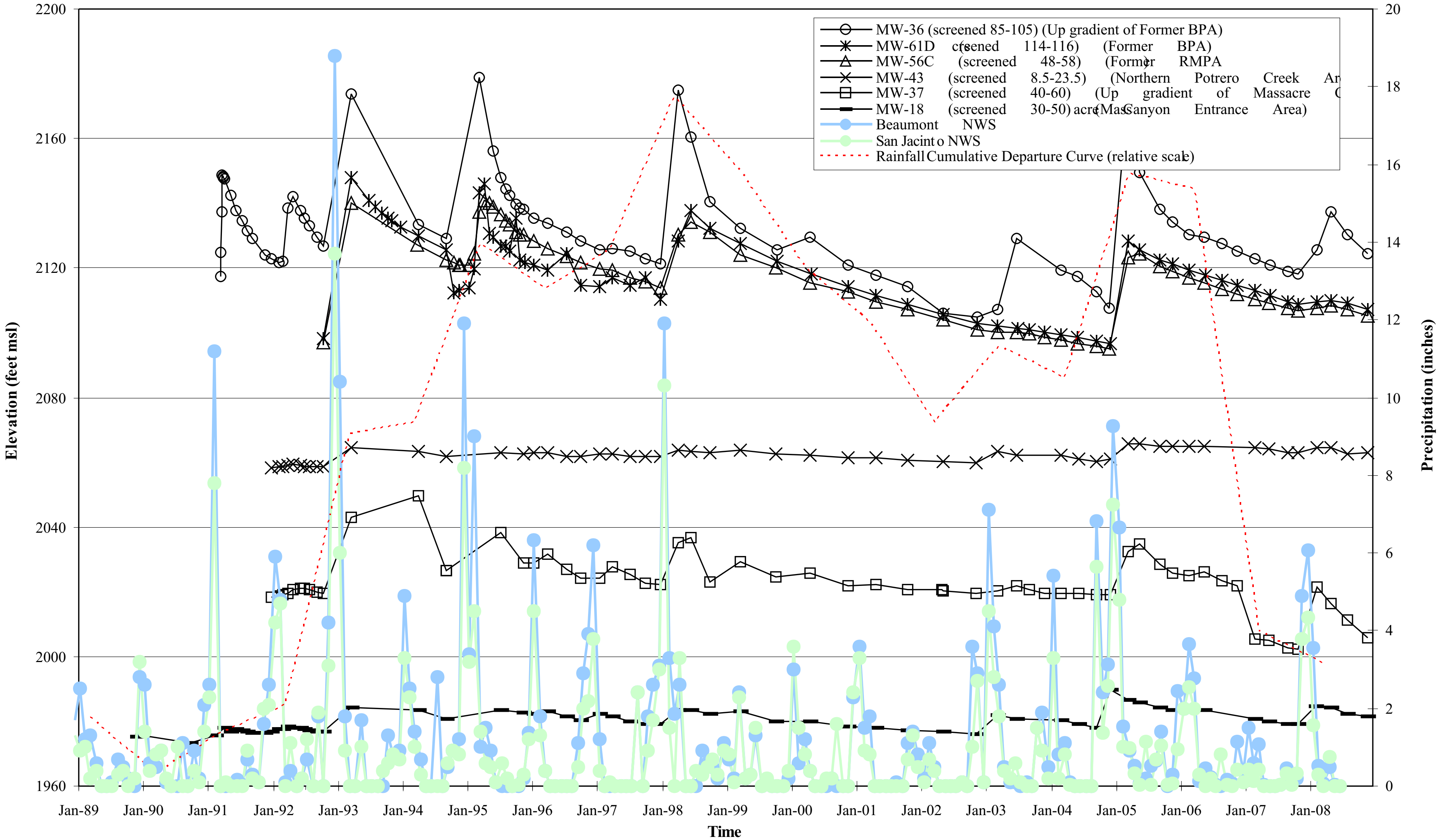
X:\GIS\22288-0606\FIG 3-6.CDR



Beaumont Site 1

Figure 3-6

Groundwater Elevation vs. Time, Selected Alluvial and Shallow Mt. Eden Formation with Percipitation Overlay

TETRA TECH

Updated 8-2008

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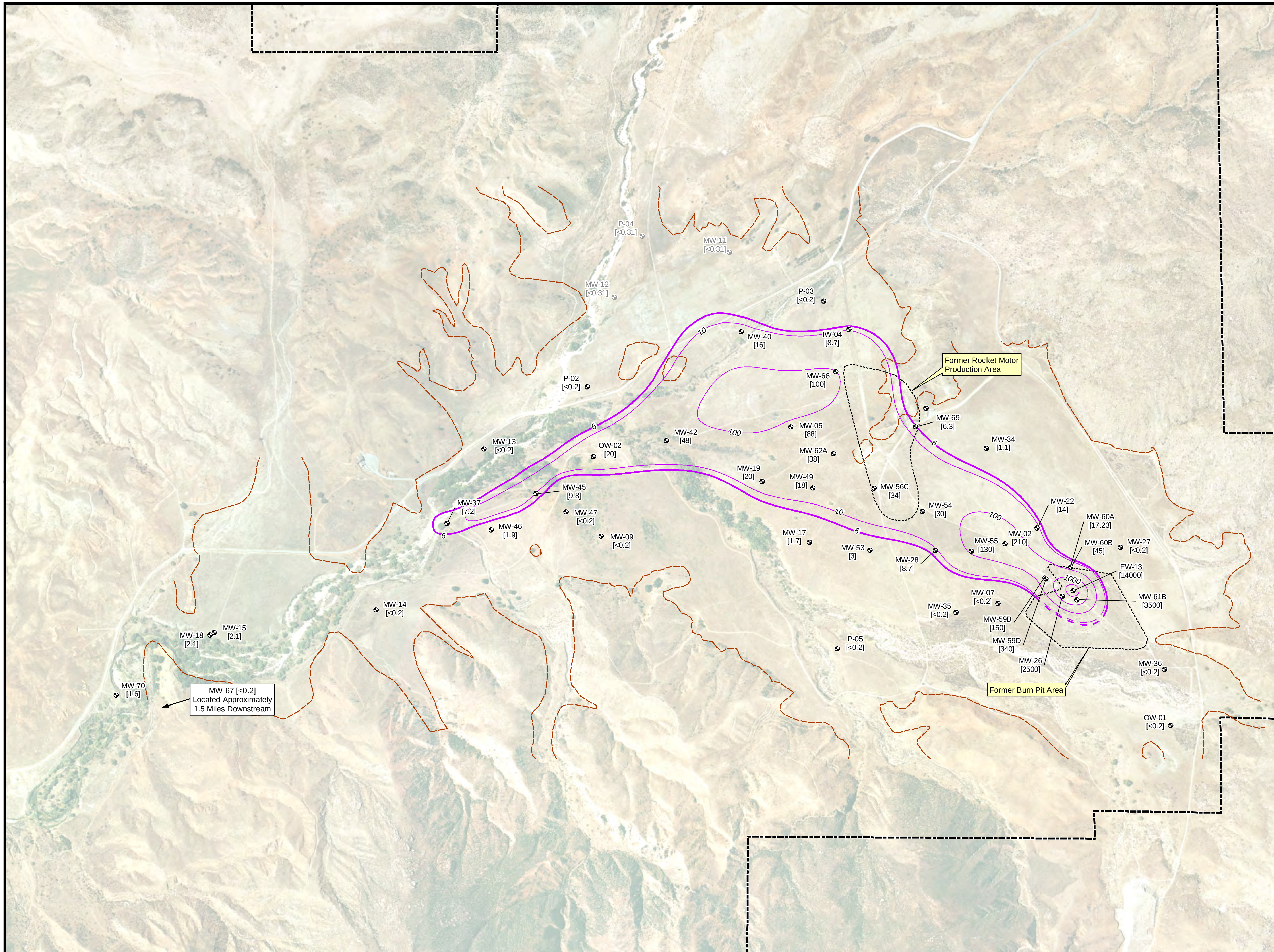


0 500 1,000 Feet

Adapted from: March 2007 aerial photograph.
Well locations from Hillwig and Goodrow survey, 2003.

LEGEND

WELLS

- Quaternary Alluvium or Shalllow Mount Eden Formation Screened Well
- 1,1-DCE Concentration Contour (µg/L) - Dashed Where Inferred
- Maximum Contaminant Level Contour (6.0 µg/L) - Dashed Where Inferred
- Mt. Eden/Alluvium Surface Contact
- Beaumont Site 1 Property Boundary
- (<) Compound was not reported above indicated Method Detection Limit

Notes: Beaumont Site 1 boundary is approximate.

Well locations from Hillwig-Goodrow survey 2007.

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

Concentrations shown are in micrograms per liter (µg/L).

Concentrations shown in black are from Second Quarter 2007 Groundwater Monitoring Event. Concentrations shown in gray are from Second Quarter 2006 Biannual Groundwater Monitoring Event.

Beaumont Site 1

Figure 3-7
1,1-DCE Isoconcentration Map (µg/L) for Alluvium and Shallow Mt. Eden Formation

TETRA TECH

Pliocene to Pleistocene age Mount Eden Formation; the sedimentary San Timoteo Formation; and Quaternary alluvium. A thick sequence of saturated recent alluvium occurs in Bedsprings Creek Valley in the vicinity of Potrero and Bedsprings Faults (Figure A-2). This forms a small alluvial basin (the Bedsprings Creek alluvium) found near the confluence of Potrero and Bedsprings Creeks, extending westward a short distance down Potrero Creek to well MW-67. Bedsprings Creek alluvium is bounded by outcrops of granitic rocks to the east and north; and the Mount Eden and San Timoteo Formations to the northwest, northeast, south, and west. Northwest to southeast trending faults within the area further bound the alluvial sediments.

3.2 CONCEPTUAL HYDROSTRATIGRAPHIC MODEL

Groundwater occurs in four primary units: shallow Quaternary alluvium and deep Quaternary alluvium/ weathered Mount Eden with a total saturated thickness from 0 to 150 feet, the competent Mount Eden Formation with saturated thickness from 100 to 800 feet, and the granitic/metasedimentary basement complex (Figures 3-3 and 3-4). Weathered portions of the Mount Eden are included in the alluvium hydrostratigraphic unit in some areas as they are in direct hydraulic communication, and can sometimes also be difficult to differentiate. The basement rocks provide a base for the shallow water bearing groundwater zones in the alluvium and Mount Eden, since groundwater in the basement rocks is only found in weathered or fracture zones. There may, however, be some communication between the granite and Mount Eden via faults or fracture zones.

The alluvium is sub-divided into a shallow, 0 to 100 feet thick low hydraulic conductivity zone and a deeper, 0 to 50 feet thick high hydraulic conductivity zone that includes some weathered Mount Eden (see further discussion at the end of this section in "*Comparison to Previous Groundwater Conceptual Model*"). These units are depicted in cross-section and schematic form in Figures 3-3 and 3-4. The ground surface elevations are given in the digital elevation model (Figure 3-2). The base of the alluvium/weathered Mount Eden (top of the hard Mount Eden formation) elevations are given in the base of the alluvium contour map (Figure A-1), and these data were used to define a contour map of the thickness of saturated alluvium/ weathered Mount Eden (Figure A-2). The base of the deep high permeability Quaternary alluvium/weathered Mount Eden unit was chosen as the top of the competent Mount Eden formation based upon the contacts observed between the weathered Mount Eden and competent Mount Eden in site drilling logs and geophysical surveys. The deep high permeability Quaternary alluvium and the weathered Mount Eden were treated as a single HSU since they are in direct hydraulic communication; cannot be differentiated in the site well logs and geophysics; have well screens that generally straddle both units; and their hydraulic properties are thought to be quite similar. The base of the Mount Eden (top of the granitic rock) elevation is given in the base of the Mount Eden contour map

(Figure A-3), and these data were used to define a contour map of the thickness of Mount Eden formation (Figure A-4). The thickness of saturated alluvium map shows that the zero thickness contour correlates very well with the alluvium/bedrock contact at the ground surface (Figure A-2), with the zero thickness contour area being slightly smaller in areal extent due to the 10 to 30 foot depth to groundwater observed across the site. Thickness of the granitic zone is not well known since the base of the formation was not encountered in any site borings or in other investigations in the area. The maximum penetration into the granitic zone in any site borings is 127 feet in the MW-73 well cluster, and the maximum penetration into the granitic zone in any borings in the area is 667 feet in boring DH-4 that was completed in 1932 as part of the San Jacinto Tunnel investigation.

3.3 GROUNDWATER FLOW SYSTEM

Alluvial aquifer saturated thickness varies from negligible on the perimeter of the Potrero valley to roughly 100 to 150 feet east of Bedsprings Creek on the flat valley floor (Figure A-2). Groundwater in the alluvium and weathered Mount Eden occurs under unconfined water-table conditions, though silt and clay beds serve as semi-confining members causing different head conditions between hydrostratigraphic units at some locations and artesian conditions near Potrero Fault. Groundwater in the competent Mount Eden and granitic rocks occurs under confined conditions.

3.3.1 Recharge and Discharge Areas

The area is primarily recharged by the infiltration of surface waters draining the adjacent mountain areas and entering the valley along Bedsprings Drainage. Thus, the main recharge area is to the southeast where there are strong downward gradients in the alluvium and large seasonal water table rises in the wet season (see Figures 3-4 and A-5). Recharge also occurred due to groundwater injection when the RMPA system was operating. Groundwater discharge occurs principally as evapotranspiration to the riparian areas, discharge into the lower portions of Potrero Creek, underflow down the canyon below MW-15, leakage into the Mount Eden and granitic rocks, and as groundwater pumpage when the RMPA system was operating. Note that all alluvial groundwater below MW-15 eventually discharges to Potrero Creek since the alluvium pinches out against the Mount Eden below MW-67. Although extraction rate data are not available, groundwater pumpage for other purposes is also known to have occurred in the area, but it is not likely to have been significant based upon known land uses.

3.3.2 Groundwater Elevation and Flow Direction

Groundwater flow is generally consistent with the direction of surface water flow and topography, although it is also influenced by well pumping and injection during the RMPA operations and streamflow recharge during the wet season. Elevation and slope of the water table suggest flow is to the northwest through the Bedsprings Creek alluvium turning southwest through the canyon (see Figure 3-5). Gradient varies from 0.002 in the flat portion of the valley between the BPA and the RMPA, and then increases to 0.01 to 0.02 below the RMPA as fine sediments become more common near the faults and as flow drops into the canyon (Figure 3-5). 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. The alluvial cross-sectional area also decrease in this area, which may also contribute to the higher gradient. Based upon the very high gradients and aquifer thinning near Potrero Fault, this fault appears to restrict groundwater flow to some degree. Groundwater converges toward Massacre Canyon in the southwest.

Seasonal variations in groundwater levels are typically 10 to 30 feet in the recharge areas with smaller variations of 2 to 5 feet in discharge areas (Figures 3-6 and A-5). The greatest change occurs in the recharge areas to the southeast (Figure A-5), where MW-36 has shown up to 60 feet of annual variation. 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 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. Water levels in the alluvium are up to 15 feet higher than in the competent Mount Eden formation, and up to 50 feet higher than in the granitic rocks.

3.3.3 Groundwater Flow Velocity

Groundwater velocity values are estimated to average 354 feet per year in the RMPA, assuming a typical hydraulic conductivity value of 40 feet per day (see discussion in "*Conceptual Model Hydraulic Properties*" below), a gradient of 0.004, and a specific yield (effective porosity) of 0.165. Groundwater velocity values are estimated to be up to 1,725 feet per year in Massacre Canyon, assuming a hydraulic conductivity value of 60 feet per day, a gradient of 0.013, and a specific yield (effective porosity) of 0.165.

3.4 HYDROLOGIC BOUNDARIES

Hydrologic boundaries for the alluvium (see also Figure 4-1) include no-flow conditions in areas where the alluvium pinches out at the cross-gradient perimeter of the valley (see Figure A-2); inflow conditions due to discharge from the Mount Eden in areas where the pinch out is oriented along-gradient; a leakage boundary at the base of the alluvium for flow into the Mount Eden; and a leakage boundary at the base of the Mount Eden for flow into the granitic zone. Interior boundaries include a flow recharge boundary along and under Bedsprings Creek; a flow discharge boundary along Potrero Creek; and partial flow barrier boundaries across Potrero Fault. Based upon water level contour and lithologic data, there appears to be a partial flow barrier within the model area that restricts flow across Potrero Fault.

3.5 HYDRAULIC PROPERTIES

As estimated in site pumping and slug tests (Radian, 1992c and Tetra Tech, 2009b), aquifer hydraulic conductivity values for the alluvium range from 0.24 to 318 feet per day with a geometric mean of 5.7 feet per day (Figure A-6 and A-8). Note that the geometric mean is used since the hydraulic conductivity values are log-normally distributed. Aquifer hydraulic conductivity values for the Mount Eden Formation range from 0.31 to 19.6 feet per day with a geometric mean of 1 foot per day. Hydraulic conductivity values vary with depth and have a geometric mean of 3.1 feet per day for the shallow alluvium and 11.6 feet per day for the deep alluvium (Figure A-8). Hydraulic conductivity values also vary by area, with high values between the RMPA and BPA and low values below the RMPA where fine grained sediments are more common (Figure A-6). As estimated in the site pumping and slug tests (Radian, 1992c and Tetra Tech, 2009b), aquifer transmissivity values are in the range of 1,000 to 2,000 ft^2/day in the RMPA; 100 to 750 ft^2/day downgradient of the RMPA where the gradient steepens; and 500 to 2,500 ft^2/day in Massacre Canyon where the flow area is constricted to a narrow canyon (Figure A-7). Specific yield values are 0.05 to 0.19 as estimated in the site pumping tests (Radian, 1992c and Tetra Tech, 2009b). Thickness values for the alluvium/weathered Mount Eden vary from 0 to 150 feet (Figure A-2). Thickness values for the Mount Eden vary from 100 feet south of the BPA to 800 feet in the RMPA (Figure A-4). Aquifer leakance values between alluvium and competent Mount Eden are estimated to be 1×10^{-6} day^{-1} assuming a competent Mount Eden hydraulic conductivity of 0.01 feet per day (geometric mean value for competent sandstone from Heath, 1987), a horizontal to vertical hydraulic conductivity ratio of 100, and a thickness of 100 feet between the competent Mount Eden and alluvium water bearing zones. Aquifer leakance values between competent Mount Eden and granite are estimated to be 1×10^{-7} day^{-1} assuming a competent granite hydraulic conductivity of 1×10^{-3} feet per day (upper end of value for competent granite from Heath, 1987), a horizontal to vertical hydraulic conductivity ratio of 100, and a thickness of 100 feet between the competent Mount Eden and granite bearing zones. While site wells in the granite have very small yields and permeability, it should be noted that large inflows from the granite were observed in the San Jacinto tunnel southeast of the site, however, this is at depths much greater than the site wells and the inflows were only observed in the tunnel when faults were encountered. Leakance values are likely to be higher near fault and or fracture zones that can provide vertical conduits for groundwater flow. Leakance values may also be adjusted during model calibration to match the vertical gradients between hydrostratigraphic units and water budget estimates of leakage.

3.6 WATER BUDGET

A preliminary water budget is defined as part of the basis for construction of the numerical flow model. Key elements of the groundwater water budget are given in Sections 3.6.1 through 3.6.3 and Table 3-1. This water budget is preliminary to serve as a guide for the model construction and calibration, and some elements of the water budget were revised during the model calibration and verification process. More detailed water budgets including seasonal and inter-annual variations in flows are given in Sections 4 and 5.

3.6.1 Precipitation and Streamflow

The watershed area above the modeled area is 35 square miles, the valley floor is 800 acres, and the valley floor underlain by saturated alluvium is roughly 600 acres. Streamflow is fed by runoff in the Beaumont and San Gorgonio Pass areas, and ephemeral streams such as Bedsprings Creek draining off the foothills of the San Jacinto Mountains (Figure 3-2). Annual average streamflow estimated to be 1,230 acre feet per year for Potrero Creek at Massacre Canyon (Leighton and Associates, Inc., 1983), with a baseflow of roughly 100 acre feet per year. Total volume due to precipitation is estimated to be 24,408 acre feet per year for the sub-watersheds above Massacre Canyon based upon precipitation values of 14 to 20 inches per year (Leighton and Associates, Inc., 1983) and the watershed area. Runoff is only a small fraction (about 5 percent) of precipitation.

3.6.2 Aquifer Recharge

Total recharge to the alluvium is estimated to be 231 acre feet per year using the groundwater elevation changes measured in the site groundwater monitoring program (Figure A-5) and the specific yield value of 0.05 to 0.19 determined during site pumping tests (Radian, 1992c and Tetra Tech, 2009b). These values are in general agreement with values proposed earlier (Leighton and Associates, Inc., 1983) and are apportioned as follows:

- Direct Precipitation – Estimated to be 99 acre feet per year assuming a diffuse recharge rate of 1.5 inches per year applied over the valley floor.
- Recharge from Bedsprings Creek – Estimated to be 132 acre feet per year based upon the difference of diffuse and total recharge.
- Underflow – No significant underflow from San Gorgonio Pass to the north or Bedsprings Creek drainage to the southwest, but there may be minor volumes of mountain front recharge from the Mount Eden in this area. Note there is underflow of 5 to 18 acre feet per year into the BPA from the narrow channel of alluvium to the south (Table 3-1), but that is derived from diffuse and creek recharge.
- Injection – Values averaged 48 acre feet per year during injection operations between 1994 and 2002, and zero for other years (Table 3-2). Note that injection was approximately balanced by extraction.

Table 3-1
Underflow Calculations for Alluvial Aquifer at Beaumont Site 1

Area	Zone	Gradient (ft/ft)		Hydr Conduct (ft/day)		Thickness (ft)		Transmissivity (ft^2/day)		Width (ft)		Underflow (acre-ft/year)	
		value	comment	value	comment	value	comment	value	comment	value	comment	value	comment
Massacre Canyon below MW-15 (wet period)	Qal	0.0125	MW-14-MW-18 data	12 to 24	average (up 85 in gravel)	70	Qal thick at MW-18 & MW-15	850 to 1700	MW-15 data	500	Qal width at MW-18	45 to 90 (28 to 56 gpm)	Qal Outflow
Massacre Canyon below MW-15 (dry period)	Qal	0.0063	MW-14-MW-18 data	12 to 24	average (up 85 in gravel)	70	Qal thick at MW-18 & MW-15	850 to 1700	MW-15 data	500	Qal width at MW-18	22 to 44	Qal Outflow
Middle Potrero Creek at MW-14 (wet period)	Qal	0.0170	MW-14-MW-37 data	38	EW-19 Pump Test	60	Qal thick at EW-19	2455	EW-19 data	425	Qal width at EW-19	149 (92 gpm)	Qal Outflow
Middle Potrero Creek at MW-14 (dry period)	Qal	0.0090	MW-14-MW-37 data	38	EW-19 Pump Test	60	Qal thick at EW-19	2455	EW-19 data	425	Qal width at EW-19	79 (49 gpm)	Qal Outflow
Middle Potrero Creek at MW-14 (average)	Qal	0.0120	MW-14-MW-37 data	38	EW-19 Pump Test	60	Qal thick at EW-19	2455	EW-19 data	425	Qal width at EW-19	105 (65 gpm)	Qal Outflow
Middle of Bedspings Creek Qal (wet period)	Qal	0.0167		7.5		100		750		3500		367	
Middle of Bedspings Creek Qal (dry period)	Qal	0.0111		7.5		100		750		3500		245	
Bedspings Creek Qal between BPA and RMPA (wet period)	Qal	0.0036		22 to 34		80		1744 to 2700	MW-30 pump test	2300	Qal width at MW-23/30	121 to 187	
Bedspings Creek Qal between BPA and RMPA (dry period)	Qal	0.0018		22 to 34		80		1744 to 2700	MW-30 pump test	2300	Qal width at MW-23/30	61 to 93	
Bedspings Creek Qal south of BPA (wet period)	Qal	0.0286		6		50		300		250		18	
Bedspings Creek Qal south of BPA (dry period)	Qal	0.0077		6		50		300		250		5	

Table 3-2
RMPA Groundwater Extraction Volumes and Rates

Quarterly Period	Start Date	End Date	End Cumulative Volume (gallons)	Period Volume (gals)	Rate (gpm)	Rate (acre-ft/yr)
1	10/1/92	12/31/92	0	0	0	0
2	12/31/92	4/1/93	0	0	0	0
3	4/1/93	7/1/93	0	0	0	0
4	7/1/93	10/1/93	0	0	0	0
5	10/1/93	12/31/93	0	0	0	0
6	12/31/93	4/1/94	0	0	0	0
7	4/1/94	7/2/94	414,900	414,900	3.2	5.1
8	7/2/94	10/1/94	7,280,293	6,865,393	52.2	84.2
9	10/1/94	12/31/94	14,368,100	7,087,807	53.9	87.0
10	12/31/94	4/2/95	20,955,274	6,587,174	50.1	80.8
11	4/2/95	7/2/95	27,260,665	6,305,391	48.0	77.4
12	7/2/95	10/1/95	34,662,335	7,401,670	56.3	90.8
13	10/1/95	1/1/96	40,969,880	6,307,545	48.0	77.4
14	1/1/96	4/1/96	47,292,135	6,322,255	48.1	77.6
15	4/1/96	7/1/96	51,757,459	4,465,324	34.0	54.8
16	7/1/96	10/1/96	55,814,639	4,057,180	30.9	49.8
17	10/1/96	12/31/96	60,324,400	4,509,761	34.3	55.3
18	12/31/96	4/1/97	62,803,174	2,478,774	18.9	30.4
19	4/1/97	7/1/97	64,811,557	2,008,383	15.3	24.6
20	7/1/97	10/1/97	66,642,257	1,830,700	13.9	22.5
21	10/1/97	12/31/97	69,318,507	2,676,250	20.4	32.8
22	12/31/97	4/1/98	72,276,092	2,957,585	22.5	36.3
23	4/1/98	7/2/98	77,164,382	4,888,290	37.2	60.0
24	7/2/98	10/1/98	79,458,682	2,294,300	17.4	28.1
25	10/1/98	12/31/98	84,404,382	4,945,700	37.6	60.7
26	12/31/98	4/2/99	89,064,282	4,659,900	35.4	57.2
27	4/2/99	7/2/99	92,684,984	3,620,702	27.5	44.4
28	7/2/99	10/1/99	95,470,784	2,785,800	21.2	34.2
29	10/1/99	1/1/00	96,917,385	1,446,601	11.0	17.7
30	1/1/00	4/1/00	100,996,385	4,079,000	31.0	50.0
31	4/1/00	7/1/00	103,626,414	2,630,029	20.0	32.3
32	7/1/00	10/1/00	105,974,414	2,348,000	17.9	28.8
33	10/1/00	12/31/00	106,286,414	312,000	2.4	3.8
34	12/31/00	4/1/01	106,574,414	288,000	2.2	3.5
35	4/1/01	7/1/01	110,128,414	3,554,000	27.0	43.6
36	7/1/01	10/1/01	113,252,414	3,124,000	23.8	38.3
37	10/1/01	12/31/01	113,433,354	180,940	1.4	2.2
38	12/31/01	4/1/02	116,438,259	3,004,905	22.9	36.9
39	4/1/02	7/2/02	119,066,423	2,628,164	20.0	32.2
40	7/2/02	10/1/02	121,796,594	2,730,171	20.8	33.5
41	10/1/02	12/31/02	123,789,093	1,992,499	15.2	24.4
42	12/31/02	4/2/03	0	0	0	0
43	4/2/03	7/2/03	0	0	0	0
44	7/2/03	10/1/03	0	0	0	0
45	10/1/03	1/1/04	0	0	0	0
46	1/1/04	4/1/04	0	0	0	0
47	4/1/04	7/1/04	0	0	0	0
48	7/1/04	10/1/04	0	0	0	0

Table 3-2
RMPA Groundwater Extraction Volumes and Rates

Quarterly Period	Start Date	End Date	End Cumulative Volume (gallons)	Period Volume (gals)	Rate (gpm)	Rate (acre-ft/yr)
49	10/1/04	12/31/04	0	0	0	0
50	12/31/04	4/1/05	0	0	0	0
51	4/1/05	7/1/05	0	0	0	0
52	7/1/05	10/1/05	0	0	0	0
53	10/1/05	12/31/05	0	0	0	0
54	12/31/05	4/1/06	0	0	0	0
55	4/1/06	7/2/06	0	0	0	0
56	7/2/06	10/1/06	0	0	0	0
57	10/1/06	12/31/06	0	0	0	0
58	12/31/06	4/2/07	0	0	0	0
59	4/2/07	7/2/07	0	0	0	0
60	7/2/07	10/1/07	0	0	0	0
61	10/1/07	1/1/08	0	0	0	0
62	1/1/08	4/1/08	0	0	0	0
63	4/1/08	7/1/08	0	0	0	0
64	7/1/08	10/1/08	0	0	0	0

EX-1 Rate = 87.3% of total

EX-2 Rate = 12.7% of total

3.6.3 Aquifer Discharge

Total discharge from the alluvium is estimated to be 231 acre feet per year to balance inflow. These values are apportioned as follows:

- Extraction – Values averaging 48 acre feet per year during extraction operations between 1994 and 2002, and zero for other years (Table 3-2). There was no significant known volume of extraction in the area for other purposes.
- Evapotranspiration – Estimated to be 120 acre-feet per year into the Riparian Area near the confluence of Bedsprings and Potrero Creeks, where there is an abundance of high water consuming vegetation such as bulrush-cattails, cottonwood trees, and willow trees. There also may be some evapotranspiration further down the canyon near Potrero Creek; however, since the groundwater table is generally 25 to 30 feet below the canyon ground surface, evapotranspiration would be limited to the area where the creek bed is incised some 10 to 15 feet. Since the creek bed comprises only roughly 7 acres in this area, evapotranspiration would be limited to roughly 18 acre-feet per year if there is riparian vegetation along the entire creek bed.
- Discharge to Potrero Creek – Estimated to be 107 acre feet per year based upon a balance of recharge and other discharge terms. This equals roughly 5 to 10 percent of the average annual streamflow in Potrero Creek, which seems a reasonable estimate of baseflow in this area. Streamflow measured during the dry season below MW-18 in the site groundwater monitoring program is 70 to 101 acre feet per year.
- Underflow – Estimated to be 50 acre-feet per year below MW-15 based upon underflow calculations (Table 3-1), although this volume discharges to Potrero Creek between MW-15 and MW-67.
- Leakage – Estimated leakage to the Mount Eden is 4 acre feet per year using a leakance factor of 1×10^{-6} day^{-1}, an area of 665 acres, and a head difference of 15 feet between the alluvium and Mount Eden (i.e., 15 feet x 1×10^{-6} day^{-1} x 665 acres = 4 acre feet per year). Leakage estimated to the granitic zone is 1.6 acre feet per year using a leakance factor of 1×10^{-7} day^{-1}, an area of 665 acres, and a head difference of 60 feet between the Mount Eden and granitic zone.

3.6.4 Annual Variation in Water Budget

The water budget given in Sections 3.6.1 through 3.6.3 represents values given for average conditions, but there is a good deal of year to year variability in the water budget (Leighton and Associates, Inc., 1983). Table 3-3 shows precipitation data and estimated aquifer recharge for the period 1991 through 2008, where aquifer recharge is estimated from the seasonal increase in aquifer volume assuming an average aquifer specific yield of 10 percent. The change in aquifer storage volume due to recharge varies from 0 to 1,395 acre-feet per year, with an average value of 213 acre-feet per year during wet years. During roughly one-half the period there is very limited aquifer recharge during dry year, which typically occurred if precipitation is below approximately 12 inches (Table 3-3), and during these years storage actually declines. When precipitation increases above this threshold value of 12 inches, recharge increases proportional to precipitation. The sensitivity of groundwater recharge to a threshold value of precipitation has been well documented in groundwater investigations in arid and semi-arid areas (Danskin, 1998; and

Table 3-3
Precipitation and Aquifer Recharge from 1991 through 2008

Water Year	Precipitation			Aquifer Recharge Volume
	Rate (in)	Cumulative Departure (inch)	Volume* (AFY)	Rise in Storage (AFY)
1991	17.9	-15.9	883	282
1992	16.7	-16.0	824	88
1993	38.7	5.9	1,909	1,395
1994	15.3	4.4	755	~0
1995	30.4	18.0	1,500	502
1996	10.2	11.4	503	~0
1997	17.7	12.3	873	~0
1998	28.08	23.6	1,385	655
1999	7.6	14.4	375	~0
2000	5.6	3.2	276	78
2001	9.3	-4.3	459	~0
2002	5.2	-15.9	257	~0
2003	21.2	-11.5	1,046	55
2004	11.33	-17.0	559	~0
2005	32.66	-1.1	1,611	988
2006	13.35	-4.6	659	~0
2007	5.44	-15.9	268	~0
2008	16	-16.7	789	~0
Average	16.8	0.4	830	225

* Volume refers to precipitation over alluvial aquifer area (entire watershed is roughly 35 times greater)

Kumar and Seethapathi, 2002). The amount of recharge also varies with the cumulative departure curve and antecedent conditions, with higher recharge values occurring when there is an excess in cumulative precipitation and wet antecedent conditions, and lower recharge values occurring when there is a deficit in cumulative precipitation and dry antecedent conditions. Average storage change over the entire period is +37 acre-feet per year.

3.7 CONTAMINANT DISTRIBUTION

Detailed maps depicting the distribution of site contaminants are given for the alluvium in many prior site reports (Radian Corporation, 1990 and 1992c, and Tetra Tech Inc., 2007c and 2008). No specific maps depicting the distribution of site contaminants are given for the Mount Eden or granite, in part because of the limited extent of contamination in these units. However, outside the BPA significant contamination is generally not observed in the competent Mount Eden and granite formations (Tetra Tech, 2007c and 2008). Contamination observed in the weathered Mount Eden formation is lumped with the alluvium (Tetra Tech, 2007c). Primary contaminants at the site are perchlorate, 1,1-dichloroethene (1,1-DCE), trichloroethene (TCE), and 1,4-dioxane (see plume maps in Figures C-12 and C-13). The highest concentrations of contaminants have consistently been reported in groundwater samples collected from shallow screened wells located in the former BPA and concentrations appear to rapidly decrease outside, and down gradient, of the footprint of the former BPA (Figure 3-7).

3.8 COMPARISON WITH PRIOR SITE CONCEPTUAL MODELS

The updated groundwater conceptual model given in this memorandum is generally similar to the previous groundwater conceptual model. However, based upon the more recent data, one significant revision was made to the hydrostratigraphic model in the updated conceptual model. The previous groundwater conceptual model considered only two primary units - alluvium/weathered Mount Eden and consolidated rock - but the updated conceptual model considers four primary units: shallow alluvium, deep alluvium/weathered Mount Eden, sedimentary rocks, and basement rocks (Figures 3-3 and 3-4). The alluvium is sub-divided in the updated conceptual model into an upper low hydraulic conductivity unit and a deeper high hydraulic conductivity unit based upon lithologic, hydraulic, water level, and water quality data as follows:

- Lithologic Data – As shown in Figure 3-3 and Figure 3-4, fine-grained units are far more prevalent in the upper saturated alluvium and coarse-grained units are far more prevalent in the lower saturated alluvium in most areas of the site. In many areas of the site a gravel zone is encountered directly overlying the Mount Eden contact;
- Hydraulic Data – The geometric mean hydraulic conductivity of the shallow saturated alluvium (3.1 feet per day) is significantly lower than the geometric mean hydraulic conductivity of the deep saturated alluvium (11.6 feet per day; see Figure A-8). In addition, while independent

pumping tests showed a hydraulic conductivity value of 4.8 ft/day in shallow well MW-23 and 46.4 feet per day in deep well MW-30, as a shallow observation well MW-23 showed only a weak response to pumping in deep well MW-30. These data together indicate wells MW-23 and MW-30 are in separate zones;

- Water Level Data – Artesian conditions occur in areas of the site, where shallow fine grained alluvium confines deeper coarse grained alluvium; and
- Water Quality Data – The shallow alluvium generally has a higher TDS and calcium-alkaline dominated water (Table 3-4), while the deeper alluvium generally has a lower TDS and calcium/magnesium-alkaline dominated water.

In addition to sub-dividing the alluvium, the deeper consolidated rock is sub-divided in the updated conceptual model into a competent Mount Eden unit and the underlying granitic/metasedimentary basement complex unit based upon lithologic, hydraulic, water level, and water quality data as follows:

- Lithologic Data – The Mount Eden is a porous, semi-permeable sedimentary rock, while the basement complex is very low porosity granitic rock that only yields water through fractures;
- Hydraulic Data – The hydraulic conductivity of the water bearing intervals in the competent Mount Eden is about 1 feet per day, while hydraulic conductivity of the water bearing intervals in the granitic rock is 0.1 feet per day; and
- Water Level Data – Water levels in the deep Mount Eden wells are about 15 feet lower than in the alluvial aquifer, while water levels in the deep granitic wells are up to 60 feet lower than in the alluvial aquifer.

This updated conceptual model is proposed as part of the basis for construction of the numerical flow model. Although there are uncertainties in some aspects of the conceptual model, this is typical for hydrogeologic studies, and there do not appear to be any data gaps that would preclude proceeding with development of the numerical groundwater flow model or the design of remediation systems.

Table 3-4
Water Quality Data from Monitoring Wells at Beaumont Site 1

Well	Depth	Unit	Sodium (NA^{+1}), meq/L	Calcium (CA^{+2}), meq/L	Magnesium (MG^{+2}), meq/L	Chloride (CL^{-1}), meq/L	Alkalinty (ALK^{-1}), meq/L	Sulfate ($SO4^{-2}$), meq/L	TDS (mg/L)	Comment
EW-15	S	ME	2.54	3.81	0.75	3.45	1.12	0.48	847	CA-ALK
MW-01	I	ME	1.82	0.65	0.13	0.26	1.41	0.37	191	NA-ALK
MW-07	S	Qal	0.59	0.73	0.20	0.22	0.86	0.12	124	CA-ALK
MW-12	S	Qal	6.48	14.45	3.61	1.70	7.15	14.79	1,660	CA-ALK
MW-19	S	Qal	0.75	1.10	0.31	0.25	1.44	0.19	163	CA-ALK
MW-40	S	ME	1.33	1.75	0.20	0.26	1.69	0.42	255	CA-ALK
MW-42	S	Qal	1.03	1.69	0.42	0.27	1.82	0.56	219	CA-ALK
MW-43	S	Qal	0.67	1.24	0.29	0.18	1.30	0.21	146	CA-ALK
MW-45	S	Qal	0.62	1.14	0.32	0.18	1.06	0.21	143	CA-ALK
MW-46	S	Qal	1.15	1.89	0.40	0.21	2.61	0.22	254	CA-ALK
MW-50	S	Qal	0.49	0.93	0.27	0.16	1.00	0.09	121	CA-ALK
MW-57A	S	Qal	0.81	1.33	0.41	0.20	1.01	0.20	181	CA-ALK
MW-58D	I	Qal	0.89	1.29	0.41	0.21	1.06	0.21	192	CA-ALK
MW-59B	I	ME	2.34	0.82	0.85	0.25	1.00	0.34	282	NA-ALK
MW-62A	S	Qal	0.80	1.50	0.46	0.21	1.12	0.23	221	CA-ALK
MW-63	S	Qal	0.66	1.33	0.38	0.20	0.94	0.20	219	CA-ALK
OW-02	S	Qal	0.55	0.94	0.28	0.18	1.00	0.16	252	CA-ALK
		Data below are for well pairs								
MW-02	I	Qal	1.22	1.25	0.34	0.22	0.96	0.20	229	CA/MG-ALK; compare with deep well MW-03
MW-03	D	ME	2.40	0.08	0.00	0.37	1.06	0.27	185	NA-ALK; compare with shallow well MW-02
MW-05	S	Qal	1.08	2.06	0.62	0.27	1.95	0.25	229	CA-ALK; compare with deeper well MW-06
MW-06	I	Qal	1.04	1.06	0.19	0.27	1.72	0.06	172	CA/MG-ALK; compare with shallow well MW-05
MW-18	S	Qal	1.94	3.46	0.74	0.36	4.18	0.78	388	CA-ALK; compare with deeper well MW-15
MW-15	I	Qal	2.14	2.16	0.62	0.37	3.02	0.99	307	CA/MG-ALK; compare with shallow well MW-18
MW-56B	I	Qal	1.33	1.38	0.40	0.24	1.42	0.23	236	CA/MG-ALK; compare with deep well MW-56A
MW-56A	D	ME	2.51	0.14	0.08	0.39	0.96	0.24	184	NA-ALK; compare with shallower well MW-56B

S=shallow, I=Intermediate, D=Deep, Qal = alluvium, ME = Mount Eden, meq/L = milli-equivalents per liter
meq/L = concentration in mg/L divided by the ion molecular weight and charge

(yellow) =dominant cation
(green) =dominant anion
(blue) =lower TDS in well pair

4.0 NUMERICAL FLOW MODEL DEVELOPMENT

The design, construction, and calibration of the numerical flow model are discussed in Section 4. The conceptual model presented in Section 3 is used as the underlying basis for developing the numerical model. Previous modeling in the area, discussed in Section 1.2, is utilized where appropriate to aid in the model constructed for this study. The Numerical Model is later used in Section 5.0 as a hydrogeologic planning tool to evaluate various remedial and monitoring alternatives for the Site.

4.1 MODEL DESIGN AND CONSTRUCTION

This section presents the approach used to extend the groundwater conceptual model to a numerical MODFLOW groundwater flow model (Harbaugh et al., 2000) including layering, the model extent, boundary conditions, aquifer stresses, initial ranges for hydraulic properties, approach to steady-state and transient calibration, choice of calibration targets, and identification of a validation period.

Layering

Based upon the four primary units defined in the hydrostratigraphic model (shallow Quaternary alluvium, deep Quaternary alluvium/weathered Mount Eden, competent Mount Eden Formation, and the granitic/metasedimentary basement complex), four layers are proposed for the numerical model. The shallowest two layers (1 and 2) represent the alluvium, with the top of layer 1 defined as the ground surface (Figure 3-2) and the base of layer 2 defined as the Top of the hard Mount Eden (Figure A-1). The base of layer 1 or top of layer 2 (Figure A-9) represents the boundary between the shallow, lower permeability alluvium and the deep, higher permeability alluvium/weathered Mount Eden, which is picked to occur at the top of the gravel/high permeability zone encountered above the Mount Eden contact. The base of layer 2 (deep high permeability Quaternary alluvium/weathered Mount Eden unit) or top of layer 3 is defined as the top of the hard Mount Eden (Figure A-1). The base of layer 3 or top of layer 4 is defined as the top of the granite (Figure A-3). The base of layer 4 or bottom of the model is defined as the top of the granite minus 127 feet in order to coincide with the deepest screened interval in the granite at Well MW-73A (the maximum granite penetration observed in a site boring). An illustration of the layer elevations and thickness values is shown for the constructed MODFLOW model in Appendix B, Figures B-6 through B-11.

Note that flows into or out of the granite are likely very small and may have very limited impact on shallow groundwater flow. However, recent drilling in the granite in the BPA has found perchlorate and a reversal of the regional shallow groundwater gradient, and there is a possible concern about groundwater seeping into the San Jacinto tunnel bored deep into the granite southeast of the site. Therefore, it was decided to include the granite in the model to provide some basis for quantifying the possible flows, and hence contaminant fluxes, into the granite unit.

Note also that the maps in Figures A-1 and A-2 do not explicitly show fault discontinuities in the contours since there is limited control on the offset and location of the fault in the available well logs and geophysics, and any attempt to create a sharp offset in the fault would have been arbitrary in terms of both the fault placement and offset. Instead, the bedrock highs and lows near the fault trace in Figure A-1 and the large alluvium thickness values between the two fault traces in Figure A-2 are a smoothed reflection of the fault discontinuities. Thus, the thick basin of alluvium southeast of the Potrero Fault is attributed to the offset of the fault. Considering that MODFLOW flow models also represent the fault using a Horizontal Flow Barrier that is calibrated to simulate the flow restrictions of the fault, it was concluded the smoothed version of the maps would have a very similar impact on groundwater flows to a version with abrupt changes. Therefore, the maps were left in a smoothed format.

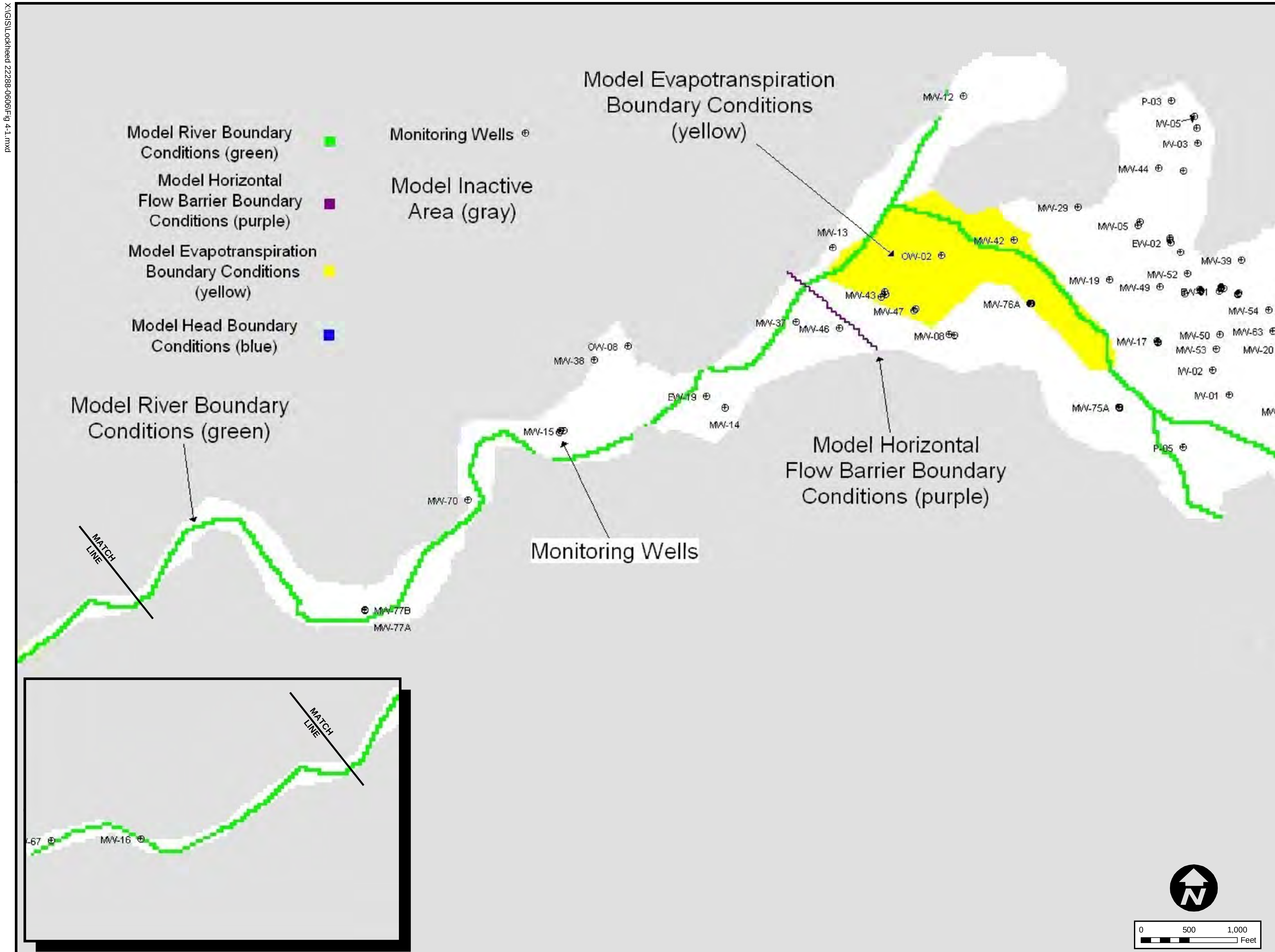
Model Extent

The model areal extent as given in Figure 4-1 is primarily limited to the 592 acre area where the saturated alluvium is present as indicated by the zero contour in Figure A-2. The one small exception is the small area in the BPA where the alluvium is dry and the groundwater table occurs in the Mount Eden (Figure A-2). This model extent is similar to the grid area considered in the prior Site groundwater model (Radian Corporation, 1993b), except that the current model area extends down Potrero Creek to well MW-67 whereas the prior model only ended at well MW-15/18. The model layer boundaries were designed to be constrained by the land topography, the stratigraphic boundary between the various water bearing units, and by the bedrock topography. In addition, model layers are constrained in their horizontal extents according to the extents of saturated alluvium.

The model has 203 rows, 520 columns, and four layers. Each column and row is 35 feet wide and is aligned parallel to the California State Plane coordinate system (1983, Zone VI) with an origin at 6,338,600 feet Easting and 2,253,800 feet Northing. Constant grid spacing of 35 feet is used since this promotes stability in MODFLOW models, and provides adequate resolution of the aquifer without excessive run-time constraints. As discussed above in “Layering”, the vertical extent of the model covers the entire saturated alluvium (layers 1 and 2), the entire Mount Eden formation (layer 3), and 127 feet of the granitic formation (layer 4).

Boundary Conditions

The numerical flow model boundary conditions were chosen to coincide with natural hydrogeologic boundaries discussed in the conceptual model (Section 3.4) as shown in Figure 4-1. Boundary conditions



Beaumont Site 1

Figure 4-1
MODFLOW Model Boundary Conditions for Shallow Alluvium/ Weathered Mt. Eden (Layer 1)

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are no-flow conditions against the sides of the valley floor where the saturated alluvium pinches out cross-gradient against bedrock. River boundaries (RIV) are added to the areas under Potrero and Bedspring Creeks, resulting mainly in recharge boundaries in the upper portion of the model and discharge boundaries in the lower portions of the model. Use of the stream (STR) package was also considered; however, the STR package requires input of stream flow and stream hydraulics data that are not available for the site. Instead, a groundwater/surface water balance is evaluated outside the model to assure that a reasonable match with the conceptual model water budget is maintained.

Elevations for the river package were set using the ground surface DEM of the site (Figure 3-2), with the streambed incised 10 feet as per the site conditions (Leighton and Associates, Inc., 1983). River conductances were set using a hydraulic conductivity value of 1 feet per day for the streambed in all areas except where clay is present near the confluence of Potrero and Bedsprings Creeks, where the value was 0.01 feet per day.

Time-varying head inflow boundaries are used in a small area in the southeast portion of the model (Figure 4-1) to account for mountain front recharge that enters the alluvium from the Mount Eden in the most upper reach of Bedsprings Creek. However, very little flow comes in the model through this boundary and nearly all the flow comes into the model via diffuse percolation of precipitation to the water table and recharge from the streams. The limited use of head boundaries best reflects the natural hydrogeologic conditions and helps to ensure the model water budget conforms to actual site conditions. Leakage is allowed between the alluvium and Mount Eden formations, and between the Mount Eden and granitic formations. In addition, in the upper and lower boundaries of the model area, underflow is allowed via time varying head boundaries in Layers 3 and 4 (Mount Eden and Granitic formations) since these units extend beyond the model area. The partial flow barrier that restricts flow across the Potrero Fault is treated as a horizontal flow barrier (HFB) boundary within the model area. Evapotranspiration boundaries are modeled in the riparian area, with an estimated extinction depth of 25 feet and an average evapotranspiration rate of 3.83 feet per year (Radian Corporation, 1993b and California Irrigation Management Information System, 2008). The extinction depth of 25 feet was correlated with the ET measurememts observed in site wells such as MW-70, where ET is clearly observed at depths at groundwater of 26 to 31 feet. The evapotranspiration rate varies seasonally from a low value of 1.9 feet per year to a high value of 6.5 feet per year, as per evapotranspiration rates measured from diurnal fluctuations in groundwater levels measured in the site riparian area (California Irrigation Management Information System, 2008; and Tetra Tech, 2009a).

Aquifer Stresses

Based upon the conceptual model and water budget, the model considers the following aquifer stresses: diffuse recharge that varies seasonally and inter-annually based upon precipitation; stream recharge/discharge that varies seasonally and inter-annually based upon precipitation, streamflows, and groundwater elevations; evapotranspiration from the water table that varies depending upon the depth to groundwater and seasonal varying maximum evapotranspiration rates; and well extraction/injection that varies based upon the historical operating data for the RMPA and BPA clean-up systems. Seasonal and yearly variation in recharge from river seepage was obtained by varying the river stage elevation, which in MODFLOW can vary by stress period. The river stages were varied with time in order to distribute stream recharge in proportion to the precipitation and net recharge observed from historic groundwater monitoring events, where the overall recharge was constrained to match the general ranges of water budgets in the site CSM and groundwater levels measured at the site. Stream recharge for various stream reaches are varied in proportion to watershed drainage area, which results in the bulk of the stream recharge (roughly 70 percent) being applied to the main reach of Bedsprings Creek in the southeastern corner of the model. In addition, flows across the model boundaries vary based upon the time-varying water levels measured in the monitoring program, but these flows are very small since there is very little flow into the alluvium via boundaries. Stress periods are quarterly to allow for seasonal and inter-annual variation in aquifer stresses.

Initial Ranges for Hydraulic Properties

The initial ranges for aquifer hydraulic properties were defined based upon the values summarized in the "*Conceptual Model Hydraulic Properties*" section above. Aquifer hydraulic conductivity values varied with depth and area in a simplified version of the variations depicted in Figures A-6 and A-8. Aquifer thicknesses and layer elevations are defined based upon the alluvium, Mount Eden, and granitic formation contour maps (Figures A-1 through A-4). Aquifer specific yield values are initially set in the range observed in site pumping tests and the conceptual model (0.05 – 0.19). The LPF package is used to represent model layer elevations and properties, which is the default setting for MODFLOW2000 in GWVistas (Environmental Simulations, Inc., 2008).

Approach to Steady-state and Transient Calibration

The approach to Steady-state and Transient Calibration was developed considering data availability, variations in aquifer stresses, and the overall flow model objectives. The chosen approach was to perform a steady-state calibration during a period with quasi-steady aquifer stresses and water levels, and then use the calibrated steady-state water levels as a starting condition for a transient calibration during a period when aquifer stresses change over time. The steady-state calibration time was chosen as Fall (October)

1992 since (1) water levels at this time were fairly constant; (2) precipitation values were typical for the water year; (3) sufficient monitoring data are available for calibration and assessing trends before the calibration period; and (4) this period is before start-up of the RMPA/BPA clean-up systems. The transient calibration time was chosen to be the ten-year period from October 1992 through 2002 since this is roughly the operating period the RMPA/BPA clean-up systems. Key transient calibration events will be the time-varying RMPA/BPA extraction/injection rates, and the seasonal and inter-annual variation in precipitation. The time after shut-down of the RMPA system (2003 to present) was chosen as the validation period as discussed below.

Calibration Targets

Primary calibration targets are the water levels measured in the site monitoring program during the calibration period, and a secondary calibration target is the site water budget given in the conceptual model. In particular, the outflow at the lower end of the valley and the evapotranspiration rate in the riparian area are good calibration targets since they are key components of the conceptual model. Since some small areas of the site have an excess of monitoring wells in the same hydrostratigraphic zone that can bias the calibration by overly weighting one area over another, the spatial network of targets was also screened to remove redundant locations. This was done using the "Target Thinning" procedure in the MODFLOW pre-processor Groundwater Vistas (Environmental Simulations, Inc., 2008), which deletes targets in areas where there are too many. Target Thinning average duplicates, and allow only one target at the same location and hydrostratigraphic zone based upon both the distance between targets and whether targets are in the same model cell. Target thinning was performed separately for each hydrostratigraphic zone, considering the need to retain the co-located nested wells that monitor the various hydrostatigraphic zones at one location. Model calibration was then evaluated using both the full data set and the "Target Thinning" data sets to assure small areas of the site with an excess of monitoring wells in the same hydrostratigraphic zone do not bias the calibration procedure.

Validation Period

The time after shut-down of the RMPA system (2003 to present) was chosen as the validation period for the model. This will test the calibrated model against a different set of hydrologic conditions after the shut-down of the RMPA extraction/injection system.

4.2 MODEL CALIBRATION

The MODFLOW model was calibrated in both steady-state and transient conditions. The term "steady-state" signifies that groundwater levels are relatively stable at that time, and that groundwater inflows and outflows are relatively equal and constant.

4.2.1 Steady-State Conditions

Steady-state, saturated flow conditions were simulated using MODFLOW-2000. Groundwater levels at the model head boundaries were set using October 1992 water level data. Recharge values were initially determined using the site water balance, and adjusted during calibration. The final calibrated annual average recharge rate in the model was 114 acre-feet per year, with 74 acre-feet per year from the streams and 40 acre-feet per year (0.8 inch per year) due to diffuse recharge. These recharge rates are on the low end of those reported for the water budget in the transient calibration (see Section 4.2.2) reflecting the rather low water levels and the cumulative precipitation deficit at that time (see Figure 3-6). More detailed discussion on the site water budget is given in the transient calibration, which is typically a better estimate of the overall long-term site water balance, while steady-state calibration typically provides a good indication of the site hydraulic conductivity.

Model Parameters

Model hydraulic conductivity values were initially set based upon the main trends in site well data (Figures A-6 through A-8 and Section 3.5). The final calibrated values of hydraulic conductivity are given in Figures B-1 and B-2 in Appendix B and are as follows:

- Mean hydraulic conductivity values are 4 feet per day for the shallow low permeability alluvium (Layer 1) and 22 feet per day for the deeper high permeability alluvium. Median hydraulic conductivity values are 1 feet per day for the shallow low permeability alluvium (Layer 1) and 30 feet per day for the deeper high permeability alluvium;
- Hydraulic conductivity values for Layer 1 are generally 1 feet per day except in lower Potrero Creek where values are 10 to 30 feet per day;
- Hydraulic conductivity values for the deeper high permeability alluvium vary spatially with values of 30 feet per day near MW-30 between the RMPA and BPA; 10 to 17 feet per day towards the confluence of Bedsprings and Potrero Creeks; 1 feet per day right along the Potrero Fault; and 30 to 75 feet per day in the Potrero Creek canyon;
- Hydraulic conductivity values for the competent Mt Eden are 0.1 feet per day, yielding competent Mt Eden transmissivity values of 20 to 80 ft^2 per day;
- Hydraulic conductivity values for the granite are 0.01 feet per day, yielding granite transmissivity values of 2 ft^2 per day;
- Vertical hydraulic conductivity values in the alluvium are one-tenth of horizontal hydraulic conductivity values except for the shallow alluvium in the fine-grained (clay) sediments near the confluence of Bedsprings and Potrero Creeks, where vertical hydraulic conductivity values are one-hundredth of horizontal hydraulic conductivity values; and
- At the Potrero Fault, the HFB package used hydraulic conductivity values of 0.1 feet per day with a thickness of 10 feet in the alluvium.

These calibrated hydraulic conductivity values compare reasonably well with those given in pumping test and slug test data for these units and areas, and in the site conceptual model as illustrated by the data shown in Appendix A. In particular, the model transmissivity values (Figure B-3) generally match those reported in site pumping tests, with values of roughly 1,500 ft^2 per day in the wells screened in the deep high permeability alluvium; 150 ft^2 per day in the wells screened in the shallow low permeability alluvium; and 20 ft^2 per day in the wells screened in the competent Mt Eden. Model transmissivity value vary spatially in a similar manner as the site data, with values of 20 ft^2 per day in the BPA, 1,500 ft^2 per day in the area between the RMPA and BPA, 100 to 500 ft^2 per day in the lower RMPA, and 1,500 to 2,500 ft^2 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.

Water Levels

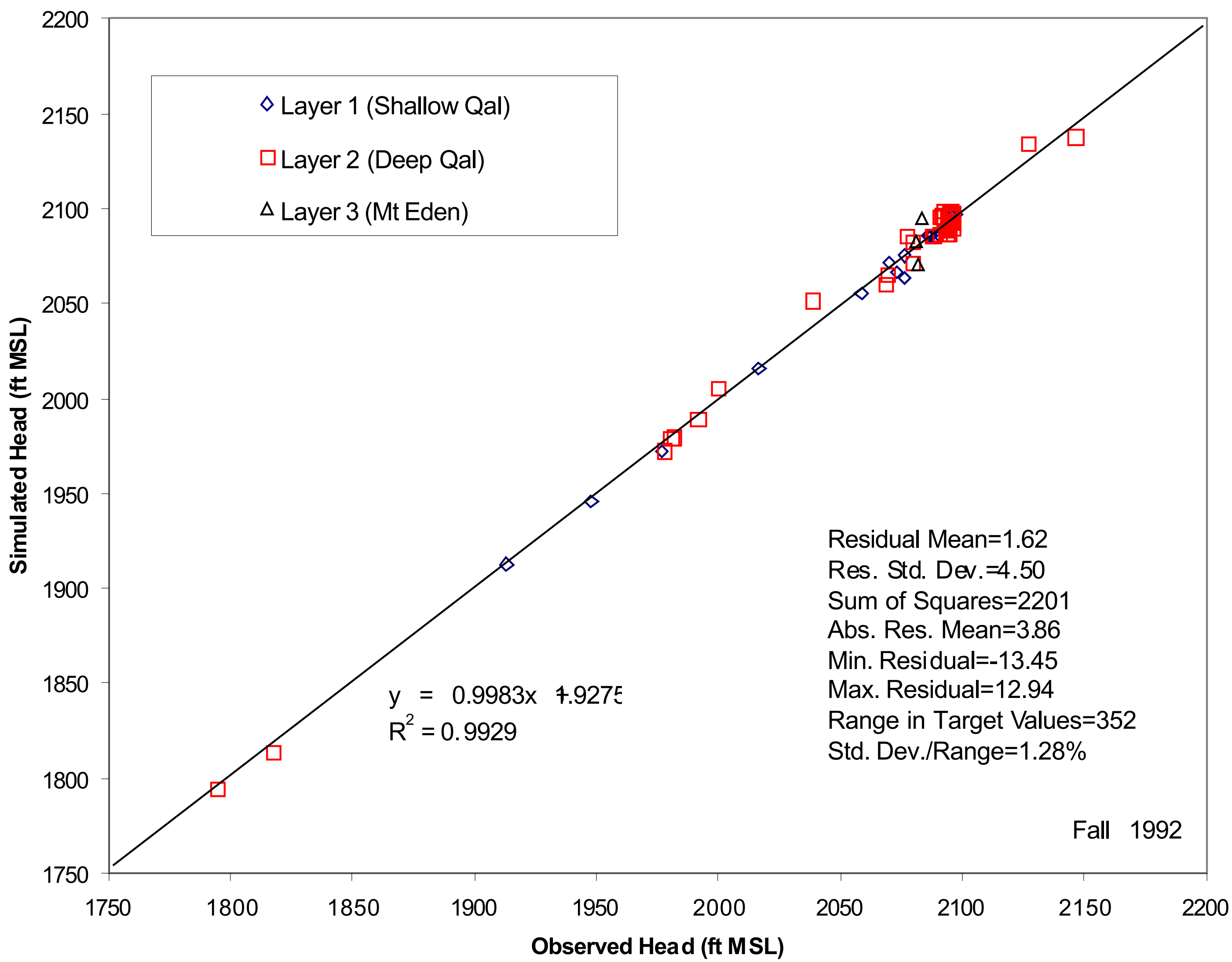
The predicted groundwater elevation for the calibrated steady-state flow model is shown in comparison to the October 1992 measured elevations in Figure 4-2. The cross-plot of the simulated and measured water levels shows the comparison is good between simulated and observed water levels for both the sediments (Layers 1 and 2) and Mt Eden (Layer 3) wells. A contour plot of the simulated and observed water levels is given in Figure 4-3, showing the model results correlate well with the gradient changes and flow directions observed across the site. A plot of residual errors given in Appendix C-1 shows errors are generally less than 5 feet, with no significant trends in errors across the site. The largest errors are generally located near the groundwater flow barrier at the Potrero Fault. For the steady-state calibration, the mean error was 1.6 feet, the standard deviation of error was 4.5 feet, and the relative error (defined as the ratio of the root mean square (RMS) error to the decline in head across the site cluster) was 1.3 percent. The model predicted water levels also show the following important site features:

- Very flat gradients between the RMPA and BPA that steepen considerably as flow moves into Potrero Creek canyon, with a large drop in elevations across the Potrero Fault (Figure 4-3); and
- In the alluvium, there are small downward very gradients of 0.005 ft/ft due to a head difference of +0.1 between layers 1 and 2 in the recharge area between the RMPA and BPA, and very large upward vertical gradients of 0.2 ft/ft due to a head difference of up to -7 between layers 1 and 2 near the confluence of Bedsprings and Potrero Creeks. Artesian heads were also simulated in this area (see Figure C-2).

The values of model head error are also small based upon groundwater flow model calibration guidance (Anderson and Woessner, 1991), and appear reasonably small given complex site conditions such as:

- There is a large variation in water levels of over 350 feet across the site and between the shallow and deep units; and
- The groundwater conditions in this area are very heterogeneous, with significant differences in the properties and gradients that vary from as flat as 0.002 to as steep as 0.02; and

X:\GIS\22288-0606\FIG 4-2.CDR



Beaumont Site 1

Figure 4-2

Cross-Plot of Simulated and Observed Heads for Steady-State Calibration

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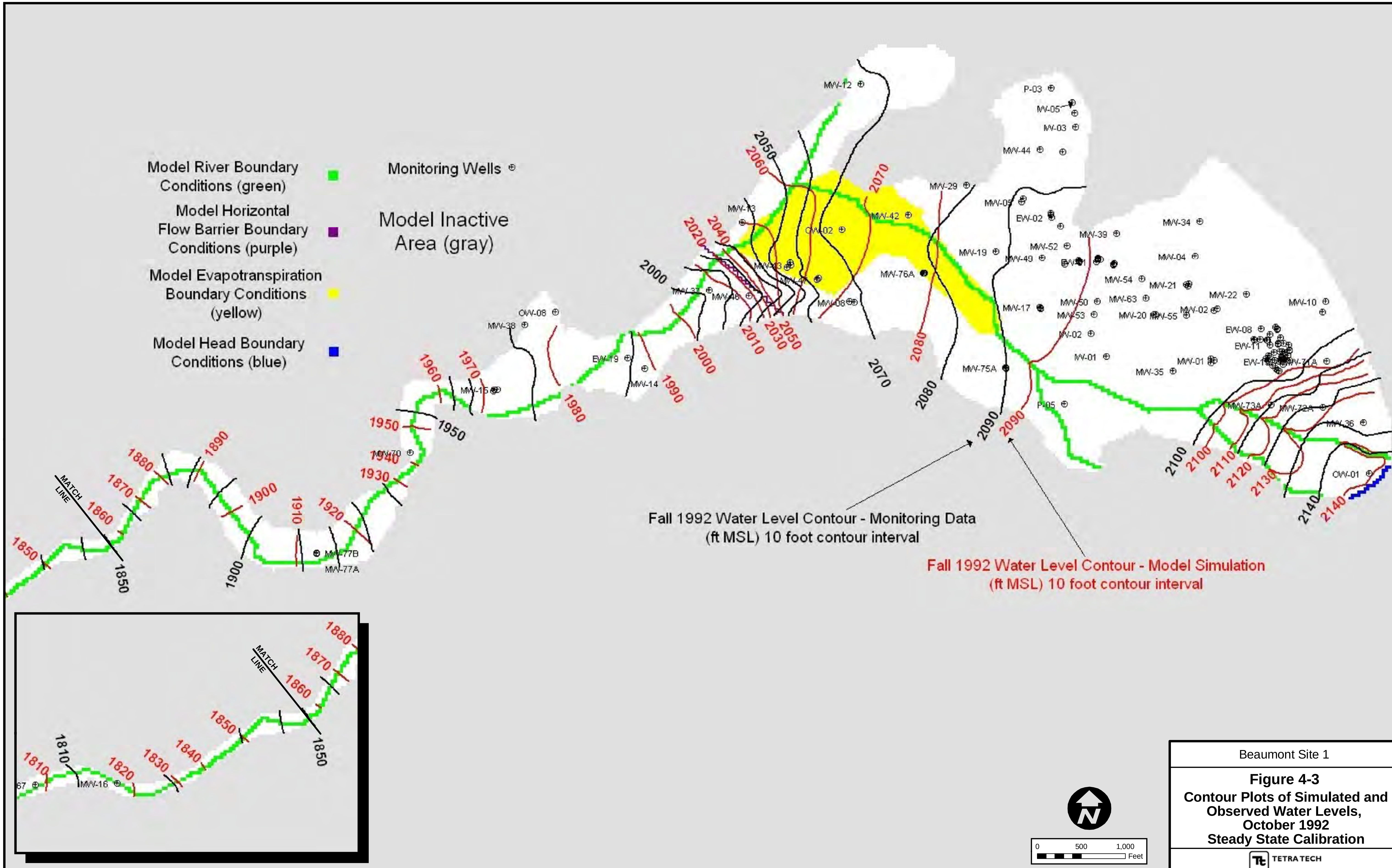

Beaumont Site 1

Figure 4-3
Contour Plots of Simulated and Observed Water Levels, October 1992
Steady State Calibration

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In addition, the model calibration is somewhat limited by the small amount of characterization data available in the deep bedrock units outside the BPA and RMPA site areas.

Water Budget

Notable components of the water budget include the following:

- Recharge rates of 40 acre-feet per year due to diffuse recharge;
- Stream recharge rates of 74 acre-feet per year;
- Underflow rates of 2 acre-feet per year into the alluvial aquifer from head boundaries;
- Evapotranspiration rates of 64 acre-feet per year;
- Stream discharge rates of 48 acre-feet per year;
- Leakage of alluvial groundwater through the confining layer and into the competent Mt Eden of 3 acre-feet per year; and
- Leakage of Mt Eden groundwater through the confining layer and into the competent granite of 1 acre-feet per year.

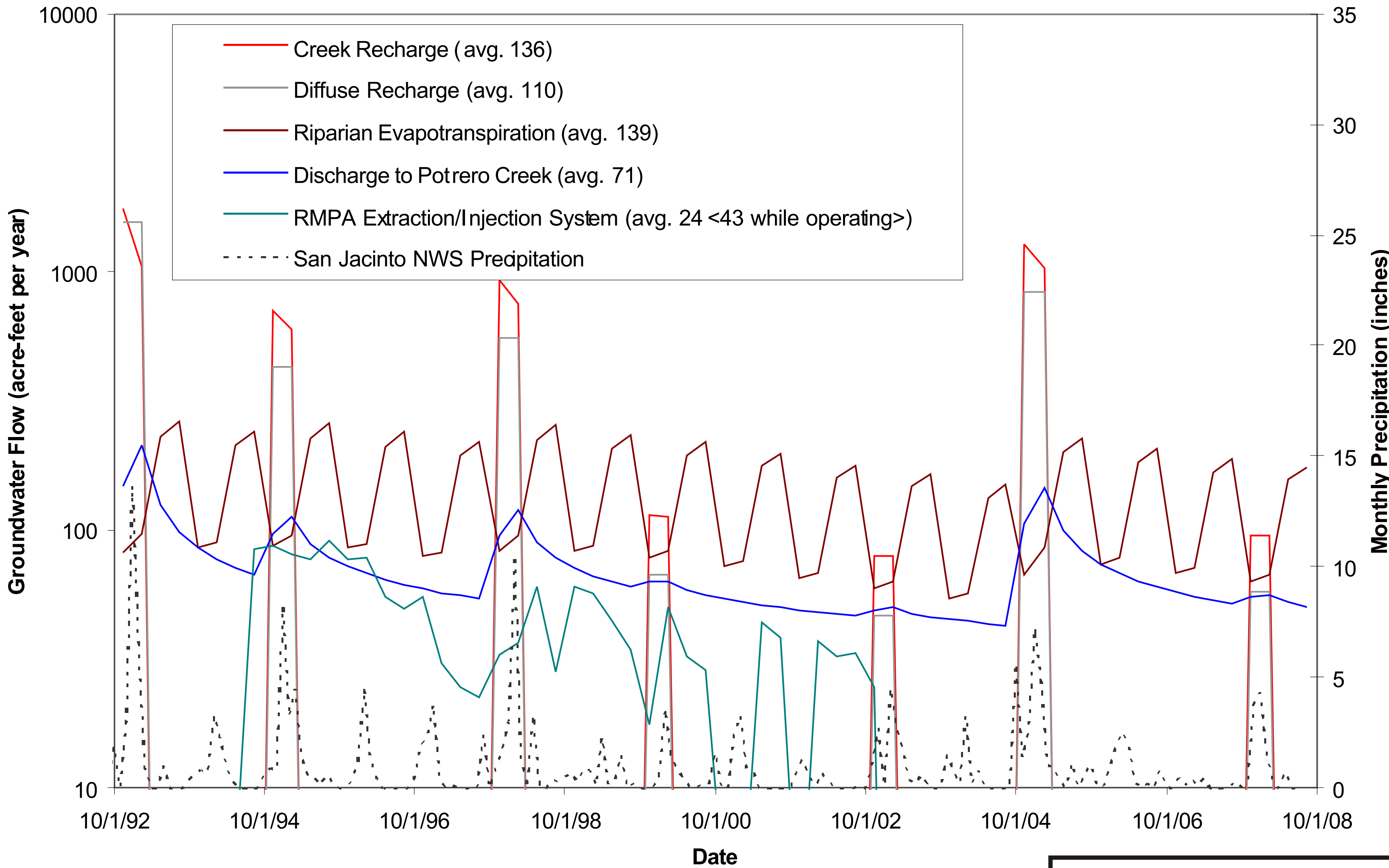
Average values of 2.5 feet per year were used for evapotranspiration in the steady-state calibration, which is between the low values of 1.9 feet per year during the dormant season and high values of 5.7 feet per year during the growing season. The groundwater water budget for the calibrated steady-state flow model generally matches the conceptual water budget calculations given in Section 3, and the range of values given for the transient model (Section 4.2.2 and Figure 4-4). Thus, the model water balance is quite close to the site conceptual model water budget and water budgets from prior studies at the site given the dry conditions (both seasonally and inter-annually) at the calibration time.

Thus, the numerical model matches the conceptual model and the water levels, gradients, and flow directions observed at the site within an acceptable degree. Given that the model parameters, water levels, gradients, and water budget agree well with the site conceptual model, the groundwater steady-state flow model appears to be adequately calibrated for steady-state flow conditions.

4.2.2 Transient Conditions

A transient model calibration is conducted for the period from Fall (October) 1992 to Fall (October) 2008 to calibrate the model for the effects of seasonal and inter-annual variations in groundwater recharge and discharge. The primary model calibration parameters were the specific yield and specific storage that are not sensitive to the steady-state calibration. All model parameters, boundary conditions, and starting water levels are identical to those given in the steady-state calibration. In addition, the following parameters are used for the transient calibration:

X:\GIS\22288-0606\FIG 4-4.CDR



Beaumont Site 1

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

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- Time-varying boundary heads – Water levels in the constant head cells southeast of the BPA (Figure 4-1) were set to time-varying based upon the monitoring data collected at the site;
- Time-varying diffuse and streamflow recharge rates – Recharge rates were increased and decreased over time to reflect the variation in precipitation and recharge discussed in the conceptual model water budget (Section 3.6.4), with no recharge for years with less than 12 inches of precipitation and recharge for other years varied in proportion to precipitation following the relationship given in Table 3.3. Stream recharge was varied over time by varying the river stage elevation, which is allowed to vary per stress period in MODFLOW;
- Time-varying evapotranspiration rates – Evapotranspiration rates vary due to seasonal and inter-annual variations in the depth to groundwater, as well as seasonal variations in the maximum evapotranspiration rate that reach a minimum of 1.5 feet per year during winter and a maximum of 6.9 feet per year in the summer with an annual average of 3.9 feet per year (California Irrigation Management Information System (CIMIS), 2008). These evapotranspiration rates were recently corroborated by measurements of daily water level fluctuations in the site groundwater monitoring program during January through June 2008 (Tetra Tech, Inc., 2009a);
- Specific Yield values – Specific yield values were initially determined from the site conceptual model, then adjusted during calibration. Final calibrated specific yield values (Figure B-4) were relatively uniform in the alluvium at 10 percent, consistent with the predominately fine to moderate-grained units in the shallower portions of the aquifer. Smaller specific yield values of 1
- percent were used in the BPA where the water table is located in the Mt Eden formation. The final specific yield values were chosen to match the changes in water levels and aquifer storage observed at the site during the 1992 through 2002 period; and
- Specific Storage Coefficient - Specific storage coefficient values were set based upon pump test data for the site as well as published values for alluvial and bedrock systems (Heath, 1987), with values of 2×10^{-5} ft^{-1} for the alluvium, 3.3×10^{-7} ft^{-1} for the competent Mt Eden, and 8×10^{-8} ft^{-1} for the granite. Model results for the alluvium were not particularly sensitive to the specific storage coefficient values since the storage effects due to specific yield are so much greater in the unconfined aquifer.

Water Levels

The predicted groundwater elevations for the calibrated transient flow model are shown in comparison to the October 1992 through September 2008 measured elevations in Figure 4-5. A comparison of simulated and observed water levels over time is given for a total of 30 monitoring wells located throughout the site as shown in the hydrographs given in Figures 4-6, 4-7, and C-4 through C-11. A contour plot of the simulated and observed water levels is given for Spring1998 in Figure C-3, showing the model results during a wet period as opposed to the dry period water level contours given in Figure 4-3. For the entire simulation period, the mean water level error was 1.4 feet, the standard deviation of error was 8.9 feet, and the relative error (defined as the ratio of the root mean square (RMS) error to the decline in head across the site cluster) was 2.3 percent. The model predicted water levels also show the following important site features:

- Water levels rise abruptly over time by 40 feet in response to precipitation in the recharge areas in the upper reaches of the model between the BPA and RMPA (see for example wells P-05 and OW-1 in Figure 4-6);

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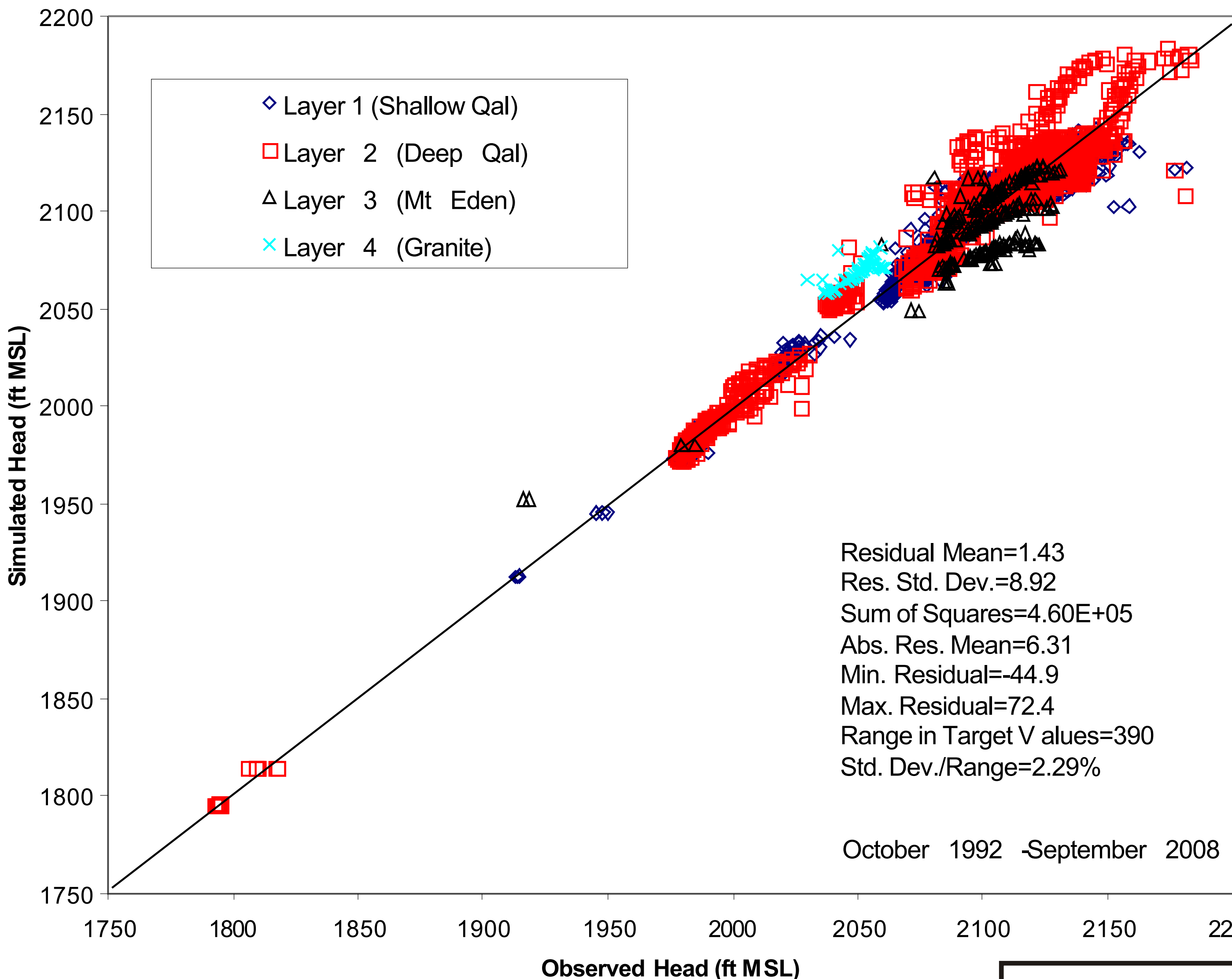

Beaumont Site 1

Figure 4-5
Cross-Plot of Simulated and Observed Heads for 1992-2008

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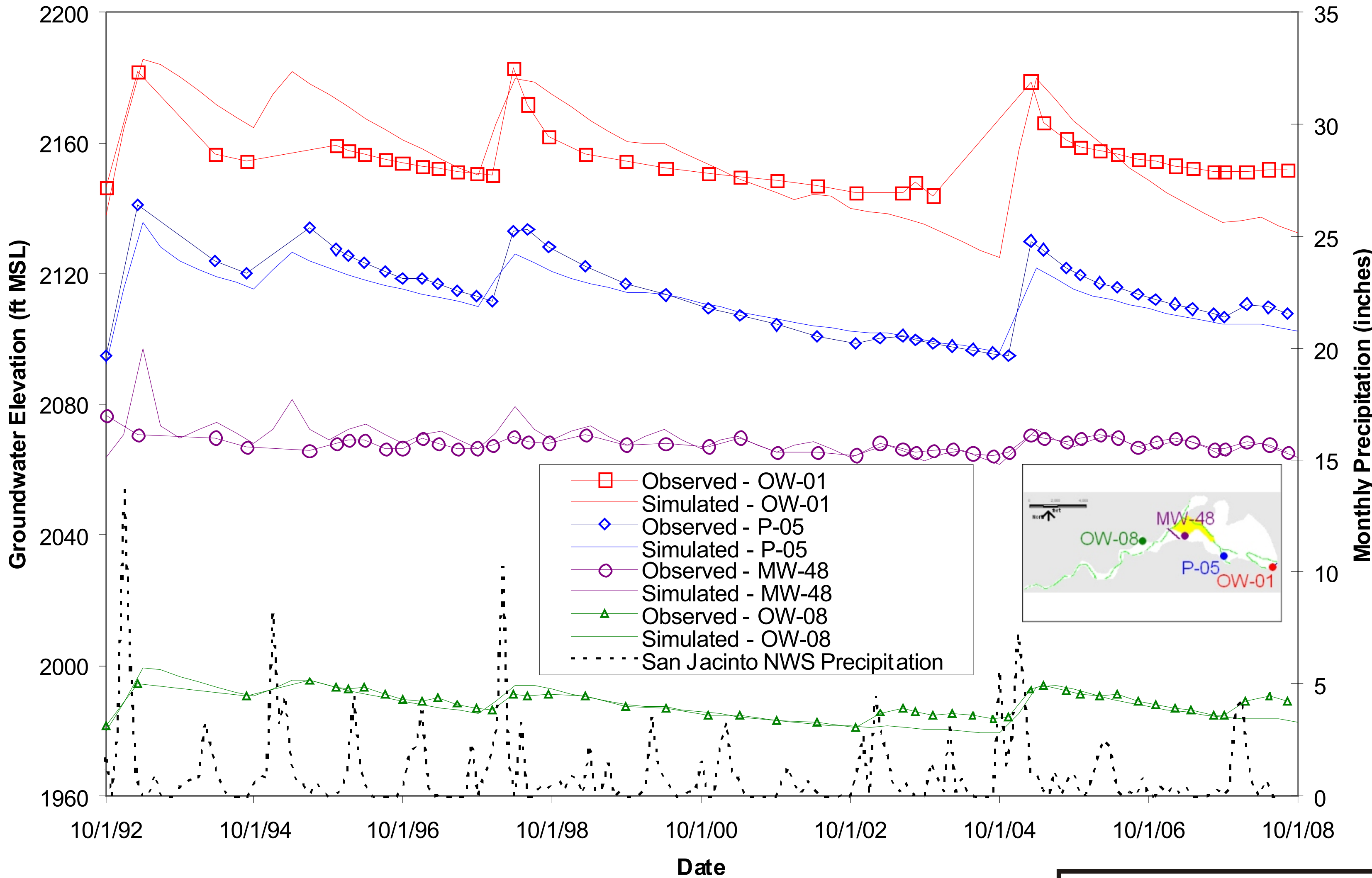

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Figure 4-6

Simulated and Observed Hydrographs for Monitoring Wells OW-01, P-05, MW-48, and OW-08

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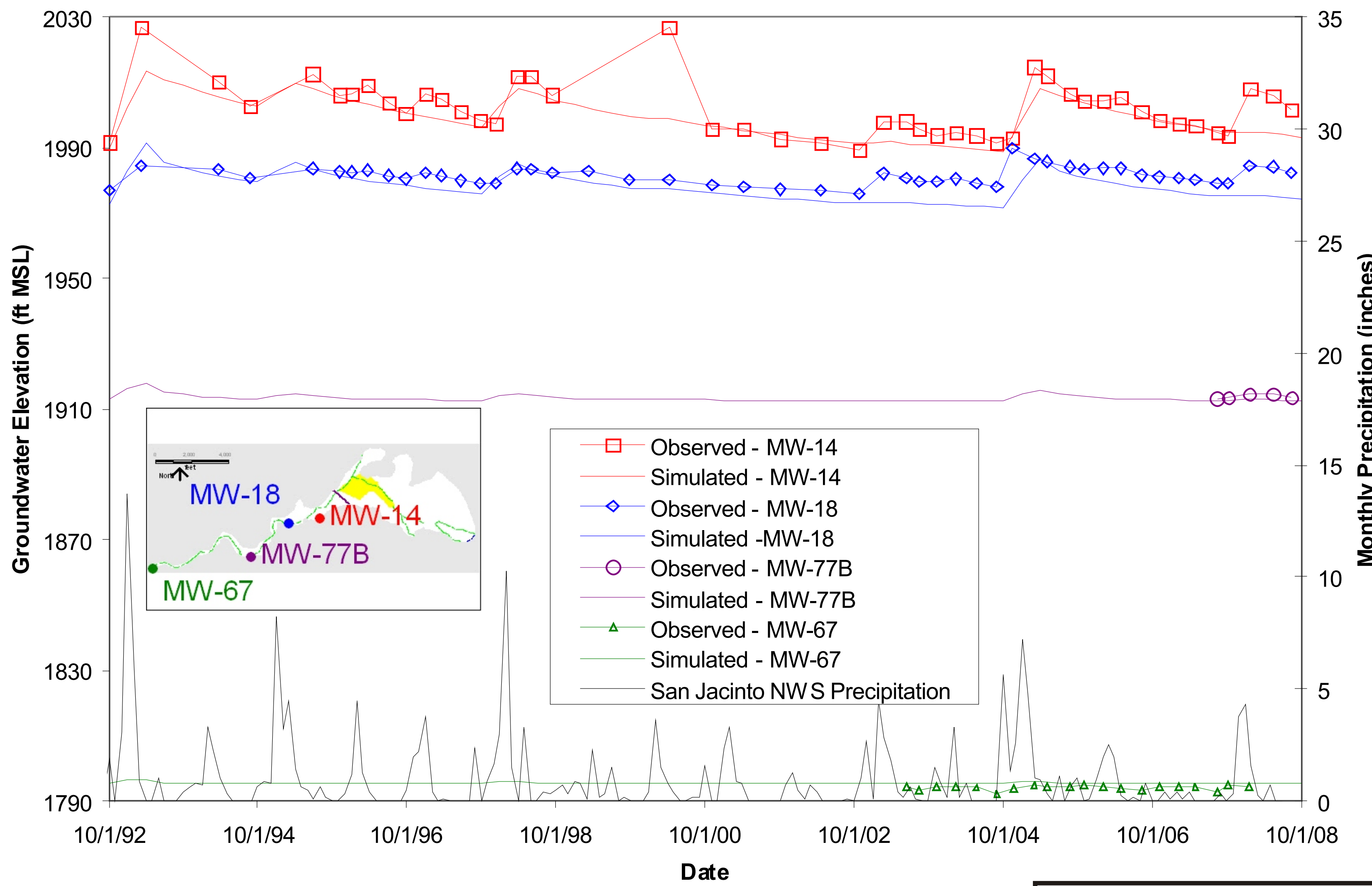

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Figure 4-7

Simulated and Observed Hydrographs for Monitoring Wells MW-14, MW-18, MW-77B, and MW-67

TETRA TECH

- Water levels fluctuations over time are much smaller in the groundwater discharge area near the riparian areas where water levels also cycle seasonally in response to seasonal variations in evapotranspiration (see for example well MW-48 in Figure 4-6);
- Water levels also rise abruptly over time in response to precipitation in the groundwater recharge area below the riparian areas and above MW-18, although the magnitude of water level rise is generally much smaller than near the BPA (see for example wells OW-08 and MW-18 in Figures 4-6 and 4-7);
- Water levels are very flat over time in the groundwater discharge areas in the lower reaches Potrero Creek, where water levels are generally controlled by the stream elevation where groundwater discharges (see for example wells MW-67 and MW-77B in Figure 4-7); and
- Groundwater flow directions are different during the wet season in the recharge areas in the upper reach of Bedsprings Creek valley, as flow that is to the northwest away from the BPA during the dry season (Figure 4-3) turns to the northeast towards the BPA from the creek during the wet season (Figure C-3).

These transient water level trends show the comparison is reasonably good between simulated and observed water levels given the significant variations observed at the site. Thus, the numerical model appears to match the conceptual model, and the seasonal and inter-annual variations in water levels, gradients, and flow directions observed at the site.

Water Budget

The groundwater water budget for the calibrated transient flow model is summarized in Figures 4-4 and 4-8, which show changes over time in key groundwater flows (Figure 4-4) and storage (Figure 4-8). The components of the water balance in Figures 4-4 and 4-8 generally match the conceptual water budget calculations given in Section 3-6 and Table 3-2, and the steady-state model results given the dry conditions for the steady-state calibration. Notable components of the transient water budget include the following:

- Total recharge averages 246 acre-feet per year, with 136 acre-feet per year due to creek recharge and 110 acre-feet per year due to diffuse recharge. This compares to total recharge estimates of (1) 231 acre-feet per year in the conceptual model calculations, with 132 acre-feet per year due to creek recharge and 99 acre-feet per year due to diffuse recharge; and (2) 213 acre-feet per year based upon the changes in aquifer storage volume recorded in the site groundwater monitoring program. Recharge in the model varies over time in a manner that reflects the precipitation patterns at the site (Figure 4-4), with most recharge occurring during the wet season in years with average and above-average precipitation. Model recharge is zero during the dry season and during years with below normal precipitation, consistent with observations from the site groundwater monitoring program;
- Evapotranspiration rates from the riparian area average 139 acre-feet per year, which compares to evapotranspiration rates of 120 acre-feet per year estimated in the conceptual model. Evapotranspiration in the model varies over time in a manner that reflects the seasonal fluctuations in evapotranspiration rate and the long term changes in the riparian groundwater elevation (see Figure 4-4 and well MW-43 in Figure 3-6). Note, however, that long-term variations in groundwater levels in the riparian area are rather small;

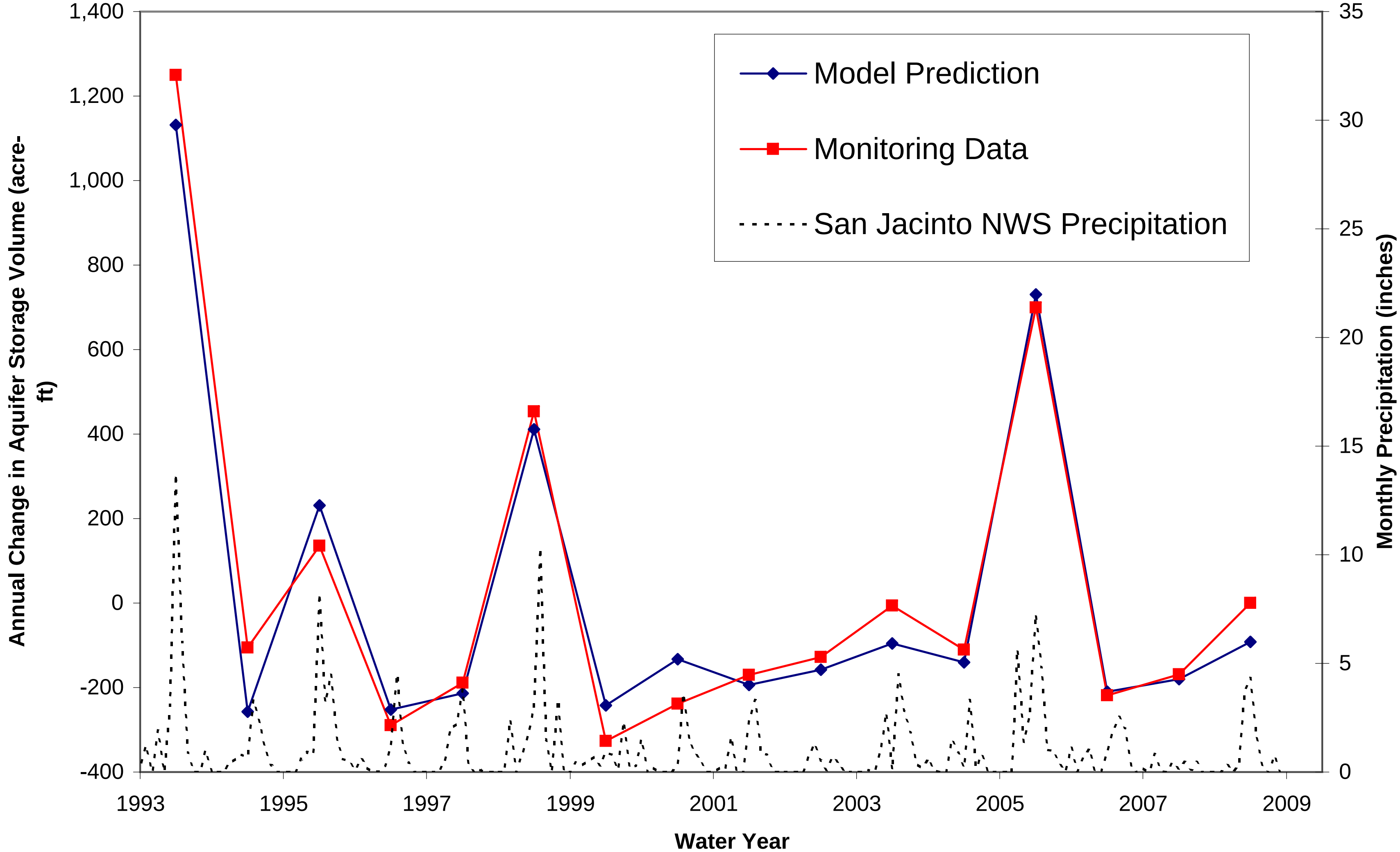
- Discharge rates from groundwater into the lower reaches of Potrero Creek below MW-18 averages 71 acre-feet per year and ranges from 43 to 212 acre-feet per year, which compares to rates of 70 to 107 acre-feet per year estimated in the conceptual model. Discharge rates from groundwater into the lower reaches of Potrero in the model varies over time in a manner that reflects the precipitation patterns at the site (Figure 4-4), with higher discharge rates occurring during the wet season in years with average and above-average precipitation and lower discharge rates occurring during the dry season in years with below-average precipitation;
- Underflow rates average 3 acre-feet per year into the alluvial aquifer from head boundaries;
- Leakage of alluvial groundwater through the confining layer and into the competent Mt Eden averages 8.4 acre-feet per year; this compares to estimates of 4 acre-feet per year in the conceptual model. Leakage of alluvial groundwater through the confining layer and into the competent granite averages 2.8 acre-feet per year; this compares to estimates of 1.6 acre-feet per year in the conceptual model; and
- Water year storage changes predicted by the model in the alluvial aquifer range from -257 to +1,132 acre-feet per year, which compares to a range from -327 to +1,250 acre-feet per year obtained from the monitoring data (Figure 4-8). Water year storage changes predicted in the model varies over time in a manner that reflects the precipitation patterns at the site (Figure 4-8), with large increases in storage observed during years with above-average precipitation and large
- decreases in storage observed during years with below-average precipitation. Average storage changes predicted by the model in the alluvial aquifer range are +29 acre-feet per year, which compares to +37 acre-feet per year obtained from the monitoring data (Figure 4-8).

Thus, the transient model water balance is reasonably close to the site conceptual model water budget, measured parameters at the site such as the stream flow rate in Potrero Creek and water levels, and water budgets from prior modeling studies at the site. Given that the model parameters, water levels, gradients, and water budget agree reasonably well with the site conceptual model, the groundwater transient flow model appears to be adequately calibrated for transient conditions. Considering the uncertainty that is inherent in some elements of the conceptual model water budget, the MODFLOW model water budget is likely a better estimate of groundwater flows at the site.

4.2.3 Plume Transport Considerations

Another consideration for the groundwater flow model calibration is the ability to predict groundwater flow paths that generally coincide with the plume trajectory as estimated by the groundwater plume contour maps at the site. Figures C-12 and C-13 show the groundwater flowpaths estimated using the calibrated groundwater MODFLOW model and the MODPATH particle tracking model (Pollock, 1994). The only additional parameter required for the MODPATH model is the aquifer effective porosity, which was set equal to the aquifer specific yield value (10 percent for alluvium and 1 percent for Mt Eden). Figure C-17 gives both flowpaths and travel times in the more permeable alluvium (layer 2), which shows travel times from the BPA to the RMPA are approximately 5 years and travel times from the RMPA to the Middle Potrero Creek area are approximately 5 years. Figure C-12 shows that the groundwater flowpaths for the steady-state model generally follow the centerline of the plume trajectory away from the

Figure 4-8. Annual Change in Aquifer Storage: Comparison of model results with monitoring data



BPA, through the Bedsprings Creek Alluvium and the RMPA, into the riparian area, and ultimately down Potrero Creek Canyon. Many of the steady-state flowlines are captured by evapotranspiration in the riparian area; however, some flow (approximately 34 acre-feet per year) also continues through the Potrero Fault zone down Potrero Creek Canyon. For transient flow (Figure C-13), the flow deviates slightly more from the centerline as a result of flow direction variations due to recharge events that turn the flow direction from the northwest to the northeast near the BPA (see Figures 4-3 and C-3), but the flow still stays within the plume boundaries. In addition, some flowlines are also captured by the groundwater extraction system that is active during the transient simulation flow period. These analyses indicate the groundwater flow model is reasonably consistent with the groundwater plume observed at the site.

4.3 MODEL VALIDATION

Another consideration in the groundwater flow model is the ability to predict groundwater flow conditions for different ranges of hydrologic conditions, which can be referred to as model validation if the model parameters from the calibration event are not adjusted for the validation event (Anderson and Woessner, 1991). Figures C-14 and C-15 present model calibration statistics for two different hydrologic condition periods: the period from October 1992 through December 2002 when the RMPA groundwater extraction system was operational, and the period from January 2003 through October 2008 when the RMPA groundwater extraction system was not operational. The calibration statistics are very similar for both hydrologic events, although the model calibration statistics are modestly better for the post-operational period when the relative model error was only 1.8 percent as opposed to the operational period when the relative model error was 2.7 percent. The level of error for both these periods generally meets target model calibration criteria, thus validating the model for use during these two different hydrologic periods. The greater water level errors during the RMPA extraction system operation is likely attributed to the wider fluctuations observed in the water levels of the RMPA extraction, injection, and monitoring wells during actual extraction/injection operations.

Figure C-16 presents observed and simulated drawdown values at monitoring wells MW-56D, OW-3, MW-58D, and MW-57C located at distances of 47, 54, 175, and 215 feet, respectively, from extraction well EW-1. Well EW-1 pumps approximately 87 percent of the total water extracted by the RMPA extraction/injection system, and is one of the only RMPA extraction/injection system locations with water levels in nearby monitoring wells. The simulated drawdowns match the observed drawdown in the monitoring wells quite well, and interpretation of the drawdown distance plot shows an aquifer transmissivity value from the observed data of 1,856 ft^2/day that is similar to the model transmissivity of 1,677 ft^2/day at EW-1. This favorable comparison of the observed and simulated drawdown and aquifer parameters at EW-1 validates the use of the model for simulating the hydraulic effects of the RMPA extraction/injection system.

4.4 SENSITIVITY ANALYSIS

Model sensitivity analyses are conducted to quantify the uncertainty in the calibrated model and rank the importance of model parameters in the calibration process (Anderson and Woessner, 1991). In order to evaluate the sensitivity of the calibrated flow model to various model parameters, a sensitivity analysis was conducted by varying key flow model parameters to values above and below the calibrated values, and calculating the resulting changes in the model water level error and key water budget components such as stream discharge and evapotranspiration. The maximum and minimum parameter values (see Table 4-1) were chosen based upon the range of data and conditions encountered at the site, and were limited to values that were thought to be reasonable parameter estimates for the site conditions.

Table 4-1 shows the sensitivity analysis results for 50 percent increases and decreases in the following key model parameters: hydraulic conductivity, diffuse recharge rate, stream recharge rate, and specific yield values. The most sensitive model parameter with respect to water level error was the diffuse

recharge rate and hydraulic conductivity value, while the most sensitive model parameter with respect to water budget was stream recharge. The sensitivity analysis results also demonstrate that the model is not excessively sensitive to these key model parameters, particularly the stream discharge and evapotranspiration rates. The results of this model sensitivity analysis also provide support for the choice of the final calibrated model parameters, as the calibration parameter values have the lowest model error, better match the site conceptual model water budget, and are closer to measurements observed in field tests.

4.5 MODEL UNCERTAINTIES AND LIMITATIONS

The calibrated flow model reasonably matches water levels, field measurements of aquifer parameters, and the groundwater flow budget estimated for the site. However, there are model uncertainties that may limit the predictive ability of the model, most notably:

- Mt Eden and Granitic Zones – Data are very limited for the Mt Eden and granitic zones. For example, (1) water levels in the granitic zone are only available in a very limited area of the BPA and water levels in the Mt Eden are only available for a period of approximately two years in the areas outside the BPA and RMPA; and (2) there are no significant pumping tests conducted in the Mt Eden and granitic wells. These data limitations introduce uncertainty in any predictions of groundwater conditions in the Mt Eden and granitic zones. However, due to the limited interchange between the alluvial aquifer and the Mt Eden and granitic zones, groundwater predictions in the alluvial aquifer are unlikely to be overly sensitive to these limitations. In effect, the model essentially incorporates the Mt Eden and granitic zones as regional features of the

Table 4-1
Groundwater Flow Model Sensitivity Analysis
LMC Beaumont Site 1

Flow Model Scenario	Residual Mean (feet)	Residual Standard Deviation (feet)	Absolute Residual Mean (feet)	Relative Error (percent)	Stream Discharge (acre-feet per year)	Evapotrans-piration (acre-feet per year)	Comment
Base Case Steady-State Calibration	1.62	4.50	3.86	1.3	48	64	Oct 92 Water Levels
Decrease hydraulic conductivity by 50 percent	-14.3	9.95	15.5	2.8	31	76	
Increase hydraulic conductivity by 50 percent	8.15	5.43	8.80	1.5	49	65	
Decrease diffuse recharge by 50 percent	11.0	12.8	11.5	3.6	38	56	largest change in head error
Increase diffuse recharge by 50 percent	-3.33	4.96	4.64	1.4	54	78	
Decrease river recharge by 50 percent	12.0	5.96	-14.3	1.7	43	40	
Increase river recharge by 50 percent	-8.68	6.55	9.52	1.9	55	89	largest change in flow
Base Case Transient Calibration	1.43	8.92	6.31	2.3	71	139	Oct 92 - Sept 08 WLs
Decrease specific yield by 50 percent	7.23	14.8	-14.3	3.8	77	114	
Increase specific yield by 50 percent	3.73	10.5	8.32	2.7	67	134	small change in flow

aquifer in order to obtain an approximate estimate of the water balance between the alluvial and deeper groundwater.

- Alluvium below MW-18 – Data are limited for the alluvium below MW-18, and in addition, there may be complex interactions of the groundwater between the alluvium and stream caused by undulations in the bedrock surface that are beyond the resolution of the current data. Thus, it may be difficult to precisely estimate the re-infiltration of groundwater previously discharged upstream, and the relative contributions of stream or groundwater flow rates at specific locations along the creek from MW-18 to MW-67. However, the overall water budget for the entire stream and aquifer system between MW-18 and MW-67 is thought to be reasonably accurate given that data are constrained by the overall water budget at the site, and the measurement of stream flow during dry conditions in Potrero Creek below MW-18.
- Potrero Fault Zone – Data are limited and groundwater conditions are very complex in the Potrero Fault Zone, which effectively restricts the flow of alluvial groundwater further down Potrero Creek. For example, there have been no pumping tests to quantify aquifer parameters through this zone. The recent site pumping test at EW-19 and the site stream flow measurements downgradient of the Potrero Fault Zone hopefully provide adequate constraints on the water budget through this area. However, the models ability to predict water levels in the vicinity of the Potrero Fault Zone is limited, as demonstrated by the larger model errors in this area.

5.0 MODEL PREDICTIONS

The calibrated flow model presented in Section 4 is used in Section 5 to predict groundwater flow conditions in the site area for the following groundwater remediation and management scenarios:

- No Action Alternative, including an evaluation of the phytoremediation potential in the riparian area;
- Operation of a Middle Potrero Creek Extraction System;
- Operation of a re-started RMPA Groundwater Extraction and Injection System;
- Operation of an Expanded RMPA Groundwater Extraction and Injection System (options A and B); and
- Operation of both the Middle Potrero Creek Extraction System and an Expanded RMPA Groundwater Extraction and Injection System.

The model predictions are made using the transient flow model with current water levels as the starting heads.

Future hydrologic conditions for the transient model simulation period are estimated from historical variations in hydrologic conditions observed at the site. Thus, future seasonal and inter-annual precipitation and boundary water level trends are modeled after observed seasonal and inter-annual precipitation and boundary water level trends. Considering the historical record of groundwater levels, precipitation, and groundwater recharge at the site as given in Figure 3-6, the current site conditions in terms of cumulative precipitation deficit, antecedent conditions, and groundwater levels appears to reasonably match those conditions observed during and leading up to the 1992 water year. Thus, the precipitation and water level trends observed during the 1993 through 2008 water year period were chosen as a reasonable prediction for the precipitation and water level trends expected during the 2010 to 2025 period. The simulated water budgets for the model predictions are given in Appendix D and discussed in detail in Section 5.6. Simulated water levels and drawdowns for the model predictions are given in Appendix E and discussed in detail in the following sections.

5.1 NO ACTION ALTERNATIVE

The No Action Alternative is evaluated as a base case scenario, which consists of current groundwater conditions without re-starting or expanding the RMPA extraction/injection system or operating a Middle Potrero Creek Extraction System. Although this alternative is not necessarily a likely choice for the long-term management of groundwater conditions at this site, this scenario is evaluated as a reference point for estimating the impacts of other potential site remedial alternatives.

Water levels and the simulated water budget for this scenario are given in Appendices D and E. The water budget and water levels predicted for the 2010 to 2025 period are generally similar to site conditions during the 1992-2008 period. For example,

- Comparing the predicted flows for 2010 to 2025 (Figure Appendix D-1) to those for the 1992-2008 model transient calibration period (Figure 4-4), flows are nearly the same except for the impact of 51 acre-feet per year extraction/injection during July 1994 through December 2002 from the RMPA extraction/injection system. Note that since extraction and injection were nearly perfectly balanced for the RMPA remedial system there was little net impact on the other components of the water budget due to operation of the RMPA extraction and injection system; and
- Comparing the predicted 2025 water levels and drawdown (Figures Appendix E-1 and E-2), the 2025 water levels are generally with one-half of a foot of the current 2009 site conditions, consistent with the assumption that the 2010-2025 hydrologic conditions would be similar to those observed for the 1992 through 2008 period. Note that since (1) extraction and injection were nearly perfectly balanced for the RMPA remedial system, and (2) the RMPA system has been inactive since the end of 2002, the RMPA had little net impact on the 2008 water levels. This explains the similarity between the predicted 2025 water levels and the 2008 water levels, even though the RMPA was active for the 1992 through 2002 period.

5.1.1 Riparian Zone Phytoremediation Potential

The groundwater conceptual model and water budget includes an evapotranspiration area in the riparian zone near the confluence of Bedsprings and Potrero Creeks. Evapotranspiration may act as a form of phytoremediation for the site by providing hydraulic containment of some portion of the groundwater plume, as illustrated in the groundwater flowpaths given for the steady-state model in Figure C-12.

Figures 5-1 and 5-2 shows predicted 2025 water levels, 2010-2025 groundwater pathlines, and shallow alluvium and deep alluvium capture zone analyses for groundwater flowing through the riparian area during the 2010-2025 period in order to illustrate the extent to which the site plume is contained by evapotranspiration in the riparian area during the No Action Scenario. Approximately 85 percent (250 acres) and 75 percent (220 acres) of the shallow alluvium and deep alluvium plume area is hydraulically contained in Figures 5-1 and 5-2, allowing approximately 15 percent (40 acres) and 25 percent (70 acres) of the 290 acre plume area to continue flowing downgradient. Analysis of the model water budget indicates that approximately 127 acre-feet per year of contaminated groundwater is removed by evapotranspiration allowing approximately 52 acre-feet per year of contaminated groundwater to flow further downgradient. Approximately 6 acre-feet per year of contaminated groundwater also flows downward from the alluvium into the Mount Eden. Based upon this analysis, if some form of enhancement is added to the riparian area vegetation to increase evapotranspiration by 66 acre-feet per year, this would most likely result in full containment of the site plume.

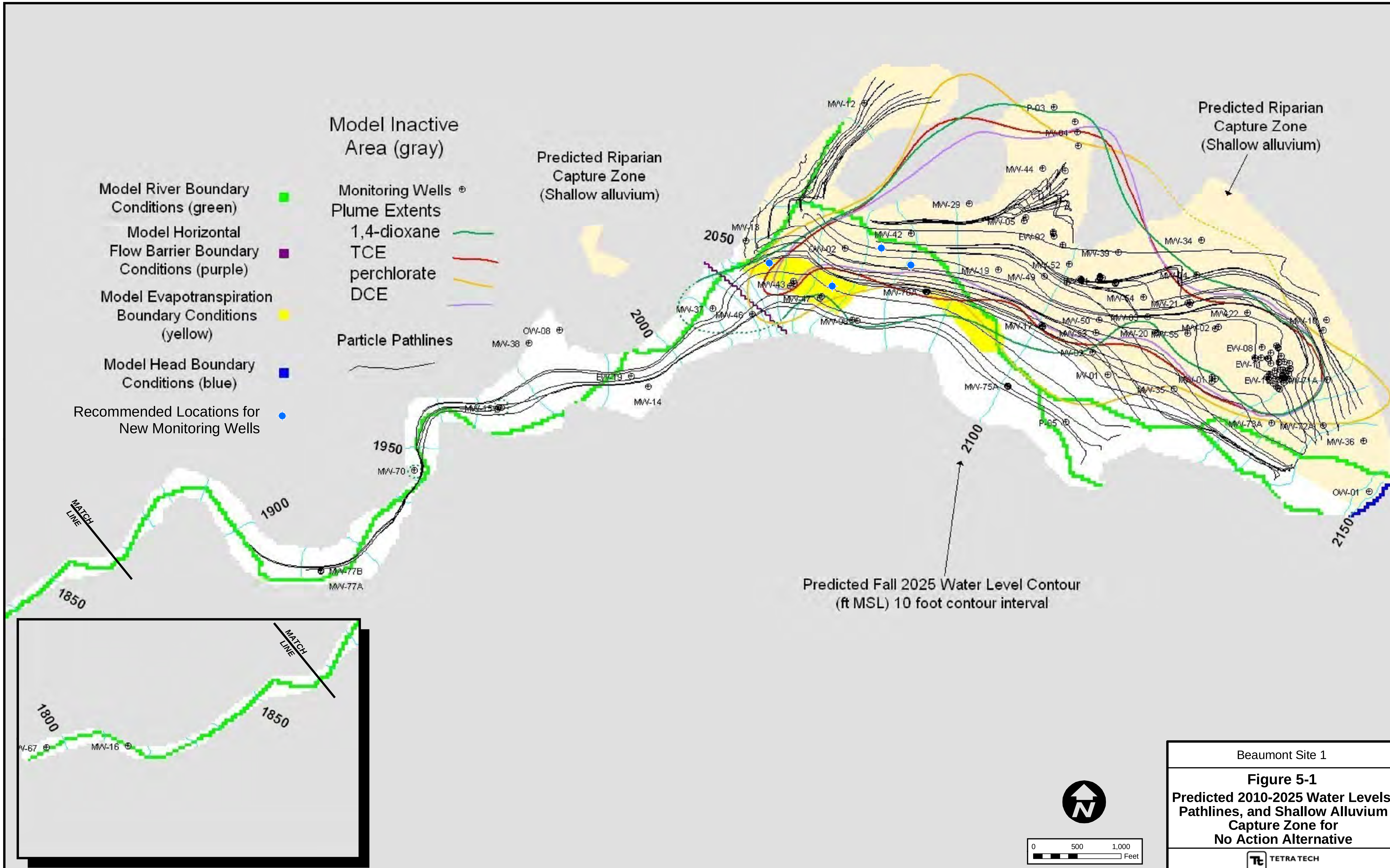


Figure 5-1
Predicted 2010-2025 Water Levels, Pathlines, and Shallow Alluvium Capture Zone for No Action Alternative

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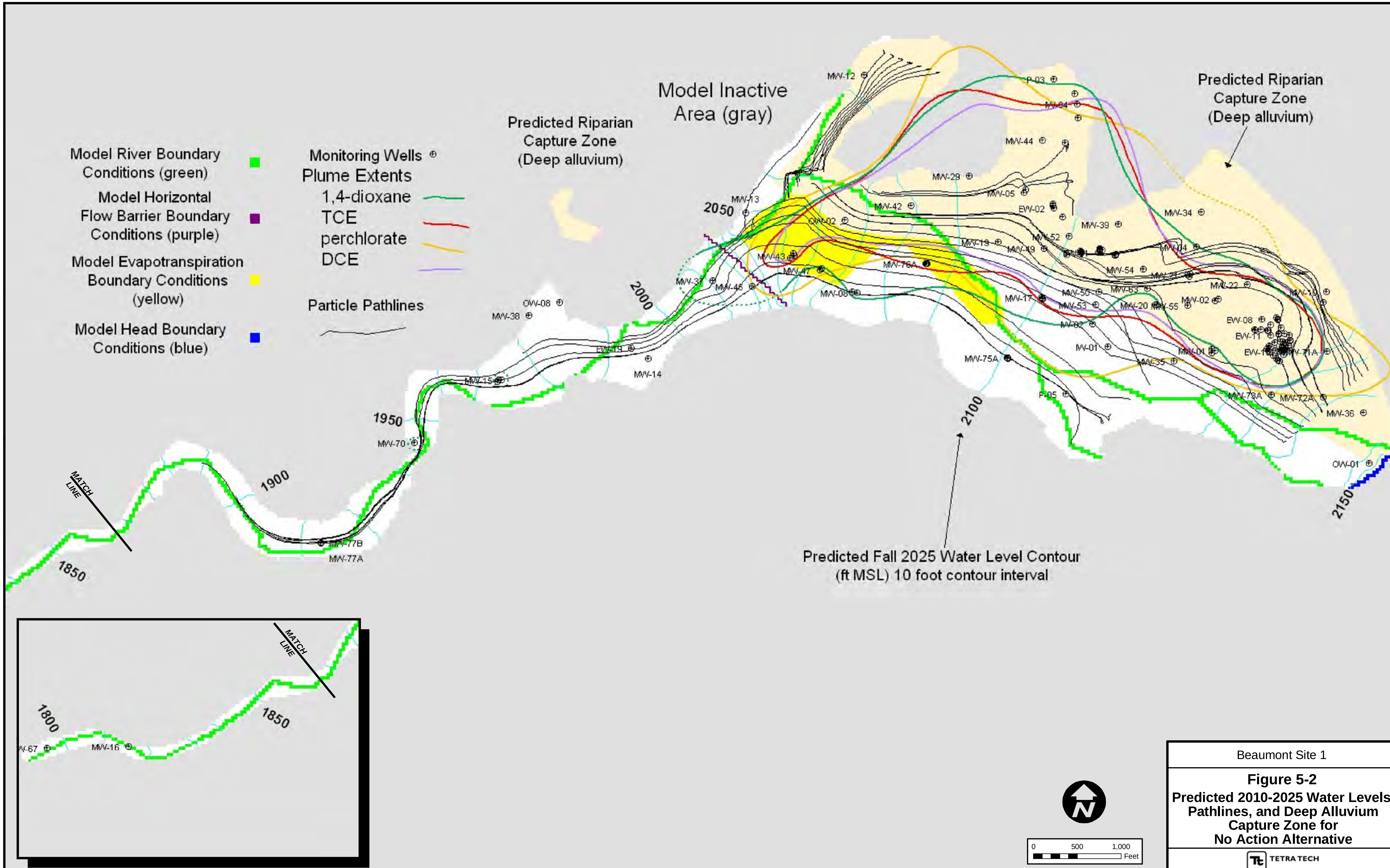

Beaumont Site 1

Figure 5-2
Predicted 2010-2025 Water Levels, Pathlines, and Deep Alluvium Capture Zone for No Action Alternative

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The current total plume pore volume is approximately 1,650 acre-feet, and the plume pore volume currently contained by evapotranspiration is approximately 1,150 acre-feet. Given that the evapotranspiration containment rate is 127 acre-feet per year implies that approximately 0.11 plume pore volumes is removed per year by evapotranspiration. Thus, a total of 1.8 plume pore volumes are removed by evapotranspiration over the 16 year prediction period. However, most of this groundwater is pulled from the more dilute portion of the plume as opposed to the higher concentrations near the former RMPA and BPA source areas, and therefore this flow has limited pore volume flushing effect on the contaminated source areas.

The installation of four new shallow monitoring wells at the locations shown in Figure 5-1 may be recommended in the future to better delineate evapotranspiration and plume capture in the riparian area, depending upon the alternatives selected in the FS. The data collected from these new monitoring wells could be used to increase confidence in the phytoremediation potential of the riparian area, and possibly allow an earlier shut-down of the IRM-Middle Potrero Creek extraction system and/or Expanded RMPA extraction/injection system if these systems are ever operated depending on the outcome of the site FS.

5.2 IRM-MIDDLE POTRERO CREEK EXTRACTION SYSTEM

In order to mitigate the migration of contaminants from the groundwater plume into Potrero Creek, LMC had considered a potential IRM consisting of a groundwater extraction system to cut off the plume near its' leading edge before it discharges to surface water. The extracted groundwater would be treated to remove contaminants, and then discharged directly to the drainage to maintain the water balance in the riparian areas and summer baseflows in Potrero Creek. Since the contaminants in the IRM area have currently dropped below probable action levels, there is currently no need for implementing the IRM in this area..

During Fall 2008, one new groundwater extraction well (EW-19) was installed and a pumping test was conducted in Middle Potrero Creek near monitoring well MW-14 (Figure 4-1). The Pumping Test site was chosen at a location that hopefully will be favorable for long term use in the potential IRM. Analysis of the results of the pumping test given in the IRM Well Installation and Pumping Test report (Tetra Tech, 2009b) indicates that the target underflow rate through the plume in the alluvial aquifer at Middle Potrero Creek near EW-19 averages 74 acre-feet per year, and ranges from 56 acre-feet per year during dry periods to 105 acre-feet per year during wet periods (Tetra Tech, Inc., 2009b).

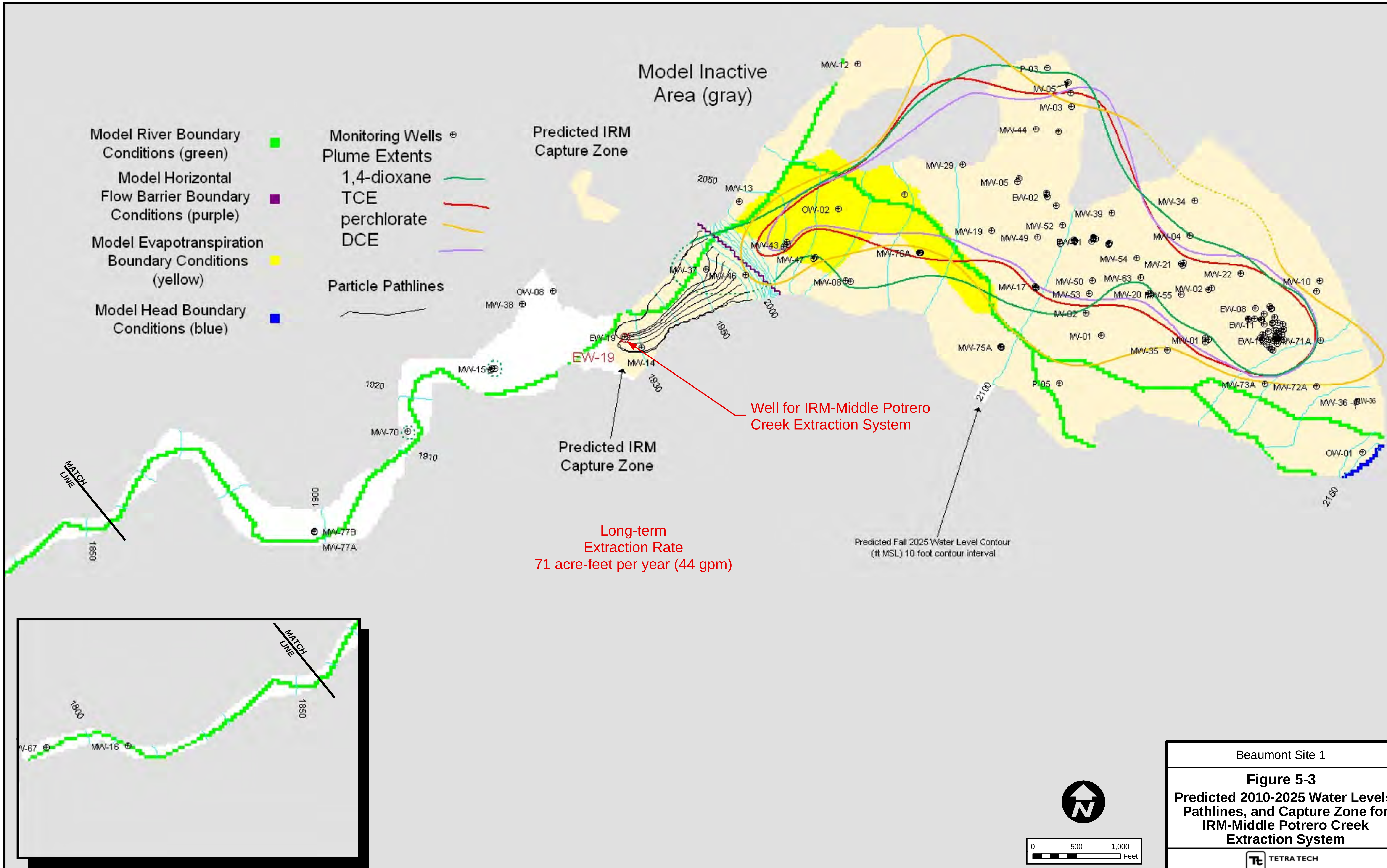
The flow budget for the transient groundwater model calibration indicates that the groundwater discharge rate to Potrero Creek averages 71 acre-feet per year and ranges from 43 to 212 acre-feet per year (Section 4.2.2 and Figure 4-4). This generally matches the underflow calculations given in the IRM Well

Installation and Pumping Test report, although the model peak flow is higher than other estimates. This average flow of 71 acre-feet per year or 44 gpm was used as the long-term extraction goal for the Middle Potrero Creek capture system. Considering the high flow rates (90 gpm) and specific capacity (over 10 gpm/foot) observed in the pumping test at well EW-19, these target extraction rates of 71 acre-feet per year or 44 gpm should be sustainable in one well (EW-19).

Thus, the groundwater model was modified to include extraction at EW-19 at a pumping rate of 71 acre-feet per year or 44 gpm. As a worst case scenario it was assumed that the IRM was operated at 44 gpm for the entire future prediction period (2010 through 2026), but in all likelihood the IRM will only operate for 3 to 10 years since the plume in Middle Potrero Creek should clean-up long before 2026 due to the projected impacts of the expanded RMPA groundwater extraction/injection system (Section 5.4).

The model predicted 2025 water levels, 2010-2025 groundwater pathlines, and capture zone analyses in the vicinity of EW-19 are given in Figure 5-3. The water budget is given in Figure D-2 and groundwater levels and drawdown is given in Figures E-3 and E-4. The groundwater levels and flow lines show complete capture of the groundwater flowing down the Potrero Creek alluvium. The water budget for the model predictions given in Appendix D and discussed in Section 5.6 shows that groundwater discharge rates to Potrero Creek during 2025 decrease from the value of 55 acre-feet per year in the No Action Alternative to 5 acre-feet per year or nearly zero with the operation of the IRM-Middle Potrero Creek Extraction System. The small amount of groundwater discharge rate to Potrero Creek that remains after implementation of the EW-19 capture system (5 acre-feet per year) is due to the diffuse recharge and Potrero Creek recharge that occurs far downstream from EW-19, which cannot be captured by EW-19. However, this groundwater should not be contaminated in the long-term since the origin is due to recharge that occurs far downslope from the site groundwater source areas and plume. Thus, extraction from EW-19 at a rate of 71 acre-feet per year or 44 gpm should completely stop the plume migration down Middle Potrero Creek alluvium and the plume discharge to Middle Potrero Creek.

Four monitoring wells P-6S, P-6D, P-7, and P-8 were recently installed surrounding EW-19 for the recent 2008 site pumping tests (Tetra Tech, 2009b). Due to access constraints associated with the proximity of Potrero Creek to EW-19, the P-6S, P-6D, P-7, and P-8 monitoring locations provide reasonably accessible upgradient, downgradient, and cross-gradient positions from EW-19 to evaluate capture of the plume at EW-19. Thus, these monitoring locations would likely be adequate to confirm plume capture at EW-19, should pumping occur there, and additional monitoring locations are not anticipated at this time.



Beaumont Site 1

Figure 5-3

Predicted 2010-2025 Water Levels, Pathlines, and Capture Zone for IRM-Middle Potrero Creek Extraction System

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To simplify system operations, the current design basis calls for steady extraction set at an average rate that is higher than underflow conditions during the dry seasons/years and lower than underflow conditions during the wet seasons/years. This was done since model predictions indicate that any temporary by-passing of EW-19 during wet periods can be pulled back during dry periods, and it simplifies system operations. In the event plume pull-back after wet periods is not as effective as anticipated, the system may require pumping at higher rates during some wet periods (up to 105 acre-feet per year or 65 gpm); however, both the extraction well and treatment system are being installed with a nominal capacity of 75 to 125 gpm to accommodate these sorts of uncertainties in site conditions.

The water budget for the model predictions given in Appendix D and discussed in Section 5.6 shows that groundwater discharge rates to the riparian area for the IRM scenario average 126 acre-feet per year, similar but somewhat lower than groundwater discharge rates to the riparian area for the No Action Alternative (141 acre-feet per year). The water level and water level drawdown plots for the IRM Scenario (Figures E-3 and E-4) show that water levels for most of the riparian zone drop less than 1 foot from the No Action Scenario, although there is a portion in the far west of the riparian zone near the Potrero Fault where water levels drop by 2 to 4 feet. Future monitoring will need to be conducted to evaluate whether this predicted drop in water levels actually occurs and whether this decline has any significant impact on the riparian zone vegetation. However, the water budget indicates the impact on groundwater availability in the riparian zone is likely to be small, and the presence of the Potrero Fault should also diminish the impact of any drop in water levels in the Potrero Creek alluvium on the Bedsprings Creek alluvium.

In addition, it is also useful to consider that this evaluation considers a worst case scenario where the potential IRM is operated for a period of 16 years, while in all likelihood the potential IRM would only operate for 3 to 10 years due to the projected impacts of the expanded RMPA groundwater extraction/injection system (Section 5.4). For example, (1) analysis of the model groundwater flowpaths indicates that the typical groundwater travel time between the downgradient edge of the proposed RMPA capture zone (Figure 5-4) and well EW-19 is less than 5 years, and (2) groundwater model predictions for a revised scenario where the IRM is only operated for 5 years (Figures D-3, E-5, and E-6) indicate almost no long-term impacts on the riparian area water balance or water levels. Thus, it appears that the IRM system will only need to be operated in this manner for 5 to 10 years to achieve full plume containment at the leading edge of the plume, and this can likely be done without adversely impacted the groundwater levels in the riparian area.

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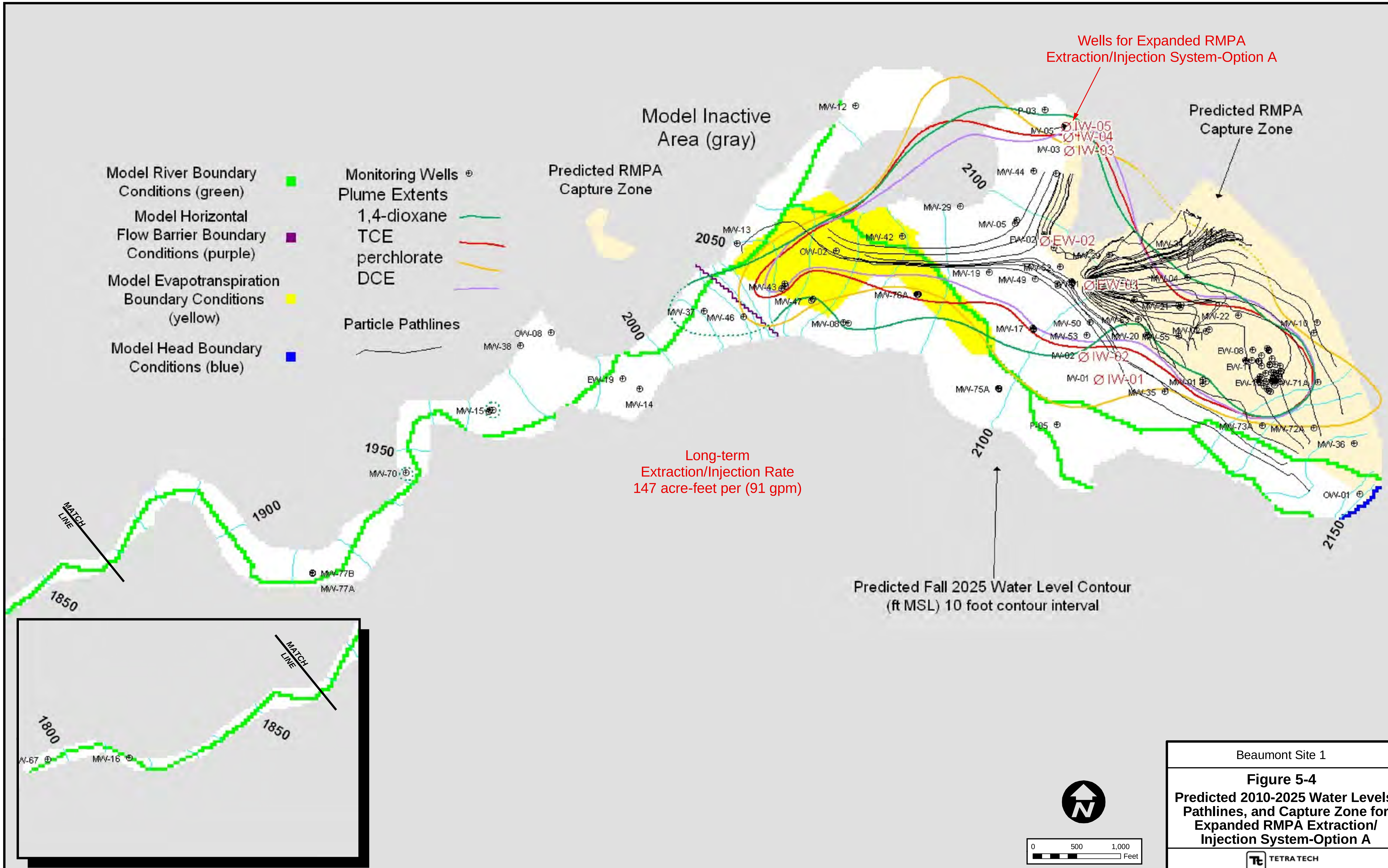

Beaumont Site 1

Figure 5-4
Predicted 2010-2025 Water Levels, Pathlines, and Capture Zone for Expanded RMPA Extraction/ Injection System-Option A

TETRA TECH

Since the potential IRM would be operated as a temporary plume cut-off alternative by extracting groundwater along the plume leading edge, the extraction location (EW-19) is located very far downgradient from the main source and hot spot areas of the plume. Therefore, the IRM will have very limited impacts on the pore volume flushing of the plume to accelerate plume remediation, and pore volume flushing rates are not calculated for this alternative.

5.3 RE-STARTED RMPA GROUNDWATER EXTRACTION AND INJECTION SYSTEM

The RMPA Groundwater Extraction and Injection System operated from August 1994 through December 2002 extracting, treating, and re-injecting 124 million gallons of groundwater from the Bedsprings Creek alluvium at an average rate of about 30 to 55 gpm. The historical RMPA extraction/injection system operations were included in the 1992 through 2008 transient model calibration. An example of the effects of the capture zone for the RMPA system during this period is given in Figure C-13, which shows particle pathlines predicted by the model during 1992 through 2008. Many of the flowpaths through the BPA plume in Figure C-13 during this 1992 through 2008 period are captured in well EX-1. However, since the RMPA system was operating for only a portion of this 1992 through 2008 period, the 1992 through 2008 transient simulation does not necessarily represent the long-term containment potential of the existing RMPA system.

In order to evaluate the long-term containment potential of the existing RMPA system, a future 2010 through 2026 simulation scenario was constructed with the RMPA operating continuously for the entire period. This scenario consists of re-starting and operating the existing RMPA Groundwater Extraction and Injection System at the same average rate of 39 gpm or 61 acre-feet per year observed during historical operations. Thus, the groundwater model was modified to include extraction and injection in the existing RMPA extraction/injection wells at the rates given in Table 5-1. The model predicted 2025 water levels, 2010-2025 groundwater pathlines, and capture zone analyses in the vicinity of the RMPA system are given in Figure 5-5. The water budget is given in Figure D-4 and groundwater levels and drawdown is given in Figures E-7 and E-8.

The predicted plume area captured by the re-started RMPA extraction/injection system is approximately 110 acres covering 38 percent of the total site plume area of 290 acres, allowing approximately 62 percent (180 acres) of the 290 acre plume area to continue flowing downgradient. Such a large portion of the plume is not contained because of the locations of the extraction wells between the RMPA and BPA, where the entire downgradient portion of the plume is not contained with the existing system. In addition, there is a 500 to 1,000 foot wide portion of the plume directly west of the BPA and cross- to upgradient of the extraction wells that also bypasses the extraction wells.

Table 5-1
Rates for the Re-started and Expanded RMPA Extraction and Injection System, LMC Beaumont Site 1

Location	Northing Coordinate	Easting Coordinate	Depth to Top of Screen (feet)	Depth to Bottom of Screen (feet)	Proposed well rate* (gpm))	Comment
Re-started RMPA System						
Existing Locations						
EW-01	2,258,178.81	6,353,216.58	34.6	76.0	-33	
EW-02	2,258,684.84	6,352,717.48	25.0	66.5	-6	
IW-01	2,257,101.37	6,353,331.11	7.0	90.0	12	
IW-02	2,257,357.49	6,353,155.66	10.0	95.0	12	
IW-03	2,259,714.02	6,352,991.06	22.2	63.2	5	
IW-04	2,259,864.23	6,352,976.98	22.2	62.9	5	
IW-05	2,259,983.46	6,352,957.53	21.2	61.7	5	
System Total					-39/ 39	injection=extraction
Expanded RMPA System	**(Option A)**					
Existing Locations						
EW-01	2,258,178.81	6,353,216.58	34.6	76.0	-33	
EW-02	2,258,684.84	6,352,717.48	25.0	66.5	-6	
IW-01	2,257,101.37	6,353,331.11	7.0	90.0	13	
IW-02	2,257,357.49	6,353,155.66	10.0	95.0	13	
IW-03	2,259,714.02	6,352,991.06	22.2	63.2	6	
IW-04	2,259,864.23	6,352,976.98	22.2	62.9	6	
IW-05	2,259,983.46	6,352,957.53	21.2	61.7	6	
Proposed New Locations						
EW-20	2,257,837.00	6,353,577.00	35.0	150.0	-52	
IW-06	2,256,844.00	6,353,523.00	10.0	165.0	23.5	
IW-07	2,257,334.00	6,352,668.00	10.0	165.0	23.5	
System Total					-91 / 91	injection=extraction
Expanded RMPA System	**(Option B)**					
Existing Locations						
EW-01	2,258,178.81	6,353,216.58	34.6	76.0	-33	
EW-02	2,258,684.84	6,352,717.48	25.0	66.5	-6	

Table 5-1
Rates for the Re-started and Expanded RMPA Extraction and Injection System, LMC Beaumont Site 1

Location	Northing Coordinate	Easting Coordinate	Depth to Top of Screen (feet)	Depth to Bottom of Screen (feet)	Proposed well rate* (gpm))	Comment
IW-01	2,257,101.37	6,353,331.11	7.0	90.0	13	
IW-02	2,257,357.49	6,353,155.66	10.0	95.0	13	
IW-03	2,259,714.02	6,352,991.06	22.2	63.2	6	
IW-04	2,259,864.23	6,352,976.98	22.2	62.9	6	
IW-05	2,259,983.46	6,352,957.53	21.2	61.7	6	
Proposed New Locations						
EW-20	2,257,837.00	6,353,577.00	35.0	150.0	-26	
EW-21	2,259,160.00	6,352,600.00	20.0	95.0	-26	
IW-06	2,256,844.00	6,353,523.00	10.0	165.0	23.5	
IW-07	2,257,334.00	6,352,668.00	10.0	165.0	23.5	
System Total					-91 / 91	injection=extraction
Expanded RMPA System	**(Option C)**					
Existing Locations						
EW-01	2,258,178.81	6,353,216.58	34.6	76.0	-33	
EW-02	2,258,684.84	6,352,717.48	25.0	66.5	-6	
IW-01	2,257,101.37	6,353,331.11	7.0	90.0	13	
IW-02	2,257,357.49	6,353,155.66	10.0	95.0	13	
IW-03	2,259,714.02	6,352,991.06	22.2	63.2	6	
IW-04	2,259,864.23	6,352,976.98	22.2	62.9	6	
IW-05	2,259,983.46	6,352,957.53	21.2	61.7	6	
Proposed New Locations						
EW-20	2,257,633.60	6,354,471.70	35.0	110.0	-26	
EW-21	2,259,160.00	6,352,600.00	20.0	95.0	-26	
IW-06	2,256,844.00	6,353,523.00	10.0	165.0	23.5	
IW-07	2,257,334.00	6,352,668.00	10.0	165.0	23.5	
System Total					-91 / 91	injection=extraction

*negative rate = extaction and positive rate = injection

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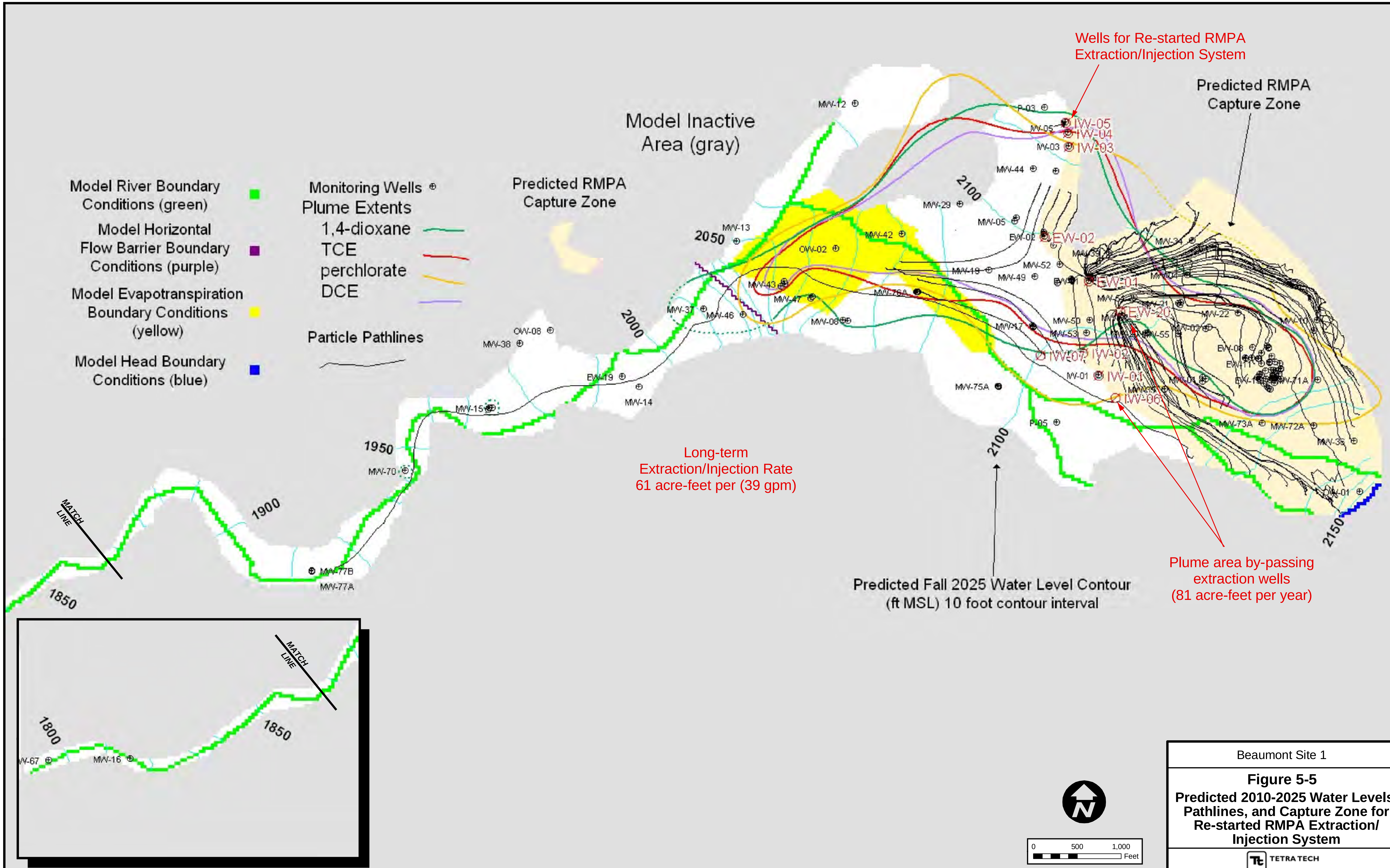

Beaumont Site 1

Figure 5-5

Predicted 2010-2025 Water Levels, Pathlines, and Capture Zone for Re-started RMPA Extraction/ Injection System

Analysis of the model water budget indicates that 61 acre-feet per year of contaminated groundwater is removed by extraction allowing approximately 124 acre-feet per year of contaminated groundwater to flow further downgradient. However, only about 81 acre-feet per year of the contaminated groundwater not captured is in the crossgradient to upgradient position of EW-1 and EW-2, while the remaining contaminated groundwater is located far downgradient of EW-1 and EW-2. Thus, the existing RMPA extraction/injection system appears capable of capturing approximately 43 percent of the groundwater flowing through the plume in the RMPA/BPA areas.

The current total plume pore volume is approximately 1,650 acre-feet, and the plume pore volume currently within the re-started RMPA extraction capture zone is approximately 750 acre-feet. Given that the extraction rate is 61 acre-feet per year implies that approximately 0.08 plume pore volumes is removed per year by extraction. Thus, a total of 1.3 plume pore volumes are removed by extraction over the 16 year prediction period, and most of this groundwater is pulled from the more concentrated portion of the plume near the former RMPA and BPA source areas as opposed to the lower concentrations near the riparian areas.

The water budget for the model predictions given in Appendix D and discussed in Section 5.6 shows that groundwater discharge rates to the riparian area for this scenario average 141 acre-feet per year, the same as the groundwater discharge rates to the riparian area for the No Action Alternative (141 acre-feet per year). This is because the RMPA extraction is balanced by re-injection upgradient of the riparian zone and cross-gradient of the plume. The water level and water level drawdown plots for the re-started RMPA Scenario (Figures E-7 and E-8) also show that water levels in the riparian zone are within one-half foot of those in the No Action Scenario. Thus, it appears that the RMPA system can be operated in this manner without adversely impacting the groundwater levels in the riparian area.

5.4 EXPANDED RMPA GROUNDWATER EXTRACTION AND INJECTION SYSTEM

The evaluation of restarting the RMPA extraction/injection system presented in Section 5.3 indicated that the existing RMPA is likely to capture only 43 percent of the groundwater flowing through the plume in the RMPA/BPA areas, and that the plume pore volume flushing rate is on the order of 0.08 pore volumes per year. Therefore, this section evaluates the impacts of an expanded RMPA extraction/injection system designed to achieve full capture of the plume in the RMPA/BPA area, and to increase the pore volume flushing rate through the plume to values of 0.3 and 2 pore volumes per year that are more typical of successful groundwater remediation pump and treat systems (Cohen et al., 1997).

In order to achieve complete capture of the existing groundwater plume and also provide better pore volume flushing of the plume, it is estimated that extraction/injection would need to be increased to approximately 91 gpm (147 acre-feet per year). Since historical site operations indicate that the long-term yield of wells EX-1 and EX-2 is only 39 gpm, additional extraction/injection wells are recommended to increase the system capacity by 52 gpm to 91 gpm. Due to the high permeability deep bedrock channel that exists in the aquifer near the middle of the current plume approximately 500 feet southeast of well EW-1 (see Figures A-1 and A-6), it appears likely that one additional extraction well (EW-20) located in the area given in Figures 5-4, A-1 and A-6 could achieve the required 52 gpm at a location with high contaminant concentrations. The specific capacity at this location is expected to be 8 gpm/foot. This production capacity should be adequate given the potential drawdown of up to 30 feet to meet the production goal of 52 gpm, as only a 6 foot drawdown would be needed to make this target rate. Plume maps indicate current contaminant concentrations at the proposed EW-20 location exceed 100 μg/l (Tetra Tech, 2009b). The high contaminant concentrations and extraction rates estimated for the EW-20 location would result in high contaminant mass removal rates, providing a good location for flushing the plume.

Due to the increased extraction rate, additional injection wells will also be needed. However, as opposed to the current injection wells that are only screened in the deep alluvium, the new injection wells are proposed to be almost fully screened through the deep alluvium. The new injection wells are proposed in another area of the deep bedrock channel that lies along the lateral perimeter of the plume towards Bedsprings Creek (Figure A-1). Aquifer properties at two locations in this area (IW-6 and IW-7) suggests that injection capacity should be on the order of 4 gpm/foot, which given the available depth to groundwater of 20 to 40 feet suggest two injection locations should be adequate for disposal of the additional 52 gpm extracted from the new well EW-20.

Option A

Thus, the groundwater model was modified to include extraction and injection in the existing and proposed new RMPA extraction/injection wells at the rates given in Table 5-1. This expanded RMPA extraction/injection scenario, referred to as "Option A", provides full containment across the width of the plume. A second expanded RMPA extraction/injection scenario, referred to as "Option B", is also presented later to evaluate the potential for accelerating mass removal rates from plume. The model predicted 2025 water levels, 2010-2025 groundwater pathlines, and capture zone analyses in the vicinity of the RMPA system are given in Figure 5-4. The water budget is given in Figure D-5 and groundwater levels and drawdown are given in Figures E-9 and E-10.

The predicted plume capture area is approximately 140 acres covering 48 percent of the total site plume area of 290 acres, allowing approximately 52 percent (150 acres) of the 290 acre plume area to continue flowing downgradient. Such a large portion of the plume is not contained because of the locations of the extraction wells between the RMPA and BPA, where the downgradient portion of the plume is not contained with the existing system. However, unlike the re-started RMPA Scenario where a 500 to 1,000 foot wide portion of the plume directly west of the BPA and cross- to upgradient of the extraction wells bypasses the extraction wells, the entire plume area upgradient of the extraction wells is captured by the expanded RMPA Scenario.

Analysis of the model water budget indicates that 147 acre-feet per year of contaminated groundwater is removed by extraction allowing approximately 38 acre-feet per year of contaminated groundwater to flow further downgradient. However, all the contaminated groundwater not captured is located far downgradient of EW-1, EW-2, and EW-20.

The current total plume pore volume is approximately 1,650 acre-feet, (Radian Corporation, 1992c and Tetra Tech, Inc., 2009a) and the plume pore volume currently within the extraction capture zone is approximately 1,036 acre-feet. The plume pore volume is driven by the contaminants TCE and perchlorate. Given that the extraction rate is 147 acre-feet per year implies that approximately 0.14 plume pore volumes is removed per year by extraction. Thus, a total of 2.3 plume pore volumes are removed by extraction over the 16 year prediction period, and most of this groundwater is pulled from the more concentrated portion of the plume near the former RMPA and BPA source areas as opposed to the lower concentrations near the riparian areas. Given the historical RMPA extraction/injection system operations removed 0.75 plume pore volume, the expanded RMPA extraction/injection system would need to be operated for 23 years to meet a target remedial objective of 4 plume pore volumes (Cohen et al., 1997). However, these cleanup time projections assume no further contribution from the vadose zone sources, and if soil source areas remain that contribute to groundwater, cleanup times will be considerably longer. The actual operation period for the expanded RMPA extraction/injection system may be less than 23 years depending on the extent to which the riparian area can be counted on to phytoremediate any remnant dilute portions of the plume.

The water budget for the model predictions given in Appendix D and discussed in Section 5.6 shows that groundwater discharge rates to the riparian area for this scenario average 142 acre-feet per year, nearly the same as the groundwater discharge rates to the riparian area for the No Action Alternative (141 acre-feet per year). This is because the RMPA extraction is balanced by re-injection upgradient of the riparian zone and cross-gradient of the plume. The water level and water level drawdown plots for the expanded RMPA Scenario (Figures E-9 and E-10) also show that water levels in the riparian zone are within 0.75 foot of those in the No Action Scenario. Thus, it appears that the expanded RMPA system can be operated in this manner without adversely impacting the groundwater levels in the riparian area.

Figures 5-4, E-9, and E-10 also show the predicted water levels in the monitoring wells at the site. The existing monitoring locations are generally adequate to monitor the expanded RMAP system, but it is recommended this monitoring network be supplemented with 8 new monitoring wells located approximately 25-50 feet from EW-20 and IW-1 through IW-7 to confirm the performance of the system (note the existing injection wells IW-1 through IW-5 do not have co-located monitoring wells and the nearest monitoring locations are often 200 to 500 feet away). To implement the RMPA system expansion, it is recommended that pumping/injection tests be conducted after the new extraction/injection wells (EW-20, IW-6, and IW-7) are drilled to verify the capacity of the system. In addition, pumping/injection tests are also recommended for the existing RMPA wells EW-1, EW-2, and IW-1 through IW-6 to verify the current capacity at these locations.

Option B

The expanded RMPA extraction/injection scenario-Option A provides full containment across the width of the plume, but it does not fully contain one high concentration area of the site groundwater and soils plume downgradient of the RMPA. Therefore, a second expanded RMPA extraction/injection scenario, referred to as “Option B”, is presented to evaluate the potential for accelerating mass removal rates from the plume and containing the high concentration area of the site groundwater and soils plume in the vicinity of wells MW-66 and MW-05. Option B includes one additional extraction well (EW-21) located between MW-66 and MW-05. Well EW-21 is in addition to the other wells given for the expanded RMPA extraction/injection scenario Option A. Well EW-21 is located in a secondary bedrock channel to the northeast of the main bedrock channel under Bedsprings Creek Valley (Figure A-1), where the total alluvium saturated thickness is expected to be 75 feet (Figure A-2) and the aquifer hydraulic conductivity if estimated to be 7 feet per day for an aquifer transmissivity of approximately 525 feet^2 per day. With this estimated aquifer transmissivity at EW-21, the well specific capacity is estimated to be 2.6 gpm/foot and the extraction rate is estimated to be approximately 26 gpm. The total rate for Option B is the same as Option A (91 gpm) to provide full containment of the plume.

Thus, the groundwater model was modified to include extraction and injection in the existing and proposed new RMPA extraction/injection wells at the rates given in Table 5-1. The model predicted 2025 water levels, 2010-2025 groundwater pathlines, and capture zone analyses in the vicinity of the RMPA system are given in Figure 5-6. The water budget is given in Figure D-6 and groundwater levels and drawdown are given in Figures E-11 and E-12.

The predicted plume capture area is approximately 140 acres – the same as Option A – covering 48 percent of the total site plume area of 290 acres, allowing approximately 52 percent (150 acres) of the 290

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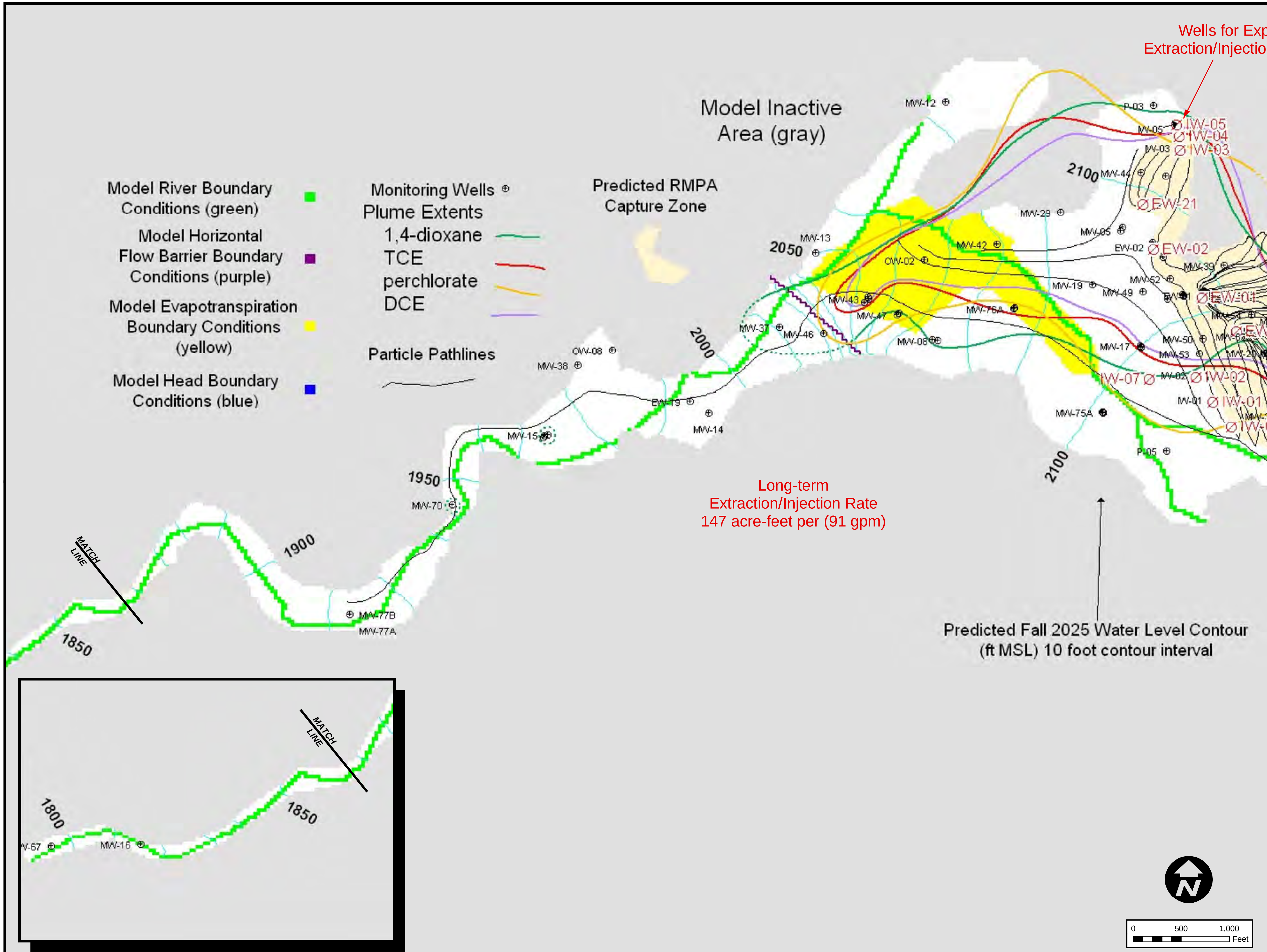


Beaumont Site 1

Figure 5-6

Predicted 2010-2025 Water Levels, Pathlines, and Capture Zone for Expanded RMPA Extraction/ Injection System-Option B

TETRA TECH

acre plume area to continue flowing downgradient. The primary difference in the predicted capture zone for the expanded RMPA-Option B in comparison to the predicted capture zone for the expanded RMPA-Option A is that for Option B there is an additional 5 acre capture area near the proposed EW-21, while for Option A there is an additional 5 acre capture zone in an area located downgradient of EW-1 and the proposed EW-20.

Analysis of the model water budget indicates that 147 acre-feet per year of contaminated groundwater is removed by extraction allowing approximately 38 acre-feet per year of contaminated groundwater to flow further downgradient. However, all the contaminated groundwater not captured is located far downgradient of EW-1, EW-2, EW-20, and EW-21. The primary difference in the predicted plume water budget for the expanded RMPA-Option B in comparison to the predicted plume water budget for the expanded RMPA-Option A is that for Option B there is an additional 43 acre-feet per year of contaminated groundwater flushing the plume near the proposed EW-21, while for Option there is an additional 43 acre-feet per year of contaminated groundwater flushing the plume in an area downgradient of EW-1 and the proposed EW-20.

Due to the similarity in the plume water budgets for Options A and B of the expanded RMPA extraction-injection system, the plume flushing estimates for Option B are essentially the same as those given for Option A above (0.14 plume pore volumes is removed per year by extraction) with the only difference being whether there is any focus of extraction and plume flushing in the EW-21 area.

The water budget for the model predictions given in Appendix D and discussed in Section 5.6 shows that groundwater discharge rates to the riparian area for this scenario average 141 acre-feet per year, the same as the groundwater discharge rates to the riparian area for the No Action Alternative (141 acre-feet per year). This is because the RMPA extraction is balanced by re-injection upgradient of the riparian zone and cross-gradient of the plume. The water level and water level drawdown plots for the expanded RMPA Scenario (Figures E-11 and E-12) also show that water levels in the riparian zone are within 0.5 foot of those in the No Action Scenario. Thus, it appears that the expanded RMPA system can be operated in this manner without adversely impacting the groundwater levels in the riparian area.

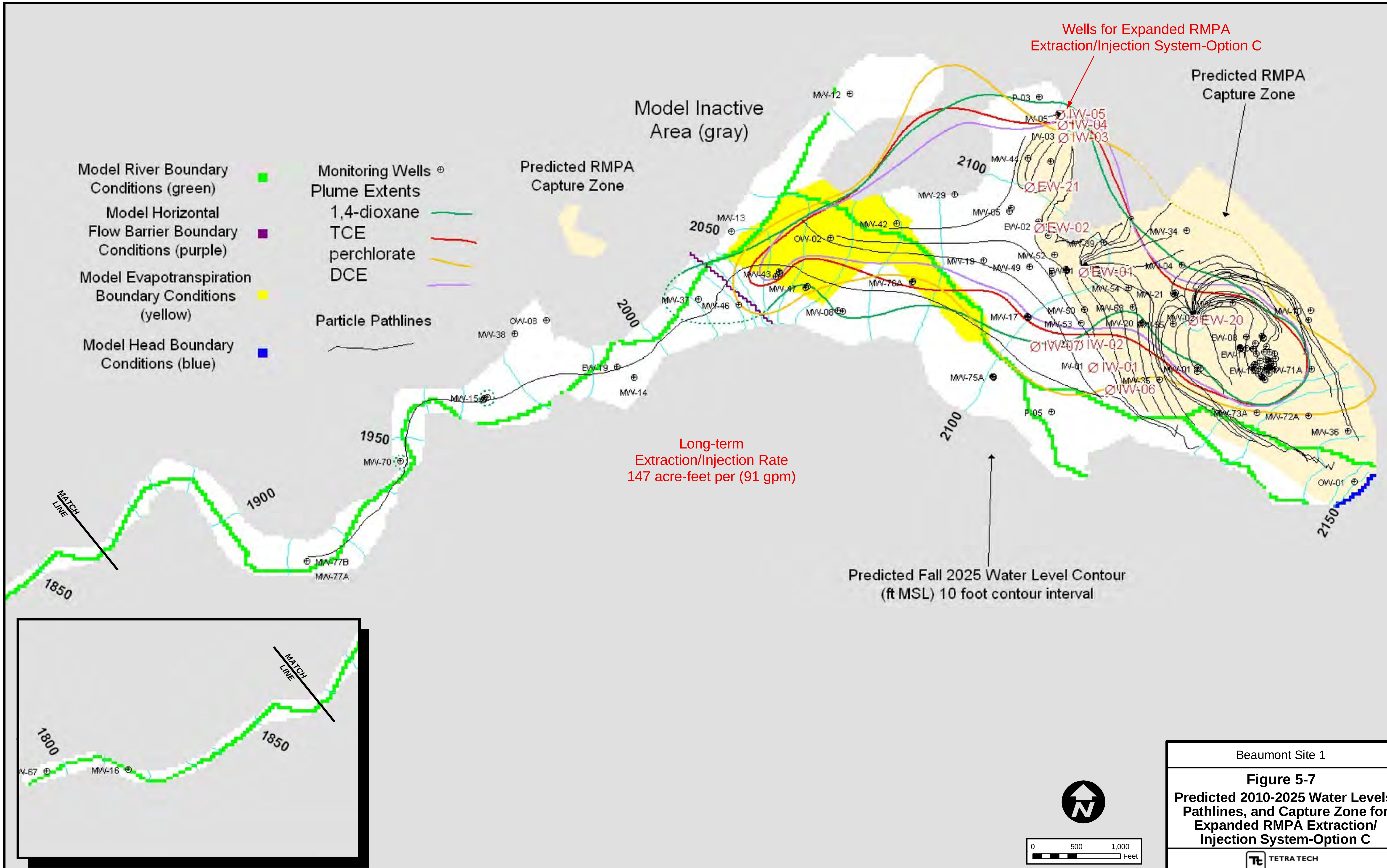
Figures 5-6, E-11, and E-12 also show the predicted water levels in the monitoring wells at the site. The existing monitoring locations are generally adequate to monitor the expanded RMAP system, but it is recommended this monitoring network be supplemented with 9 new monitoring wells located approximately 25-50 feet from EW-20, EW-21, and IW-1 through IW-7 to confirm the performance of the system (note the existing injection wells IW-1 through IW-5 do not have co-located monitoring wells and the nearest monitoring locations are often 200 to 500 feet away). To implement the RMPA system expansion, it is recommended that pumping/injection tests be conducted after the new extraction/injection wells (EW-20, EW-21, IW-6, and IW-7) are drilled to verify the capacity of the system. In addition, pumping/injection tests are also recommended for the existing RMPA wells EW-1, EW-2, and IW-1 through IW-6 to verify the current capacity at these locations.

Option C

The expanded RMPA extraction/injection scenarios-Options A and B provide full containment across the width of the plume, but they may not fully maximize plume mass removal rates as the key well EW-20 is located in a position to maximize well yield rather than total contaminant mass removals. For example, as indicated in the contaminant flux maps given in Appendix G, higher mass flux rates are found in the aquifer about 1,000 feet to the southeast of the EW-20 location proposed in Options A and B, where there is a plume hot spot at the edge of the bedrock channel between wells MW-55 and MW-02. Therefore, a third expanded RMPA extraction/injection scenario, referred to as “Option C”, is presented to evaluate the potential for accelerating mass removal rates from the plume by extracting from a location between wells MW-55 and MW-02. Option C simply moves one additional extraction well (EW-20) from the locations used in Options A and B the edge of the bedrock channel between wells MW-55 and MW-02. At the Option C location for EW-20, the total alluvium saturated thickness is expected to be 75 feet (Figure A-2) and the aquifer hydraulic conductivity if estimated to be 15 feet per day for an aquifer transmissivity of approximately 1,125 feet^2 per day. With this estimated aquifer transmissivity at the Option C location for EW-20, the well specific capacity is estimated to be 5.6 gpm/foot and the extraction rate is estimated to be approximately 38 gpm. The total rate for Option C is the same as Options A and B (91 gpm) to provide full containment of the plume.

Thus, the groundwater model was modified to include extraction and injection in the existing and proposed new RMPA extraction/injection wells at the rates given in Table 5-1. The model predicted 2025 water levels, 2010-2025 groundwater pathlines, and capture zone analyses in the vicinity of the RMPA system are given in Figure 5-7. The water budget is given in Figure D-7 and groundwater levels and drawdown are given in Figures E-13 and E-14.

The predicted plume capture area is approximately 140 acres – generally the same as Options A and B – covering 48 percent of the total site plume area of 290 acres, allowing approximately 52 percent (150 acres) of the 290 acre plume area to continue flowing downgradient. The primary difference in the predicted capture zone for the expanded RMPA-Option C in comparison to the predicted capture zone for the expanded RMPA-Option B is that for Option C extraction is focused near the contaminant mass flux hot spot between well MW-55 and MW-02 (Appendix G).



Beaumont Site 1

Figure 5-7

Predicted 2010-2025 Water Levels, Pathlines, and Capture Zone for Expanded RMPA Extraction/ Injection System-Option C

TETRA TECH

Analysis of the model water budget indicates that 147 acre-feet per year of contaminated groundwater is removed by extraction allowing approximately 38 acre-feet per year of contaminated groundwater to flow further downgradient. However, all the contaminated groundwater not captured is located far downgradient of EW-1, EW-2, EW-20, and EW-21. Due to the similarity in the plume water budgets for Options A, B, and C of the expanded RMPA extraction-injection system, the plume flushing estimates for Option C are essentially the same as those given for Options A and B above (0.14 plume pore volumes is removed per year by extraction) with the only difference being whether there is a greater focus of extraction and plume flushing in the mass flux hot spot areas.

The water budget for the model predictions given in Appendix D and discussed in Section 5.6 shows that groundwater discharge rates to the riparian area for this scenario average 142 acre-feet per year, nearly the same as the groundwater discharge rates to the riparian area for the No Action Alternative (141 acre-feet per year). This is because the RMPA extraction is balanced by re-injection upgradient of the riparian zone and cross-gradient of the plume. The water level and water level drawdown plots for the expanded RMPA Scenario (Figures E-13 and E-14) also show that water levels in the riparian zone are within 0.5 foot of those in the No Action Scenario. Thus, it appears that the expanded RMPA system can be operated in this manner without adversely impacting the groundwater levels in the riparian area.

Figures 5-7, E-13, and E-14 also show the predicted water levels in the monitoring wells at the site. The existing monitoring locations are generally adequate to monitor the expanded RMAP system, but it is recommended this monitoring network be supplemented with 9 new monitoring wells located approximately 25-50 feet from EW-20, EW-21, and IW-1 through IW-7 to confirm the performance of the system (note the existing injection wells IW-1 through IW-5 do not have co-located monitoring wells and the nearest monitoring locations are often 200 to 500 feet away). To implement the RMPA system expansion, it is recommended that pumping/injection tests be conducted after the new extraction/injection wells (EW-20, EW-21, IW-6, and IW-7) are drilled to verify the capacity of the system. In addition, pumping/injection tests are also recommended for the existing RMPA wells EW-1, EW-2, and IW-1 through IW-6 to verify the current capacity at these locations.

5.5 COMBINED IRM-MIDDLE POTRERO CREEK EXTRACTION SYSTEM AND EXPANDED RMPA GROUNDWATER EXTRACTION AND INJECTION SYSTEM

This section presents model results for a combination of the potential IRM-Middle Potrero Creek 5-Year Extraction System and an expanded RMPA Groundwater Extraction and Injection System (Option A) in order to evaluate the combined effects of these systems on groundwater conditions at the site. The model parameters are the same as those given for both these systems in Sections 5-2 and 5-4.

The model predicted 2025 water levels, 2010-2025 groundwater pathlines, and capture zone analyses in the vicinity of the IRM system and the RMPA system are given in Figure 5-8. The water budget, water levels, and drawdown are given in Figures D-7, E-13, and E-14. These results are nearly identical to the sum of those given in Sections 5.2 and 5-4 for the individual scenario predictions, which is what one would expect since the water level drawdowns for the individual scenarios (Figures E-6 and E-10) show very little overlaps of the area of influence for each scenario. Thus, the combined scenario results simply confirm expectations that the IRM-Middle Potrero Creek Extraction System and Expanded RMPA Groundwater Extraction and Injection System should have very limited effect on each other.

Capture areas, plume pore volume flushing, and impacts on the riparian areas are essentially the same as the summed results given in Sections 5-2 and 5-4. The entire 290 acre plume area is captured at the leading edge by the IRM-Middle Potrero Creek Extraction System, and approximately 140 acres of the higher concentration plume area between the RMPA and BPA is captured by the expanded RMPA system. The expanded RMPA system flushes the high concentration plume area at a rate of approximately 0.14 plume pore volumes per year for a total of 2.3 plume pore volumes removed over the 16 year prediction period.

The water budget for the model predictions given in Appendix D and discussed in Section 5.6 shows that groundwater discharge rates to the riparian area for the combined scenario average 139 acre-feet per year, similar to the groundwater discharge rates to the riparian area for the No Action Alternative (141 acre-feet per year). The water level and water level drawdown plots for the combined Scenario (Figures E-13 and E-14) show that water levels for most of the riparian zone drop less than 1 foot from the No Action Scenario. Thus, it appears these alternatives can be implemented without significant adverse impact to the riparian zone.

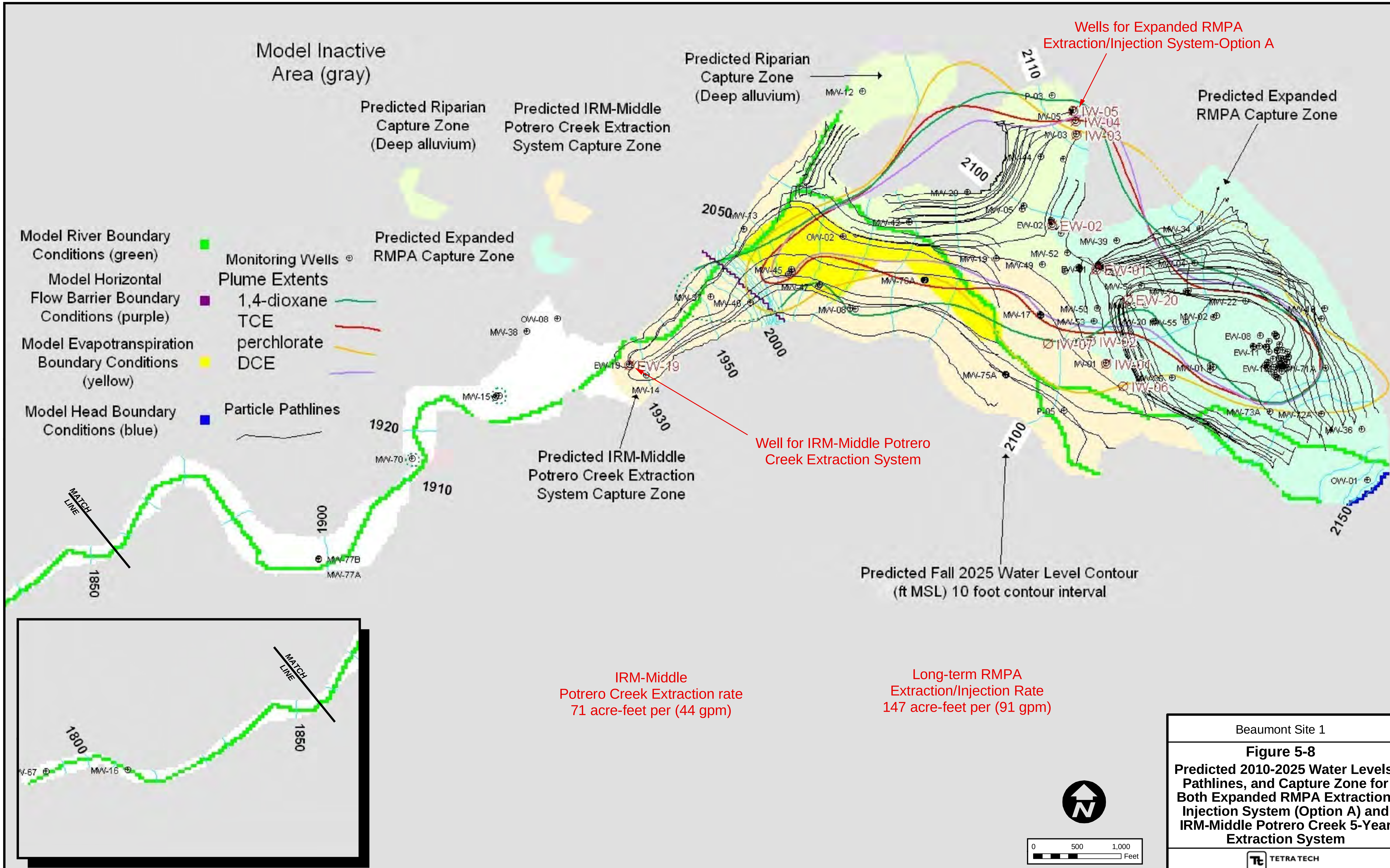
Monitoring requirements for the combined scenario are the same as those given for the individual scenarios in Sections 5-2 and 5-4, will the addition of one new monitoring well near EW-20 and the proposed testing of the new and old RMPA extraction/injection wells.

5.6 WATER BUDGET SIMULATIONS

Predicted water budget simulations for the proposed scenarios are given in Appendix D. This includes the following scenarios:

- A No Action Alternative;
- The Middle Potrero Creek Extraction System;
- A re-started RMPA extraction/injection system;
- An expanded RMPA extraction/injection system-Options A and B; and
- A combination of the expanded RMPA extraction/injection system and the Middle Potrero Creek 5-Year Extraction System.

X:\GIS\Lockheed 22288-0606\Fig 5-8.mxd



Beaumont Site 1

Figure 5-8

Predicted 2010-2025 Water Levels, Pathlines, and Capture Zone for Both Expanded RMPA Extraction/ Injection System (Option A) and IRM-Middle Potrero Creek 5-Year Extraction System

TETRA TECH

While the actual water budget for any particular year in the future is sensitive to the actual amount of precipitation that occurs in that particular year, the overall water budget for the entire period is thought to be representative of long-term site conditions. This is because (1) the predicted precipitation over the entire period is balanced out by an approximately equal number of wet and dry years, such that the average precipitation for the projected 2010-2025 period (17 inches) is the same as the long-term average at the site (17 inches); and (2) the precipitation variability during the 2010-2025 period is similar to the historical precipitation variability at the site.

The impacts of the predicted site water budget on various facets of the site such as the groundwater discharge rate to Potrero Creek; the groundwater discharge rate to the riparian area; and the number of pore volume flushing of the site groundwater plume are discussed for each scenario in Sections 5.1 through 5.5. Key points include the following:

- Groundwater discharge rates to Potrero Creek – Implementing the IRM-Middle Potrero Creek Extraction System has the potential to ultimately reduce groundwater discharge rates to Potrero Creek from 55 acre-feet per year to 5 acre-feet per year and eliminate the further migration of the plume down the Potrero Creek alluvium. The small 5 acre-feet per year groundwater discharge rate to Potrero Creek that remains after implementing the IRM-Middle Potrero Creek Extraction System is due to groundwater recharge occurring downgradient of the plume and EW-19;
- Groundwater discharge rates to the riparian area – Implementing either the re-started or expanded version of the RMPA Extraction/Injection System has little impact on the groundwater evapotranspiration rates in the riparian area. Implementing the IRM-Middle Potrero Creek Extraction System for a five-year period also has little impact on the groundwater evapotranspiration rates in the riparian area, although a longer operating time of 16 years may potentially reduce evapotranspiration rates in the riparian area from 141 acre-feet per year to 126 acre-feet per year. However, the current site groundwater remediation plan anticipates the installation and operation of an expanded RMPA Extraction/Injection System, which will cut-off the plume migration down Potrero Creek within 5 years, such that the IRM-Middle Potrero Creek Extraction System will only need to operated for a five-year period; and
- Plume capture and remediation in the RMPA – Implementing the expanded version of the RMPA Extraction/Injection System has the potential to capture the entire plume width and underflow (147 acre-feet per year) upgradient of the extraction wells, and provides for 2.3 plume pore volumes over the 16 year prediction period. The remaining plume area and underflow downgradient of the RMPA extraction wells is captured by operation of the IRM-Middle Potrero Creek Extraction System and discharge to the riparian zone within 5 years. If a total of four pore volume flushings are required to remediate the RMPA/BPA source areas, the expanded RMPA extraction/injection system will need to be operated for a total of 23 years until 2033.

5.7 RIPARIAN AREA WATER LEVELS AND EVAPOTRANSPIRATION RATES

The impacts on water levels in the riparian area are evaluated for each scenario by calculating the 2025 drawdown in water levels in the riparian area from the No Action alternative, with the results given in Appendix E. For the No Action Alternative, the 2025 drawdown is given from current conditions. The impacts on the evapotranspiration rates in the riparian area are evaluated for each scenario and given in Appendix D.

These results are discussed in detail in Sections 5.1 through 5.5 for each scenario, but the primary conclusion from the model analyses is that any of the proposed scenarios can most likely be implemented without any significant impact on the water levels, evapotranspiration rates, and hence the vegetation in the riparian area. This is because (1) all extraction activities in the Bedsprings Creek alluvium are balanced by re-injection to maintain a water balance and hence the riparian area water levels, and (2) the extraction in Middle Potrero Creek is being implemented significantly downslope and across the Potrero Fault groundwater barrier from the riparian zone and it likely to require operation for only 5 years.

6.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

These subsections present a summary of the modeling effort, including a tabulation of the primary conclusions of the study and recommendations for remedial alternatives for the site groundwater plume.

6.1 SUMMARY

A Conceptual Site Model (CSM), water budget, and numerical MODFLOW groundwater flow model were developed for the site based upon historical groundwater monitoring and remedial operations data, as well as the November 2008 pumping test data collected from Middle Potrero Creek. Key aspects of the model includes 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. The plume is generally limited to the alluvial units;
- A thick sequence of saturated recent alluvium occurs in Bedsprings Creek Valley upgradient of Potrero and Bedsprings Faults, with a thinning layer of saturated recent alluvium in the lower reaches of Potrero Creek that pinches out just west of MW-67;
- 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 canyon at a gradient of 0.01 to 0.02. Based upon the very high gradients, aquifer thinning, and artesian conditions near Potrero Fault, this fault appears to restrict groundwater flow to some degree. The marked flattening in gradients to 0.002 in the Bedsprings Creek alluvium is attributed to an increase in aquifer transmissivity in this area;
- There are downward vertical gradients and large seasonal water table fluctuations in the alluvium in the southeast of the site where there is recharge, and there are upward vertical gradients and small seasonal water table fluctuations in the alluvium in the northwest and west of the site where there is a 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;
- There is limited vertical leakage into the competent Mount Eden Formation, and very limited vertical leakage into the granitic basement, as evidenced by differences in water levels, water chemistry, and historical site operations. In the Middle Potrero Creek canyon area, the combined effects of the shallowing Mount Eden formation and the Potrero Fault appears to be forcing groundwater towards the surface;
- During the 1992-2008 period, 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; and
- 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 Fall 1992 steady-state conditions and Fall 1992 through Fall 2008 transient conditions, as well as the flowpaths evident at the site based upon the observed morphology of the groundwater plume. The time after shut-down of the RMPA system (2003 to present) was also used as a validation period for the numerical model, since there were different hydrologic conditions after the 2002 shut-down of the RMPA extraction/injection system. The numerical 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. Input/output files for the MODFLOW Model and the GWVistas pre-processor files are given in Appendix F (available only on CD in electronic format).

The calibrated groundwater flow model was used to simulate the aquifer response and impacts on the site groundwater plume for the following site groundwater remedial alternatives:

- A No Action Alternative;
- Operation of the IRM-Middle Potrero Creek Extraction System;
- Re-starting the existing RMPA extraction/injection system;
- Operating an expanded RMPA extraction/injection system (Options A and B); and
- A combination of the expanded RMPA extraction/injection system and the Middle Potrero Creek Extraction System.

The hydrologic conditions and water budget for the future predictions were estimated based upon the historical hydrologic conditions and water budget observed at the site, as well as the current antecedent site conditions. For each alternative, the hydraulic capture zone and plume flushing rate were estimated to evaluate the remedial benefits of the proposed action.

6.2 CONCLUSIONS

The following conclusions are presented based upon the CSM, water budget, numerical groundwater flow model calibration, and remedial scenario simulations:

- Currently the groundwater underflow rate through the plume area is approximately 185 acre-feet per year. The fate of the plume is as follows: 127 acre-feet per year discharges as evapotranspiration in the riparian, 6 acre-feet per year leaks downward into the Mt Eden, and 52 acre-feet per year continues to flow down the Potrero Creek alluvium where it ultimately discharges to maintain the summer baseflow conditions in Potrero Creek. Thus, current estimates indicate that 70 percent of the groundwater plume is intercepted by evapotranspiration in the riparian area;
- Installation and operation of the potential IRM-Middle Potrero Creek extraction system at rate of 44 gpm (71 acre-feet year) should completely capture all plume groundwater flowing down Potrero Creek alluvium and cut-off any potential discharge of contaminants into Potrero Creek. If the potential IRM is operated in conjunction with an expanded RMPA extraction/injection system, it is anticipated that the IRM would need to be operated for a period of five years. If the IRM is operated without any extraction in the RMPA extraction/injection system, it is anticipated that the IRM would need to be operated for a period of 75 years or longer before the plume is remediated in the Middle Potrero Creek area;

- Operation of the existing RMPA extraction/injection system at rate of 39 gpm (61 acre-feet year) should capture 43 percent of all groundwater flowing through the plume above the extraction wells. If the existing RMPA extraction/injection system is re-started, it is anticipated that the system would need to be operated for a period of 54 years before the plume is remediated in the RMPA/BPA area;
- Expansion and operation of the RMPA extraction/injection system at rate of 91 gpm (147 acre-feet year) should completely capture all groundwater flowing through the plume above the extraction wells. If the expanded RMPA extraction/injection system is installed, it is anticipated that the system would need to be operated for a period of 23 years before the plume is remediated in the RMPA/BPA area. Implementing Option B of the expanded RMPA extraction/injection system is recommended as it provides for the maximum flexibility in optimizing future plume mass removal and contaminant flushing rates, however, there is additional cost for Option B and uncertainty in the pumping rates that can be extracted from the EW-21 location. In addition, as shown in the contaminant mass flux maps derived from the MODFLOW model water budget and site contaminant concentration maps given in Appendix G, Option B targets capture at two of the site areas with the highest contaminant mass flux levels. The mass flux maps in Appendix G also suggest that a more optimum location for EW-20 may be about 1,000 feet to the southeast in the plume hot spot at the edge of the bedrock channel between wells MW-55 and MW-02, however, this alternate location presents a greater risk that well yields may not be as high as those expected in the center of the bedrock channel. This alternate location will be considered as part of the geological review for the well siting and planning that will be conducted during the detailed design of the expanded RMPA system; and
- Operating both the IRM-Middle Potrero Creek extraction system and the RMPA extraction/injection system is unlikely to significantly impact groundwater levels, evapotranspiration rates, and hence the vegetation in the riparian zone. This is because (1) the RMPA extraction/injection system maintains a net water balance by re-injecting all extracted groundwater above the riparian zone; and (2) the IRM-Middle Potrero Creek extraction system is located significantly downslope and across the Potrero Fault from the riparian zone and is only likely to operate for 5 years.

While there is some level of uncertainty associated with these conclusions, the level of uncertainty is believed to be manageable within the framework of the proposed remedial actions, such that adjustments can most likely within the framework of the proposed remedial actions in order to meet the overall site remedial objectives.

6.3 RECOMMENDATIONS

The following recommendations are presented based upon the CSM, water budget, numerical groundwater flow model calibration, and remedial scenario simulations:

- IRM-Middle Potrero Creek extraction system – Since the contaminants in the IRM area have currently dropped below probable action levels, there is currently no need for implementing the IRM in this area. Future monitoring will be conducted as part of the routine site groundwater monitoring program to confirm that concentrations remain below probable action levels, with re-evaluation of an IRM at some future date as outlined below if concentrations rise above probable action levels. In the event concentrations increase above probable action levels in the future, it may be recommended in the future to complete installation of the IRM-Middle Potrero Creek extraction system and operate this system at an extraction rate of 44 gpm (71 acre-feet per year) for a likely period of 5 years to clean-up the leading edge of the plume. To accommodate uncertainty in site conditions and the possible need for higher extraction rates during wet periods, the nominal recommended design rate for the IRM treatment system is 75 to 125 gpm. While no new additional monitoring wells are anticipated for this remedial alternative due to the recent wells installed near EW-19 for the site pumping test, monitoring will need to be conducted to confirm complete plume capture at EW-19 and to evaluate the decline in contaminant concentrations over time. The monitoring will support the decision to terminate the IRM operations after the expanded RMPA extraction/injection establishes complete plume cut-off in the RMPA and the remaining plume has flushed downgradient to the IRM location;

- Expanded RMPA extraction/injection system – The RMPA extraction/injection system can be expanded to establish hydraulic control over the entire RMPA plume by adding one extraction well (EW-20) and two injection wells (IW-6 and IW-7), and operating this system at an extraction/injection rate of 91 gpm (147 acre-feet per year) for a period of 25 years to clean-up the source area of the plume. To accommodate uncertainty in site conditions and the possible need for higher extraction rates during wet periods, the nominal recommended design rate for the expanded RMPA treatment system is 125 to 150 gpm. If the RMPA were to be expanded, additional monitoring requirements may include 8 new monitoring wells located approximately 25-50 feet from EW-20 and IW-1 through IW-7 to confirm the performance of the system, and conducting pumping/injection tests on all RMPA extraction/injection wells prior to start-up of the system. Monitoring will also need to be conducted to confirm complete plume capture and to evaluate the decline in contaminant concentrations over time. The decision to expand the RMPA, however, will be made in the upcoming FS;
- Riparian Area – Continue monitoring both groundwater levels and water quality in the riparian area to (1) evaluate any potential for negative impacts on the riparian vegetation due to the operation of the IRM-Middle Potrero Creek extraction system and the expanded RMPA extraction/injection system, and (2) further confirm the plume capture in the riparian area.
- Feasibility Study – It is recommended that the model developed in this study be used to evaluate remedial options as part of the upcoming site FS.

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8.0 ACRONYMS

bgs	below ground surface
btoc	below top of casing
BOS	bottom of screen
COPC	chemical(s) of potential concern
CSM	Conceptual Site Model
DTSC	Department of Toxic Substances Control
EC	electrical conductivity
EPA	United States Environmental Protection Agency
ft/ft	feet per foot
ft/day	feet per day
GMP	Groundwater Monitoring Program
HSUs	hydrostratigraphic units
IRM	Interim Removal Action
K	hydraulic conductivity
LAC	Lockheed Aircraft Corporation
LMC	Lockheed Martin Corporation
LPC	Lockheed Propulsion Company
MW	Monitoring well
MCLs	maximum contaminant levels
mg/L	milligrams per liter
msl	mean sea level
µg/L	micrograms/liter
NA	not applicable
NWS	National Weather Service
P	production well
PZ	piezometer
QAL	Quaternary alluvium
SAP	sampling and analysis plan

SKR	Stephens' Kangaroo rat
SS	stainless steel
SVOCs	semi-volatile organic compounds
TCE	trichloroethene
TOC	top of casing
TOS	top of screen
Unk.	unknown
U.S.	United States
USFWS	United States Fish and Wildlife Service
VOCs	volatile organic compounds

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