NIBW FIVE-YEAR REVIEW ANALYSIS OF GROUNDWATER REMEDY EFFECTIVENESS

North Indian Bend Wash Superfund Site

Prepared for:
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Prepared by:

NIBW Participating Companies

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REPORT

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EXECUTIVE SUMMARY

The objectives of this Five-Year Review (5YR) summary report for the North Indian Bend Wash (NIBW) Superfund Site (the Site) are to: (1) demonstrate the effectiveness of groundwater remedial actions and progress made toward achievement of Remedial Action Objectives (RAOs) based on historical data, and (2) evaluate future remedy performance in terms of plume containment and aquifer restoration based on model projections.

Analysis of Remedy Effectiveness and Progress Based on Historical Data

As summarized below, analysis of monitoring data demonstrates that remedial operations in the vadose zone and groundwater at the NIBW site over the past 15 years have been effective and resulted in substantial progress towards achieving RAOs.

- **Vadose Zone –** Vadose zone source control via soil vapor extraction (SVE) at Areas 6, 8, and 12 have been successfully completed. Substantial vadose mass removal has been achieved at Area 7 via SVE. Volatile organic compound (VOC) mass and concentrations in Area 7 soils have decreased to the point that residual VOC levels in Area 7 soil no longer contribute mass flux to downgradient Upper Alluvium Unit (UAU) groundwater that results in concentrations in excess of the 5 μg/L cleanup standard for NIBW contaminants of concern (COCs).
- **Upper Alluvium Unit Groundwater –** UAU groundwater monitoring data clearly demonstrate effective and widespread attenuation of VOC mass within the UAU and progress made to restore the UAU to drinking water quality by decreasing the COCs to below the cleanup standards. The total mass of VOCs present in the saturated portion of the UAU has decreased substantially with time, declining from an estimated 11,000 pounds in 1993 to approximately 400 pounds in 2009. The voluntary UAU groundwater extraction program at Area 7 has contributed significantly to VOC mass attenuation, as indicated by a reduction in trichloroethene (TCE) concentrations at 7EX-1UA from approximately 10,000 in 1994 to less than 5 micrograms per liter (μg/L) in October 2009. The remainder of the mass in the UAU has effectively migrated into the Lower Alluvium Unit (LAU) via the

southwest margin, as conceived in the site conceptual model and documented in the OU2 ROD, for extraction and treatment in the LAU.

- **Middle Alluvium Unit Groundwater Source Control Program –** Monitoring of MAU groundwater conditions has broadly demonstrated that source control programs in Area 7 and Area 12 in the Middle Alluvium Unit (MAU) have minimized the total amount of NIBW COCs that would otherwise migrate toward the southwest margin. Analysis of water level data demonstrates hydraulic containment of the plume areas where TCE concentrations are highest.
- **Middle/Lower Alluvium Unit Groundwater –** Groundwater extraction and treatment have resulted in hydraulic containment of the MAU and LAU plumes and significant progress toward aquifer restoration. The NIBW groundwater remedy has removed an estimated 70,000 pounds of TCE. In particular, monitoring of bulk LAU water quality withdrawn at Central Groundwater Treatment Facility (CGTF) extraction wells reveals systematic and substantial reductions in TCE concentrations in the southern and central portion of the LAU plume. Consistent operation of CGTF extraction wells for the past 15 years has captured and limited the migration of higher TCE concentrations to the northern LAU extraction wells connected to the Miller Road Treatment Facility (MRTF). Data trends further indicate that well PCX-1 captures the bulk of TCE in the northern LAU and substantially limits the impact to other Arizona American Water (AAW) wells connected to the MRTF.

Historical monitoring data indicate that remedial operations have been effective at vadose zone source control, hydraulic containment of source area groundwater, and protection of groundwater resources and water supply wells in the LAU, and substantial progress has been made at achieving all other RAOs.

Projection of Future Remedy Performance

The original Feasibility Study Addendum (FSA) model was updated and recalibrated for the 5YR in collaboration with the US Environmental Protection Agency (EPA) and Arizona Department of Environmental Quality (ADEQ). To meet the substantive requirement of the 5YR of evaluating the effectiveness of the operating groundwater remedy, the updated and recalibrated model (designated the 5YR model) was used to project capture zones for remedy wells and estimate groundwater cleanup times under a recommended pumping regime.

Timeframe to achieve restoration was not specified as an RAO for the site. However, to provide an analysis of remedy performance in relation to the Amended Record of Decision (AROD) expected outcome of a 50+ year aquifer restoration timeframe for the selected remedy, EPA requested that the NIBW Participating Companies (PCs) include a cleanup time assessment in the 5YR.

The following capture projections were developed using the 5YR model:

- **Middle Alluvium Unit –** The overarching RAO in the MAU is to hydraulically contain TCE mass concentrated at the Area 7 and Area 12 sources and to allow groundwater containing smaller concentrations of TCE outside of these areas to migrate into the LAU via the southwest margin. Based on model projections, continued operation of the Area 7 and Area 12 source control programs at current pumping rates is estimated to result in capture zones that are consistent with RAOs into the future.
- **Lower Alluvium Unit** – Model results indicate that the extent of capture resulting from the combined operation of remedy extraction wells PCX-1, AAW-14, and AAW-15 is projected to encompass the leading edge of the TCE plume, which would prevent further downgradient migration towards the northern-most AAW water supply wells**.** Further, the capture zone of remedy well COS75A is projected to be effective at containing higher TCE concentrations in the southern and eastern portion of the LAU plume, and the COS71 and COS72 capture zones are projected to hydraulically contain most of the remaining southern portion of the LAU plume and the area near the southwest margin. Based on these results, continued operation of the LAU extraction wells at current pumping rates is estimated to result in capture zones that are consistent with the RAO of plume containment into the future.

Using an approach that was mutually agreed upon by EPA and the PCs, the following cleanup projections were developed using the 5YR model:

- **Lower Alluvium Unit –** The overall range in projected cleanup times for individual LAU extraction wells is from 11 to 70 years. The shortest cleanup times are projected for COS71 and COS72 (11 and 14 years, respectively) because they are located in the upgradient portion of the TCE plume. Since these wells also capture TCE mass moving into the LAU from overlying units at the southwest margin, actual time to reach cleanup goals is anticipated to be longer than projected. Well PCX-1 is projected to have the longest cleanup time (70 years) because it is located along the plume axis in the downgradient portion of the plume. The projected cleanup time for well COS75A is 41 years based on the batch flush model. Extrapolation of TCE concentration trends in COS75A indicate a similar estimated cleanup time.
- **Upper Alluvium Unit –** TCE concentrations in the UAU have declined significantly over the past decade due to successful operation of soil vapor extraction remedies in the source areas and groundwater extraction at Area 7. Declines due to natural attenuation processes are expected to continue, as localized areas of TCE impacted groundwater migrate towards the southwest margin. The time required for concentrations in the UAU groundwater to attenuate to cleanup standards was estimated to be on the order of a decade.
- **Middle Alluvium Unit –** A qualitative assessment of cleanup time was made for the MAU because the quantitative method used for the UAU and LAU is believed to be inappropriate for conditions in the MAU. Cleanup in this fine-grained unit is largely

controlled by the rate-limiting process of mass diffusion, which is not accounted for in this approach. While timeframe for cleanup in the MAU is anticipated to be longer than for the other portions of the site, review of water quality and mass removal data indicate that significant and consistent progress is being made toward achievement of RAOs in the MAU. These data support a conclusion that substantial progress toward MAU cleanup is expected to occur during the 40 to 70 year cleanup timeframe estimated for extraction wells COS75A and PCX-1, respectively, in the LAU.

Conclusions

Water quality and water level data obtained at the NIBW Site demonstrate that implementation of historical and current remedial actions have resulted in substantial progress towards achievement of RAOs in all three alluvial units. Groundwater flow modeling and other analytical approaches demonstrate that continuation of current remedial operations into the future is projected to achieve hydraulic capture of the TCE plumes in UAU, MAU, and LAU groundwater and result in significant progress toward restoration of groundwater resources in the project area in accordance with RAOs. Results of cleanup time analyses indicate that projections are consistent with those made in relation to the selected remedy in the AROD.

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1.0 INTRODUCTION

1.1 DOCUMENT OBJECTIVES

The objectives of this summary report for the North Indian Bend Wash (NIBW) Superfund Site Five-Year Review (5YR) are to: (1) demonstrate the effectiveness of groundwater remedial actions and progress made toward achievement of Remedial Action Objectives (RAOs) based on historical data, and (2) evaluate future remedy performance in terms of plume containment and aquifer restoration based on model projections. A site map, showing the October 2009 trichloroethene (TCE) plumes for the Upper Alluvium Unit (UAU), Middle Alluvium Unit (MAU), and Lower Alluvium Unit (LAU), as well as locations for groundwater extraction and treatment systems, is shown on **Figure 1**.

1.2 DOCUMENT ORGANIZATION

The three sections that follow will summarize the relevant requirements of the groundwater remedy, the effectiveness of the remedial actions implemented, and projections of future remedy performance. Supporting information, tables, or figures contained in other documents are noted for reference. Section 2 provides background on NIBW Site response actions, remedy selection, and administrative requirements contained in governing decision documents. Section 3 provides an overview of the groundwater remedy effectiveness and progress toward achievement of RAOs, including a review of remedial actions implemented for the vadose zone, UAU, MAU, and LAU. Historical water quality data and current conditions, characterized by October 2009 results, the most recent comprehensive NIBW monitoring event, are incorporated into the review. Section 4 summarizes the efforts made to update and calibrate the existing NIBW Site groundwater flow model and the projections of future capture and cleanup based on the calibrated model.

2.0 REMEDIAL ACTION IMPLEMENTATION AND REQUIREMENTS

2.1 REMEDY SELECTION AND IMPLEMENTATION

Groundwater remedy selection occurred in three phases over the first 20 years of NIBW Site history through development of three Records of Decision (RODs) and accompanying Consent Decrees (CDs). The first phase, or Operable Unit 1 (OU1), addressed volatile organic compounds[1] (VOCs) impacting MAU and LAU groundwater withdrawn by City of Scottsdale (COS) production wells. The second phase, OU2, addressed groundwater in the shallow UAU aquifer and VOC-impacted soil in specific source areas. The third phase integrated supplemental MAU and LAU groundwater response actions into a comprehensive and final decision document.

The site cleanup strategy developed for the final remedy selection was based on evaluation of groundwater remedy effectiveness and enhancements documented in the Feasibility Study Addendum (FSA), dated November 15, 2000, prepared for the U.S. Environmental Protection Agency (EPA) by the NIBW Participating Companies (PCs). On September 27, 2001, EPA issued an amended ROD that consolidated previous decisions regarding both groundwater and soil cleanup actions under Operable Unit (OU)1 and OU2 RODs into one final document. An amended CD, specifying the obligations of the amended ROD, was executed by all parties to the NIBW Site cleanup and became effective on June 6, 2003 by authority of the U.S. District Court for Arizona. EPA designated the NIBW Site remedy status as “construction complete” in December 2006.

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[1] NIBW contaminants of concern consist of five VOCs, including trichloroethene (TCE), tetrachloroethene (PCE), 1,1-dichloroethene, 1,1,1-trichloroethane, and chloroform.

2.2 REMEDIAL ACTION OBJECTIVES

EPA established the following seven RAOs for the NIBW Site in the September 2001 amended ROD:

1. Restore UAU, MAU, and LAU groundwater to drinking water quality by decreasing the concentrations of the contaminants of concern (COCs) to below the cleanup standards;
2. Protect human health and the environment by eliminating exposure to contaminated groundwater;
3. Provide the COS with a water source that meets drinking water Maximum Contaminant Levels (MCLs) for the NIBW COCs;
4. Achieve containment of the groundwater plume by preventing any further lateral migration of contaminants in groundwater;
5. Reuse water treated at the Site to the extent possible in accordance with Arizona's Groundwater Management Act;
6. Mitigate any soil contamination that continues to impact groundwater; and
7. Provide long-term management of contaminated groundwater to improve the regional aquifer's suitability for potable use.

Performance standards for the RAOs have been broadly defined in the EPA Statement of Work (SOW) that is attached to the amended CD as Appendix A. Specific performance measures to demonstrate attainment of the groundwater RAOs were documented in the October 2002 EPA-approved Groundwater Monitoring and Evaluation Plan (GMEP).

3.0 PROGRESS TOWARD ACHIEVEMENT OF RAOs

The following sections summarize the results of vadose zone and groundwater remediation efforts to date at the Site.

3.1 VADOSE ZONE AND SOURCE AREA REMEDIATION

3.1.1 Vadose Zone Performance Standards and Measures

Vadose zone remediation using soil vapor extraction (SVE) has been conducted at NIBW Areas 6 (voluntary action), 7, 8, and 12. To mitigate soil contamination that continues to impact groundwater (RAO #6), section III.E.2 of the amended CD SOW requires:

The soil cleanup action currently in progress at Area 7 shall be completed in accordance with the NIBW Record of Decision dated September 1991 (1991 ROD), the 1993 Consent Decree, and the associated work plans previously approved by EPA.

The goal of soil cleanup actions was to minimize VOC mass flux from the vadose zone to groundwater. The 1991 ROD provided specific performance measures based on soil vapor monitoring and modeling of vapor phase transport to estimate the threat to groundwater from any residual soil contamination. SVE actions were deemed complete when the projected threat to UAU groundwater was less than 5 micrograms per liter (µg/L) for the NIBW COCs.

3.1.2 Summary of Vadose Zone Remedial Operations

SVE operations at Areas 6, 7, 8, and 12 resulted in removal of over 9,000 pounds of VOCs[2]. Remediation is complete at Areas 6, 8, and 12, while SVE continues at Area 7 to address limited residual TCE that remains in recalcitrant soil horizons. The Area 7 SVE system is currently shut down for a planned 3-year period to observe VOC concentration rebound following operation under a pulsing regime that was conducted from July 2008 through December 2009.

3.1.3 Current Groundwater Quality Beneath Source Areas

Previous soil vapor monitoring conducted at Area 7 indicated that little VOC mass remains in the vadose zone (FSA, Table 2-22). UAU groundwater monitoring conducted at Area 7 substantiates that SVE operations have effectively limited VOC impacts from the source area. **Figure 2** shows sampling results from October 2009 that indicate a TCE concentration of 4.4 μg/L at Area 7 in UAU groundwater extraction well 7EX-1UA and 1.7 μg/L in UAU monitor well PG-10UA. These wells are located directly downgradient from Area 7. As shown on the inset graph on **Figure 2**, TCE concentrations at PG-10UA have decreased dramatically since SVE operations began. TCE concentrations in PG-10UA have been consistently below 5 μg/L since 2002.

3.1.4 Analysis of Effectiveness of Vadose Zone Remedy

Although soil remediation at Area 7 has yet to be formally completed, substantial progress has been achieved to mitigate Area 7 soil contamination and minimize impacts to groundwater (RAO #6). VOC concentrations in Area 7 soil have decreased to the point that residual VOC mass in Area 7 soil no longer contributes VOC mass to downgradient UAU

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[2] See FSA Report; SVE resulted in an estimate removal of: 38 pounds of TCE at Area 6 (page 5a-5), 7,467 pounds of TCE and 104 pounds of PCE at Area 7 through April 2000 (page 5a-1 and Table 2-22), 631 pounds of TCE at Area 8 (page 5-31), and 553 pounds of TCE and 319 pounds of PCE at Area 12 (page 5-43).

groundwater that results in concentrations in excess of the 5 μg/L cleanup standard for NIBW COCs.

3.2 UAU GROUNDWATER REMEDIATION

3.2.1 UAU Performance Standards and Measures 3.2.1

As specified in the OU2 ROD, the remedy for UAU groundwater consists of cleanup of VOC-impacted soil at EPA-identified source areas and monitoring of UAU groundwater contaminant attenuation. EPA determined that groundwater extraction in the UAU was not warranted because the estimated time required to achieve acceptable levels of VOCs in the UAU groundwater was not likely to change significantly with remedial pumping.

To monitor attenuation of UAU groundwater contamination and to document the flux of VOCs into and out of the UAU, the NIBW PCs and SRP installed an extensive network of UAU monitor wells. This monitor well network included one monitor well every 40 acres within the zone of TCE contamination. The methodology for mass flux determination and mechanisms of mass transfer are discussed in the Final FSA (page 2-60). Performance measures associated with UAU mass flux determinations are given in Section 4.1 of the GMEP (page 37). The GMEP performance criterion used to ensure attenuation of VOC contamination in the UAU is a "reduction in total VOC mass in the UAU attributable to NIBW sources". The achievement measure that must be demonstrated is "a decrease in VOC mass in the UAU, based on a 5-year running average of reported UAU mass flux".

3.2.2 Summary of UAU Remedial Operations

Forty-four monitor wells were installed in three specified areas within the NIBW Site to meet UAU groundwater monitoring requirements of the OU2 ROD. Following well installation, water level and water quality monitoring were conducted at the 44 new monitor wells, along with 28 existing UAU monitor wells, to estimate VOC mass and mass flux in the UAU. Following approval of the GMEP in October 2002, 32 monitor wells that were no longer within the TCE plumes were removed from the UAU monitoring network. Eleven of these UAU monitor wells were formally abandoned.

Although not a required action, the NIBW PCs voluntarily implemented groundwater extraction and treatment at Area 7 to contain and remove TCE mass that was historically present in UAU groundwater in this area. The Area 7 source control remedy has included 25 to 35 gallons per minute (gpm) of groundwater extraction at UAU well 7EX-1UA since July 1994, concurrent with startup of the Area 7 SVE system. Data reported in the FSA indicate approximately 320 pounds of TCE were removed from the UAU groundwater in the first 4 years of operation. In 1999, groundwater extraction from 7EX-1UA was integrated into the Area 7 MAU source control Groundwater Extraction and Treatment System (GWETS) and an estimated 40 pounds of additional TCE have been removed from UAU groundwater since that time.

3.2.3 UAU Data Trends

Historical water quality monitoring indicates TCE concentrations in the UAU have declined throughout the Site, even though groundwater elevations have increased significantly over the past 5 years. TCE concentrations are currently low or below the detection limit across broad areas of the UAU, as shown on **Figure 2**. October 2009 data indicate only 5 of the original 65 UAU monitoring wells show TCE concentrations above the cleanup standard of 5 μg/L. The highest remaining TCE concentration is 38 μg/L at PG-31, located southwest of Area 7 (**Figure 2**). Four UAU monitor wells located west of Area 12 have TCE concentrations between 5 and 10 μg/L.

3.2.4 Analysis of Effectiveness of UAU Remedy

UAU groundwater monitoring data demonstrate effective and widespread attenuation of VOC mass within the UAU and progress made to restore the UAU groundwater to drinking water quality by decreasing the COCs to below the cleanup standards (RAO #1). **Figure 3** shows that the total mass of VOCs present in the saturated portion of the UAU has decreased substantially with time, declining from an estimated 11,000 pounds in 1993 to approximately 400 pounds in 2009. The voluntary UAU groundwater extraction program at Area 7 has contributed significantly to VOC mass attenuation, as indicated by reduction in TCE concentrations at 7EX-1UA from approximately 10,000 in 1994 to less than 5 μg/L in October 2009. Consistent with the site conceptual model, the remaining VOC mass in the UAU has largely migrated into the LAU via the southwest margin, as conceived in the OU2 ROD, for extraction and treatment in the LAU.

It should be noted that data shown on **Figure 3** also reflect the presence of tetrachloroethene (PCE) in the UAU in the vicinity of monitoring well PG-4UA. As noted in annual Site Monitoring Reports (SMRs), the PCE mass present in the vicinity of PG-4UA represents a significant component of the remaining VOC mass in the UAU. PCE observed at PG-4UA is not correlated to NIBW sources but appears to be associated with a nearby dry-cleaning facility.

3.3 MAU SOURCE CONTROL REMEDIATION

3.3.1 MAU Source Control Performance Standards and Measures

RAOs were not specifically established for the MAU source control remediation. The OU1 ROD anticipated that TCE in MAU groundwater originating from Area 7 and Area 12 would be extracted by MAU/LAU groundwater extraction wells and treated at the Central

Groundwater Treatment Facility (CGTF). However, to enhance the required remedy and more quickly remove VOCs from MAU groundwater at the principal source areas, Siemens and Motorola voluntarily installed GWETSs at Area 7 and Area 12, respectively. The amended ROD adopted the Area 7 and Area 12 MAU source control programs as required actions and Groundwater Containment Performance Standards for Area 7 and Area 12 are specified in Section III.A of the SOW (page 3). The two principal performance standards for the MAU include:

- Reduce VOC mass in MAU groundwater at Area 7 and Area 12 and achieve an overall reduction in concentrations of COCs; and
- Prevent migration of groundwater having locally higher COC concentrations at source areas to the southwest margin.

Performance measures associated with the MAU source area programs are given in Section 4.4 of the GMEP (page 47) and generally consist of:

- Monitoring of water quality and tracking of data trends to demonstrate mass removal within the zones of hydraulic containment at Area 7 and Area 12; and
- Measurement of water levels to estimate the extent of hydraulic capture associated with Area 7 and Area 12 GWETSs.

3.3.2 Summary of MAU Source Control Remedial Operations

Groundwater extraction and treatment for MAU source control were initiated at Area 7 and Area 12 in 1999. **Figure 4** provides annual totals for TCE mass removed from the MAU groundwater by the Area 7 and Area 12 GWETS. To date, a total of 1.9 billion gallons of MAU groundwater have been pumped and treated at Area 7 from 1999 to 2009, resulting in removal of nearly 14,000 pounds of TCE. At Area 12, 4.5 billion gallons of

MAU groundwater have been pumped and treated from 1999 to 2009, resulting in removal of nearly 4,400 pounds of TCE.

3.3.3 MAU Data Trends

Water level data generated from the MAU monitor well network are evaluated to interpret patterns of groundwater flow and estimate the extent of groundwater capture associated with the Area 7 and Area 12 MAU source control programs. The estimated extents of hydraulic capture at Area 7 and Area 12 based on these data are shown on **Figure 5**. Also shown on **Figure 5** are trends in TCE concentrations from MAU monitor wells PG-12MA and E-5MA, which are located near the downgradient extent of capture from Area 7 and Area 12, respectively. TCE concentrations at these monitor wells are declining as a result of the containment and removal of source area TCE mass by the Area 7 and Area 12 source control programs.

TCE concentrations at MAU extraction wells are also instructive in evaluating progress of the source control remedial actions. Average annual TCE concentrations in Area 7 and Area 12 MAU extraction wells are shown on **Figures 6 and 7**, respectively. Declining concentration trends at these extraction wells demonstrate significant and generally consistent progress.

3.3.4 Analysis of Effectiveness of MAU Source Control Remedy

Monitoring of MAU groundwater conditions has broadly demonstrated achievement of performance standards. It is readily evident that the Area 7 and Area 12 MAU source control programs, which have removed over 18,000 pounds of TCE mass, satisfy the most important aspect of the SOW performance standards, which "is to minimize the total amount of NIBW COCs that are allowed to migrate toward the southwest margin" (SOW at page 3). Declining TCE trends at monitoring wells such as PA-12MA (southwest of Area 7) and

E-5MA (west of Area 12) further demonstrate that the MAU source control programs are preventing migration of locally higher TCE concentrations at the source areas to the southwest margin (**Figure 5**). Water level contour maps, provided in annual SMRs, demonstrate achievement of the second component of the MAU source control performance evaluation, hydraulic containment of the plume areas where TCE concentrations are largest. Pumping at Area 7 and Area 12 remedial extraction wells has consistently prevented migration of VOCs from the locally higher concentration source zones to the southwest margin.

3.4 MAU/LAU Groundwater Remediation

3.4.1 MAU/LAU Performance Standards and Measures

Two RAOs specifically relate to the MAU and LAU groundwater remediation program at the Site:

- Restore the Middle and Lower Aquifers to drinking water quality by decreasing the COCs to below the cleanup standards (RAO #1), and
- Achieve containment of the groundwater contamination plume by preventing any further lateral migration of contaminants in groundwater (RAO #4).

According to the SOW, the MAU/LAU remedial action is required to provide sufficient hydraulic control by groundwater extraction within existing MAU/LAU plumes to prevent migration and impacts to peripheral production wells at levels in excess of groundwater cleanup standards. Further, the SOW requires demonstration that MAU contamination outside the source areas at Area 7 and Area 12 is declining over time.

Criteria to demonstrate performance of the MAU/LAU groundwater remediation program are specified in the GMEP. Section 4.2 of the GMEP specifies criteria to demonstrate overall containment of the MAU and LAU plumes throughout the Site. Section 4.3 of the GMEP is more specifically focused on demonstration of capture of the LAU plume in the northern portion of the Site.

3.4.2 Summary of MAU/LAU Remedial Operations

Groundwater extraction and treatment for MAU/LAU remediation began in 1994 when the CGTF became operational. Since that time over 50 billion gallons of groundwater have been pumped and treated at the CGTF, resulting in removal of an estimated 47,000 pounds of TCE. The Miller Road Treatment Facility (MRTF) began operations in 1997 and has treated over 22 billion gallons of groundwater and removed an estimated 5,600 pounds of TCE. **Figure 4** provides annual totals for TCE mass removed by groundwater extraction and treatment at the CGTF and MRTF, along with the Area 7 and Area 12 GWETSs.

3.4.3 MAU/LAU Data Trends

Water level and water quality data to evaluate MAU and LAU groundwater remediation effectiveness are obtained from a network of 79 monitoring wells, including 43 upper MAU monitor wells, 6 lower MAU monitor wells, and 30 LAU monitor wells (GMEP, Table 2).

As described in Section 3.3.2, hydraulic containment of the MAU zone of contamination is assessed by water level monitoring at area-wide MAU monitor wells and water quality monitoring of MAU indicator wells on the periphery of the Area 7 and Area 12 MAU plumes. Water quality data obtained from the MAU indicator monitor wells are tabulated in the annual SMRs and represented on plume maps that are compared each year with the 2001 MAU plume map to evaluate lateral migration[3].

Hydraulic containment of the LAU plume is assessed by water level monitoring at area-wide LAU monitor wells and water quality monitoring of LAU indicator wells on the periphery of the LAU plume. Maps depicting patterns of groundwater movement in the LAU are shown in annual SMRs. Water quality data obtained from the LAU indicator monitor wells are tabulated in the annual SMRs and represented on plume maps that are compared each year with the 2001 LAU plume map to evaluate lateral migration[4].

Hydraulic containment of the northern LAU plume groundwater is assessed by quarterly (and more frequent) monitoring of water levels and water quality data in select LAU indicator wells in the northern LAU. These data are presented in annual SMRs[5] (2009 SMR see Figure 26).

Effective removal of TCE mass in LAU groundwater is evident in annual average TCE concentration trends compiled for key extraction wells along the center-line of the LAU plume, as shown on **Figures 8 and 9**. Specifically, the trends indicate declining TCE concentrations in extraction wells COS75A and COS72, relatively stable concentrations in extraction well PCX-1, and slightly increasing concentrations in extraction well AAW-15. The observed trends in TCE concentration in these extraction wells are consistent with expectations based on the overall plume configuration and hydraulic effects of pumping.

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[3] See Figure 15 of 2009 Site Monitoring Report
[4] See Figure 16 of 2009 Site Monitoring Report
[5] See Figure 26 of 2009 Site Monitoring Report

3.4.4 Analysis of Effectiveness of MAU/LAU Remedy

The NIBW groundwater remedy has resulted in hydraulic containment of the MAU and LAU plumes and significant progress in removing VOC mass and reducing VOC concentrations to restore MAU and LAU groundwater to drinking water quality.

Water level data indicate groundwater movement within the MAU and LAU plumes is consistently toward extraction wells connected to treatment, with no substantive migration of groundwater from the MAU and LAU plumes to peripheral production wells outside of the plumes which are not currently connected to an existing treatment facility. Water quality data obtained from key indicator wells generally show expected TCE concentration trends that demonstrate that the remedy, when operated as conceived in the amended ROD, provides effective mass removal and capture of the MAU and LAU plumes.

The NIBW groundwater remedy has made significant progress toward restoring water quality in the MAU and LAU by removing an estimated 70,000 pounds of TCE through the combined groundwater extraction and treatment at the CGTF, MRTF, Area 7, and Area 12. In particular, monitoring of LAU water quality withdrawn at CGTF extraction wells reveals systematic and substantial reductions in TCE concentrations in the southern and central portion of the LAU plume. Consistent operation of CGTF extraction wells for the past 15 years has captured and limited the migration of higher TCE concentrations to the northern LAU extraction wells connected to the MRTF. Data trends further indicate PCX-1 captures the bulk of TCE in the northern LAU and substantially limits the impact to other Arizona American Water Company (AAW) wells connected to the MRTF, as demonstrated by the low TCE concentrations at wells AAW-14 and AAW-15 shown on **Figure 10**.

4.0 PROJECTION OF FUTURE REMEDY PERFORMANCE

The previous section of the memorandum demonstrated that historical operation of the groundwater remediation systems has achieved site-specific RAOs and performance standards. This section summarizes results of analyses conducted using groundwater flow modeling and other analytical approaches to demonstrate that continuation of current remedial operations into the future is projected to achieve hydraulic capture of the TCE plumes in UAU, MAU, and LAU groundwater and result in significant progress toward restoration of groundwater resources in the project area in accordance with RAOs.

4.1 GROUNDWATER FLOW MODELING

This section presents a concise summary of the development and use of the original FSA groundwater model and the activities associated with updating and recalibrating the groundwater flow component of the model for use in the 5YR. The updated and recalibrated model is designated in this report as the 5YR model. Throughout the 5YR process, information about the 5YR model effort and decisions regarding key model updates were regularly previewed with EPA and their contractor Innovative Technical Solutions, Inc. (ITSI). In addition, the final 5YR model files were provided to ITSI in September 2010. The intent of this technical memorandum is to provide an overview of the modeling conducted for the 5YR; therefore, the narrative summary focuses on important aspects of the update and recalibration process rather than a detailed comparison of the FSA and 5YR model. Additional detailed information on the FSA groundwater model can be found in the Groundwater Model Final Report (NIBW PCs, 1999).

4.1.1 Feasibility Study Addendum Model

The FSA model represented the culmination of a detailed and comprehensive effort to evaluate, interpret, and simulate hydrogeologic and water quality conditions at the NIBW Site. The FSA model was constructed using the MODFLOW^{96} model code (McDonald and Harbaugh, 1996). The model effectively represented key components of the hydrogeologic framework based on detailed field investigations and analyses. It also successfully incorporated the NIBW PCs conceptual understanding of flow and transport processes at the site, developed based on results of long-term monitoring programs. Finally, the rigorous review, vetting, and documentation process that occurred in conjunction with the FSA model development resulted in a final product that not only met or exceeded industry standards but was anticipated to comprise, if updated with new pumping or other site data over time, a reliable tool for helping to evaluate remedy performance.

The FSA model was developed by the NIBW PCs using an independent consultant in a collaborative process that included EPA, Arizona Department of Environmental Quality (ADEQ), the City of Scottsdale (COS), Salt River Project (SRP), the Paradise Valley Water Company (currently AAW), and other stakeholders. Montgomery & Associates, as part of the modeling team, provided critical support to develop the hydrogeologic framework, initial conditions, input parameters, and calibration targets for the model. Model construction and calibration were summarized in the Groundwater Modeling Final Report (NIBW PCs, 1999). Design and assessment of remedial alternatives were summarized in the NIBW FSA, Volume V, Chapter 6 and Appendices L and M (NIBW PCs, 2000).

4.1.1.1 FSA Model Objectives

The objective of the FSA modeling effort was to develop a “predictive and evaluative tool for assisting with the FSA analysis” (NIBW PCs, 1999), which included assessment of capture and containment in MAU and LAU and relative cleanup rates for various remedial alternatives.

4.1.1.2 FSA Model Use

As part of the remedy evaluation process, the FSA model was used to project changes in groundwater flow patterns and TCE distribution resulting from implementation of a range of proposed remedial alternatives. Specifically, the model was used to estimate and compare the projected "reduction in toxicity, mobility, or volume" of impacted groundwater associated with each of the remedial alternatives as part of the National Contingency Plan evaluation process. Model output after a 30-year simulation period was evaluated to provide a relative assessment of remedy performance using the following metrics:

- Completeness of hydraulic capture
- TCE mass removal over time
- Reduction in TCE plume area over time
- Reduction in TCE concentrations over time at individual production and monitor wells
- Number of monitor and extraction wells cleaning up (TCE <5 µg/L) over time

4.1.1.3 FSA Model Limitations and Uncertainties

The FSA model represents a reasonable approximation of hydrogeologic and water quality conditions at the NIBW Site to meet the project objectives. However, the model has the typical limitations and uncertainties that are inherent in any model of comparable scale and complexity. Specific limitations associated with the FSA model were documented in the FSA (NIBW PCs, 2000) and were considered with regard to future use of the model as part of the 5YR process. The model limitations reduce the applicability of the model for projection of long-term aquifer cleanup timeframes, particularly in the MAU.

4.1.2 5YR Model

4.1.2.1 5YR Model Objectives and Limitations

The GMEP framed the planned future use of the FSA model by stating that "Although EPA and the NIBW PCs agree on the need to focus on groundwater monitoring to evaluate the effectiveness of the remedy, modeling analyses and/or updates will be conducted to provide an additional "tool" to ensure that the remedy is working effectively." This statement provides a starting place for establishing the modeling objectives for the 5YR process.

Specifically, the NIBW PCs developed the following objectives for the 5YR modeling:

1. Incorporate updates and conduct calibration as appropriate to ensure that the model continues, in a manner consistent with the FSA model, to achieve the following:
   a. Match observed flow gradients
   b. Simulate observed water level responses
2. Develop a representative future simulation that can be used to:
   a. Demonstrate hydraulic containment for all units associated with long-term operation of the existing remedy
   b. Project cleanup associated with long-term operation of the existing remedy, focusing on critical areas of the site
3. Develop a basis and process for implementing future updates to the model to ensure that it comprises an effective tool for on-going use, in conjunction with monitoring data, to evaluate remedy performance.

The limitations cited for the FSA model are largely applicable to the 5YR model.

4.1.2.2 Model Update

The original FSA model was updated for use in the 5YR. **Figure 11** shows the model study area. Most of the model updates were focused on incorporating new data obtained during the period 1997 through 2009. The following sections present an overview of the model update process.

4.1.2.2.1 Grid Refinement

The FSA model grid was refined for the 5YR model. **Figure 11** shows the model grid used in 5YR modeling. The smallest node spacing in the refined grid area is 20 feet, compared to 200 feet in this area in the FSA model. The refined portions of the grid are shown on **Figure 11** as the solid gray areas. The objective of the grid refinement was to reduce the node spacing in the area near the northern-most LAU remedial pumping wells, which lie between Jackrabbit, Hayden, Indian School, and Scottsdale Roads. This area of the model is especially important because of its proximity to the leading edge of the TCE plume and water supply wells operated by AAW. In this area, steep hydraulic gradients exist due to the close proximity of the large pumping wells. The refined grid improves approximation of these gradients and associated hydraulic capture compared to the FSA model.

4.1.2.2.2 Boundary Conditions

The 5YR model lateral boundary conditions comprise the following types:

- Layer 1 – northern, eastern, and western boundaries (no-flow); southern boundary (constant head)
- Layers 2 through 10 – northern and southern boundaries (head dependent); eastern boundary (no flow); western boundary (mixed no-flow and constant head)

Like the FSA model, the head dependent boundaries were assigned using MODFLOW's general head boundary (GHB) package. In the 5YR model, the constant head boundaries were assigned using MODFLOW's time-varying constant head boundary package instead of the standard constant head boundary package. The FSA model head values from 1991 through 1996 were revised for the 5YR constant head boundary condition based on measured water level data for that period. Post-1996, the boundary head values for the GHBs and constant head boundaries were developed based on water level data obtained for the period 1997 through 2009. For the GHBs, the methodology for assigning the boundary conductance in the FSA model was retained for the 5YR model.

The extent of no flow boundaries and the model's top and bottom boundaries in the FSA model were retained in the 5YR model.

4.1.2.2.3 Groundwater Pumping

Table 1 summarizes the groundwater pumping rates and **Figure 12** shows the location of pumping wells in the 5YR model. Groundwater pumping was updated in the 5YR model based on actual pumping data obtained from 1997 through 2009. Wells drilled after the 1996 were added to the 5YR model. The methodologies used for simulating conduit wells and for proportioning the well flow rates among the screened zones in the FSA model were retained for the 5YR model.

4.1.2.2.4 Recharge

The recharge rates from natural and artificial sources on residential, recreational, commercial/industrial, and agricultural land and from canal leakage used in the FSA model were retained for the 5YR model. Recharge from the Salt River was simulated using the same assumptions in the FSA model and updated based on water release data from Granite Reef Dam for the period 1997 through 2009. Recharge from the City of Mesa Recharge Basins was added to the 5YR model. Although the City of Mesa started recharging water in 1990, the City was unable to provide records of recharge volumes until 1998.

Tempe Town Lake was constructed after the FSA modeling effort and is located within the model area. The Lake is constructed in a portion of the Salt River and is composed of an 8-foot thick soil cement base with impermeable edges. The east end of the Lake has a seepage recovery system with 10 recovery wells that pump the water back into the Lake. Due to its construction and recovery system, very little recharge is suspected to occur from the Lake, and therefore recharge was not simulated from the Lake in the model.

4.1.2.3 Model Calibration

The 5YR groundwater flow model was calibrated to water level data obtained from monitor wells screened in the UAU (layer 1), MAU (layer 3), and LAU (layer 6) during the period 1991 through 2009. The calibration process included comparison of projected and measured water levels at 125 monitor wells (also designated as water level targets) to evaluate the adequacy of calibration. Water level data for each target were developed by averaging the water level data from each year for each monitor well over the 19-year calibration period.

The calibration goals for the 5YR model were similar to those established in the FSA model. In general, the FSA and 5YR models were deemed acceptably calibrated when the simulated results matched the measured data within an acceptable measure of accuracy, and when successive calibration attempts did not notably improve the calibration statistics. An additional calibration goal for the 5YR model was to achieve a relatively unbiased model-wide scaled root mean squared error (RMSE) between projected and measured water levels of less than 10 percent over the entire calibration period. The scaled RMSE was computed as the RMSE divided by the difference between the highest and lowest water level elevations during the calibration period.

The calibration goals for the 5YR model were largely met after completing the model update. This calibration outcome indicates that the original FSA model was well constructed and calibrated. A reasonable match between projected and measured water levels and a model-wide scaled RMSE of less than 10 percent were achieved without significant changes to the calibrated horizontal and vertical conductivities, storage parameters, and recharge rates from the FSA model. Slight revisions to the layer 3 horizontal and vertical hydraulic conductivities were made to improve the calibration in the area of the operating source control extraction wells in the MAU.

Figure 13 shows a graph of projected versus measured water levels at targets in layers 1, 3, and 6 for the entire calibration period. This graph provides a concise overview of the model calibration and indicates that a relatively good correlation between projected and measure water levels was achieved. The model-wide RMSE was about 8.9 feet with a scaled RMSE of 3.2 percent. The latter calibration measure is well within the calibration goal of 10 percent. Based on the model information exchange during the 5YR process, collaborative agreement was reached between the PCs and ITSI that an acceptable model calibration for the 5YR had been achieved.

4.1.2.4 Recommended Pumping Regime

As discussed below in Sections 4.2 and 4.3, the calibrated model was used to project the extent of hydraulic capture of the remedial pumping wells and to estimate the timeframe required to reduce TCE concentrations to less than cleanup goals in the remedy extraction wells (i.e., cleanup time). These capture and cleanup simulations required the development of a future pumping regime that reflects operation of the existing remedy under conditions that are expected to exist in the model area over the next several decades. **Table 1** presents the future estimated pumping rates for all extraction wells in the model area. These pumping rates were developed based on current pumping rates, historical pumping rates, and information provided by well owners regarding anticipated future changes. For the remedy extraction wells, the future pumping rates also represent recommended pumping rates needed to maximize hydraulic capture and remedy effectiveness. Not only are the assigned pumping rates achievable for the remedy extraction wells into the future, but they are generally consistent with current pumping rates (**Table 1)**.

4.2 PROJECTED CAPTURE UNDER RECOMMENDED PUMPING REGIME

The calibrated flow model was used in conjunction with the particle tracking software package MODPATH (Pollock, 1994) to project the capture zones for the remedy wells in the MAU and LAU under the recommended pumping regime. Capture was not projected for the UAU because remedial pumping in this layer is not significant. The recommended pumping regime discussed in Section 4.1.2.4 was assumed to remain constant during future remedial operations. Reverse particle tracking was used to project capture zones. The objective of the reverse particle tracking simulations was to estimate the lateral extent of capture in the MAU and LAU to evaluate whether RAOs and performance standards are being achieved.

4.2.1 Middle Alluvium Unit

The overarching RAO in the MAU is to hydraulically contain TCE mass concentrated at the Area 7 and Area 12 source areas and to allow groundwater containing smaller concentrations of TCE outside of these areas to migrate via the southwest margin into the LAU, where it is captured at LAU extraction wells. Under the recommended pumping regime, the simulated pumping rates for MAU (model layer 3) at the NIBW extraction wells are as follows:

- Area 7 – 7EX-3MA (137 gpm), 7EX-4MA (53 gpm), 7EX-5MA (162 gpm), COS71 (360 gpm), and COS72 (288 gpm); total rate (1,000 gpm)
- Area 12 – MEX-1MA (346 gpm) and 23.6E6N (186 gpm); total (533 gpm)

These pumping rates represent the portion of the total well pumping rate that was estimated to come from the primary impacted zone in the MAU (model layer 3) based on fluid movement studies conducted at the site. The total simulated remedy pumping in layer 3 is estimated to be just over 1,500 gpm. Well COS31 is not included in the capture evaluation, as it is outside the 2009 MAU TCE plume representing conditions in layer 3.

Figure 14 depicts the projected capture zones for the MAU remedy wells. The extent of capture resulting from the combined operation of remedy extraction wells in and south of Area 7 is projected to encompass and extend beyond the zone of highest TCE concentrations (greater than 500 µg/L) near the source area. Similarly, the extent of capture resulting from the combined operation of remedy pumping wells in Area 12 is projected to encompass the zone of highest TCE concentrations (between 50 and 100 µg/L) near that source area. Based on these projections, continued operation of the Area 7 and Area 12 source control programs at current pumping rates is estimated to result in capture zones that are consistent with the RAOs of MAU source control into the future.

4.2.2 Lower Alluvium Unit

The overarching RAO in the LAU is to hydraulically contain TCE-impacted groundwater to protect the northernmost AAW water supply wells that are not tied into treatment. Under the recommended pumping regime, the simulated pumping rates for the LAU (layer 6 only) remedy wells are as follows: COS31 (82 gpm), COS71 (418 gpm), COS72 (684 gpm), COS75A (450 gpm), PCX-1 (983 gpm), AAW-14 (821 gpm), and AAW-15 (888 gpm). These pumping rates represent the portion of the total well pumping rate that was estimated to come from the primary impacted zone in the LAU (model layer 6) based on fluid movement studies conducted at the site. As with the MAU, site data indicate that mass in the LAU principally exists in the upper portion of the unit defined here as layer 6. The total simulated remedy pumping in LAU layer 6 is estimated to be 4,325 gpm.

Figure 15 depicts the projected capture zones for the LAU remedy wells. The extent of capture resulting from the combined operation of remedy pumping wells PCX-1, AAW-14, and AAW-15 is projected to encompass the leading edge of the TCE plume, which would prevent further downgradient migration towards the northernmost AAW water supply wells. Further, the capture zone of PCX-1 is projected to hydraulically contain the zone of highest TCE concentrations (greater than 100 ug/L) in the LAU. The capture zone of extraction well COS75A is projected to be effective at containing higher TCE concentrations the southern and eastern portion of the LAU plume. The capture zones at remedy wells COS71 and 72 are projected to hydraulically contain most of the remaining southern portion of the LAU plume and the area near the southwest margin. Remedy well COS31 is located near the eastern edge of the TCE plume and therefore only provides nominal benefit to the overall LAU groundwater remedy. Based on these results, continued operation of the LAU extraction wells at current pumping rates is estimated to result in capture zones that are consistent with the RAO of plume containment into the future.

4.3 PROJECTED CLEANUP TIMES

Under CERCLA, 5YRs are conducted to evaluate the implementation and performance of a remedy to determine if it is protective of human health and the environment. The protectiveness of the remedy is evaluated by determining if it is performing as intended by the decision documents for the site, in this case the AROD for the NIBW Superfund site.

One of the RAOs for the NIBW site is to "restore the Upper, Middle, and Lower Aquifers to drinking water quality by decreasing the concentrations of the contaminants of concern to below the cleanup standards." Timeframe to achieve restoration was not specified as an RAO for the site. However, the AROD notes that the "expected outcome" of the selected remedy is "restoration of the aquifer to beneficial use (drinking water source) after cleanup levels for the contaminants of concern are achieved in an estimated 50+ years."

To evaluate remedy performance in relation to the AROD expected outcome of a 50+ year aquifer restoration timeframe, the EPA requested that the NIBW PCs include a cleanup time assessment in the 5YR. The approach, which was developed in conjunction with discussions between the PCs, EPA, and ITSI during monthly 5YR coordination meetings, combines modeling, observed concentration data, and assumptions regarding transport processes occurring at the site to evaluate cleanup time. The primary focus of the analysis, as discussed and approved by EPA, is estimation of cleanup time for each of the extraction wells tied into treatment in the LAU to drinking water standards. Secondarily, qualitative assessments of cleanup time in the UAU and MAU were made to support the 5YR.

4.3.1 Previous Cleanup Time Estimates

The reference in the AROD to a 50+ year timeframe for aquifer restoration is tied to groundwater flow and TCE transport modeling conducted as part of the FSA process. Specifically, 95 percent of the mass in the NIBW groundwater system was projected to be removed after 50 years of extraction and treatment in accordance with provisions of the selected remedy for the site (Alternative 3A).

4.3.2 Cleanup Time Estimates for 5YR

To meet the requirements of the 5YR, quantitative estimates of cleanup time were developed for the UAU and LAU and a qualitative assessment of cleanup times was developed for the MAU. The quantitative cleanup time estimate for the UAU was based on an empirical approach as discussed below. The quantitative cleanup time estimate for the LAU was based on a combination of modeling and use of an empirical approach. A quantitative approach was deemed inappropriate for estimating cleanup time in the MAU, as discussed further below. Instead, a qualitative assessment of cleanup time for the MAU was developed based on knowledge of aquifer characteristics and remedial operations, as well and an evaluation of water quality data, as discussed in Section 3.0.

4.3.2.1 Lower Alluvium Unit

The 5YR groundwater flow model, which was updated and recalibrated as part of the 5YR process, was used to estimate cleanup times for the LAU remedy wells with persistent concentrations greater than the cleanup goal (i.e., PCX-1, COS71, COS72, and COS75A). Analyses were focused on the timeframe for capture of groundwater in the LAU (model layer 6) in the area where TCE concentrations exceed 5 µg/L. As indicated above, cleanup estimates for the 5YR are focused on time to restore LAU groundwater extracted by the remedy wells to drinking water standards. Layer 6, the uppermost LAU layer in the model, was used as a surrogate for cleanup of the entire LAU because site investigations indicate that mass is principally concentrated in the upper portion of the unit.

An analytical method recommended by ITSI and approved by EPA was used to estimate cleanup times for remedial action extractions wells that produce part or all of their water from the LAU. This analytical approach is derived from what are commonly referred to as “Batch Flush” or “Mixed-Reactor” models. The models are simplified representations of the processes that control aquifer cleanup and assume that the contaminant is uniformly mixed in the target cleanup zone (Brusseau, 1996). Using this approach, cleanup time can be estimated by solving the following equation (Zheng, Bennett, and Andrews, 1991):

$$t_c = PV * t_{pv}$$

where t_c is cleanup time, PV is the number of pore volumes of clean water required to flow through the impacted area to reduce concentrations to a specified cleanup goal, and t_{pv} is the time required for one pore volume to flow through the impacted area. In this case, the impacted area for each well corresponds to the portion of the well’s capture zone that lies within the LAU TCE plume, as defined by the 5 µg/L concentration contour for October 2009. A particle path modeling approach, using the 5YR groundwater flow model, was applied to estimate t_{pv} for each extraction well by evaluating travel time associated with a representative maximum flow path from the upgradient edge of the plume. The number of pore volumes required to achieve cleanup goals within the capture zone of each well, PV, was calculated using the following equation:

$$PV = - R * \ln(C_s/C_i)$$

where R is the retardation factor, C_s is the cleanup standard, and C_i is the initial groundwater concentration. To be consistent with original FSA model, a retardation factor of 1 was assumed in the LAU for pore volume calculations. The federal Maximum Contaminant Limit for TCE of 5 µg/L was assigned as the cleanup standard for extracted groundwater from the LAU, C_s, for the pore volume calculations. Initial TCE concentrations were selected for each well based on the average of observed concentrations within the well's capture zone.

Using average concentrations to compute the number of pore volumes required to reach cleanup standards is consistent with the assumption of uniform mixed concentrations in the cleanup zone made in the "batch flush" or "mixed-reactor" models. The average initial concentration was generally estimated based on observed TCE concentrations within the capture zone of each remedial action extraction well, as defined by the October 2009 data. Where multiple monitor wells were located within an extraction well's capture zone, the average initial concentration was calculated as the average of all available concentration data points. Where multiple monitor wells were not available, the average initial concentration within a well's capture zone was estimated from TCE contours. **Table 2** shows results of calculations for the number of pore volumes required to achieve cleanup standards for each of the extraction wells evaluated.

TABLE 2. CALCULATED PORE VOLUMES

	Average Concentration		
Well	**Source**	**Ci (µg/L)**	**PV**
PCX-1	Average	77	2.7
COS75A	Average	85	2.8
COS71	Contour Estimate	25	1.6
COS72	Average	33	1.9

As indicated above, the time required to flush clean water through one pore volume of the impacted portion of each capture zone, t_{pv}, was estimated using the calibrated 5YR model. The particle tracking model MODPATH was used to estimate capture zones and travel times along particular flow paths. The following process was followed:

1. A predictive transient flow simulation was run to project future groundwater levels in the project area during plume cleanup. For this simulation, it was assumed that all extraction wells tied into treatment were operated at the recommended pumping rates and that all other wells were operated at representative long-term rates, as discussed in Section 4.1.2.4. The future pumping rates were assumed to remain constant during the entire cleanup period.

2. As previously discussed in Section 4.2.2, capture zones for each of the extraction wells tied into treatment and pumping part or all of their water from model layer 6 (upper LAU) were delineated based on the projected future water levels using the particle tracking model MODPATH. The resulting capture zones are presented on **Figure 15**.

3. The longest representative travel time for an individual particle from the upgradient plume edge to each of the extraction wells was identified based on the particle tracking results, as shown on **Figure 16**. It was assumed that this travel time was equivalent to the time required to flush one pore volume through the impacted area within each capture zone, t_{pv}. **Table 3** presents the estimated pore volume flush times for each remedy extraction well evaluated.

TABLE 3. ESTIMATED PORE VOLUME FLUSH TIMES

Well	Pore Volume Flush Time, t_{pv} (years)
PCX-1	26
COS75A	15
COS71	7
COS72	7

Table 4 presents the projected cleanup times for the various LAU extraction wells estimated using the methodology described above.

TABLE 4. PROJECTED CLEANUP TIMES

Well	Cleanup Time, t_c (years)
PCX-1	70
COS75A	41
COS71	11
COS72	13

The overall range in projected cleanup times for individual LAU extraction wells is from 11 to 70 years. The shortest cleanup times are projected for COS71 and COS72 because they are located in the upgradient portion of the October 2009 TCE plume (**Figure 15**). Two things should be noted in considering cleanup time estimates for wells COS71 and COS72. First, these wells are completed in both the MAU and the LAU, and estimate provided here are only for the LAU portion of the aquifer at these well. Second, COS71 and COS72 also capture TCE mass moving into the LAU from overlying units at the southwest margin. Because this mass migration (particularly from the MAU) is anticipated to continue for more than the projected cleanup times of 11 and 13 years for wells COS71 and COS72, respectively, actual time to reach cleanup goals is anticipated to be longer than projected. Well PCX-1 is projected to have the longest cleanup time. A longer estimated cleanup time is projected for PCX-1 because it is located along the plume axis in the downgradient portion of the plume. The projected cleanup time for well COS75A is consistent with the cleanup time estimated by extrapolating the decreasing trend in measured TCE concentrations at this well, as described above.

LAU cleanup time estimates using the approach outlined above should be viewed in relation to the following assumptions, some of which would be anticipated to extend and others of which might shorten actual cleanup times:

1. TCE mass contribution to the extraction wells from other layers is ignored
2. The upper LAU (model layer 6) contains the majority of TCE mass in the LAU and will control the LAU cleanup time
3. TCE concentrations in the upper LAU (layer 6) monitor wells reflect maximum concentrations
4. No additional mass is being added to the LAU plume
5. TCE transport in LAU groundwater occurs at the same rate as groundwater flow (i.e., no retardation)
6. Reductions in TCE concentration in the extraction wells due to dilution from pumping clean water (either from outside the LAU plume or other layers) is ignored
7. The pumping regime will remain constant over the cleanup period

Historical monitoring of TCE concentrations and evaluation of data trends at COS72 and COS75A, as shown on **Figure 8,** provide an independent line of analysis to estimate LAU cleanup time. For example, observed data trends determined by depth-specific sampling at COS72 indicate TCE concentrations in the LAU declined from over 250 to 50 µg/L in the first 10 years of well operation. Extrapolating a best-fit exponential trendline to these historical data result in a projected cleanup time of 16 years for LAU groundwater at COS72, as shown on **Figure 17**. TCE concentrations at COS75A have also declined significantly from over 200 to approximately 100 µg/L in the past 7 years. Extrapolating a best-fit exponential trendline to these data result in a projected cleanup time for LAU groundwater of about 40 years at COS75A, as shown on **Figure 18**. In both cases, data trending provides estimates of cleanup time that are consistent with the batch flush method. TCE concentrations at well PCX-1 are relatively stable and therefore cannot be extrapolated to estimate cleanup time.

4.3.2.2 Upper Alluvium Unit

TCE concentrations in the UAU have declined significantly over the past decade due to successful operation of soil vapor extraction remedies in the source areas and groundwater extraction at Area 7. The TCE concentrations in groundwater in 2009 in the UAU were generally less than cleanup standards, with the exception of two localized areas located downgradient of the source areas, where concentrations range from just above 5 ug/L to a maximum of 38 ug/L. In general, TCE concentrations in the UAU are expected to continue declining via natural attenuation processes as these localized areas of TCE impacted groundwater migrate towards the southwest margin. Using the empirical batch flush model equation discussed above, the time required for concentrations in the UAU groundwater to attenuate to cleanup standards was estimated to be on the order of a decade.

4.3.2.3 Middle Alluvium Unit

The MAU is composed of a heterogeneous mixture of fine and coarse grained sediments. Under these conditions, the rate of groundwater cleanup is largely controlled by the rate-limiting process of mass diffusion from low-flow pore space in the fine grained matrix to the active flow paths in the coarse grained matrix. The quantitative, batch flushing method used for estimating cleanup time for the UAU and LAU is inappropriate for conditions in the MAU because it does not account for this rate-limiting diffusion process. It assumes a simple model of advective groundwater flow from the edges of the plume through a relatively homogeneous porous medium toward remedial extraction wells. Since mass diffusion from fine to coarse interbeds is expected to be the dominant process influencing the rate at which COCs decrease to below performance standards in the MAU, it is clear that the batch-flushing methodology would not produce a meaningful cleanup time estimate for this unit. In addition, review of the literature and various reports prepared for 5YRs at other sites did not reveal an alternate method that would account for the processes occurring in this unit. Therefore, with concurrence from EPA, a qualitative assessment of cleanup time was conducted for the MAU.

While timeframe for cleanup in the MAU is anticipated to be longer than for other portions of the Site, review of water quality and mass removal data indicate that significant and consistent progress is being made toward achievement of RAOs in the MAU. These data support a conclusion that substantial progress toward MAU cleanup is expected to occur during the 40 to 70 year cleanup timeframe estimated for extraction wells COS75A and PCX-1, respectively, in the LAU.

The NIBW PCs are committed to continuing to provide a critical review of site water level, water quality, and mass removal data. Insights gleaned into MAU cleanup processes and rates will be used to provide an updated assessment of progress toward MAU cleanup during the next 5YR. In addition, if applicable examples of cleanup time estimation approaches for sites with similar hydrogeologic conditions become available, the potential application of these approaches to the MAU at the NIBW site will be considered.

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TABLE 1. ANNUAL GROUNDWATER PUMPING, NIBW SITE 5YR MODEL

PRODUCTION WELL	ADWR REGISTRATION NUMBER	MODEL SCREENED LAYERS	GROUNDWATER PUMPING, IN GALLONS PER MINUTE																		
			1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	FUTURE
COS23	55-626823	4 through 10	226	222	172	322	287	245	263	368	48	292	510	399	204	0	163	512	452	215	336	306
COS26	55-626825	5 through 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MATTHEWS	55-611310	3 through 4	4	0	0	4	4	4	0	0	0	0	4	4	0	4	4	4	4	4	4	3
MARKLAND5	55-612419	3 through 8	20	17	30	73	73	73	111	43	286	149	243	86	37	41	60	38	63	103	61	81
COP235	55-626627	3 through 5	376	276	574	85	629	506	1,051	850	652	738	988	722	612	524	660	972	755	481	678	738
GAINEYTRUST	55-612421	1 through 3	13	8	10	11	9	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GAINEY	55-612418	1 through 5	23	23	27	39	30	30	78	37	51	41	210	72	41	41	44	46	57	34	44	64
MERRILL	55-617892	3 through 6	139	149	149	138	148	144	-44	-17	0	0	9	0	0	0	0	0	0	0	0	0
CAMELBACK	55-627600	7 through 10	905	688	844	1,069	1,174	1,037	817	767	679	975	869	1,006	1,036	968	867	932	923	898	918	947
BERNEIL5	55-609543	2 through 7	32	31	0	15	7	6	0	20	2	1	1	0	0	1	0	0	0	0	0	0
BERNEIL	55-554073	3 through 8	0	0	0	0	0	55	296	272	264	196	245	297	184	221	298	328	365	347	312	269
MRG1	55-603867	4 through 9	173	245	259	238	305	330	290	214	240	286	326	299	302	265	307	273	278	246	274	291
MCCORMICK	55-608895	7 through 10	272	207	301	288	304	296	299	271	282	263	237	291	221	188	239	273	0	250	247	219
MRG4	55-603870	4 through 8	352	288	404	578	565	519	434	429	382	444	450	419	414	412	396	455	537	464	453	441
MRG2	55-603868	1 through 4	145	20	64	19	12	7	17	39	73	16	6	9	13	17	28	25	9	0	16	16
COS11	55-626814	6 through 10	757	527	530	808	481	476	471	604	572	777	577	425	634	582	465	5	0	0	0	0
COS12	55-626815	4 through 10	218	340	373	566	456	429	777	930	1,009	1,166	895	1,034	957	1,003	817	6	0	0	0	0
MRG3	55-603869	4 through 8	323	225	347	340	241	276	399	357	344	403	360	424	355	387	326	279	340	286	324	355
COS13	55-626816	9 through 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HAWN	unknown	3 through 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COS10	55-626813	3 through 4	155	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COS9	unknown	1 through 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COS14	55-626817	3 through 8	222	137	408	605	653	505	455	437	584	755	173	0	0	0	0	0	0	0	0	0
RADISSON	55-609565	1 through 4	0	11	6	10	5	7	18	13	14	3	6	10	3	3	3	0	0	0	1	3
EQUE	55-625129	2 through 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COS5E/23.4E10.6N	55-617829	4 through 8	966	1,075	1,100	1,253	1,262	1,441	1,377	1,483	1,584	1,078	747	530	895	1,097	57	0	0	0	0	655
COS5W/23E10.8N	55-617844	4 through 6	262	116	13	65	219	14	30	11	295	666	643	282	851	333	27	40	228	0	0	586
24E10.5N	55-607710	2 through 8	215	6	1,100	216	31	233	4	5	726	895	778	1,172	1,006	815	59	87	359	22	18	521
AAW-17	55-537967	6 through 9	0	0	13	1,361	1,354	1,354	1,725	1,082	681	103	200	110	244	196	73	330	859	1,932	2,469	1,572
AAW-16	55-624809	6 through 10	2,226	1,939	2,152	1,995	1,867	2,031	2,001	1,110	806	1,031	1,330	904	789	609	650	468	1,080	1,581	1,341	578
AAW-6	55-624803	3 through 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AAW-7	55-624804	4 through 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AAW-12	55-624806	5 through 10	150	308	305	376	842	1,459	575	428	605	462	557	512	487	346	362	448	337	791	911	315
AAW-11	55-624805	5 through 10	270	19	12	94	281	365	599	446	908	586	1,031	913	518	604	446	739	452	999	672	440
I207	N/A	1 through 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MOTZ	55-800903	3 through 5	1	0	1	1	1	1	1	0	0	0	1	1	1	1	1	1	0	0	0	1
I208B	N/A	1 through 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AAW-14	55-624807	6 through 10	1,326	1,101	1,423	1,275	1,058	738	386	1,112	1,095	975	928	1,129	1,202	1,289	1,469	737	1,204	442	284	1,521

TABLE 1. ANNUAL GROUNDWATER PUMPING, NIBW SITE 5YR MODEL

PRODUCTION WELL	ADWR REGISTRATION NUMBER	MODEL SCREENED LAYERS	GROUNDWATER PUMPING, IN GALLONS PER MINUTE																			
			1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	FUTURE
22.6E10N	55-617843	4 through 8	372	19	9	351	43	190	0	0	497	1,166	1,110	1,330	1,779	1,575	186	196	550	151	119	816
COS4	55-626810	5 through 9	80	75	91	182	107	55	160	278	303	625	784	591	661	586	849	34	0	0	0	275
AAW-15	55-624808	5 through 10	1,156	1,244	1,174	769	389	550	1,197	1,808	2,029	1,896	1,544	1,738	1,936	2,060	2,015	2,030	535	796	1,694	1,974
I217A	N/A	1 through 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
QRIA	55-802113	3 through 6	33	30	26	24	26	27	33	31	38	17	31	29	28	26	25	30	27	28	25	26
AVI7	55-800928	2 through 5	150	150	170	182	174	168	177	152	160	144	151	145	134	149	131	119	104	0	101	133
COS3	55-626809	4 through 8	432	452	708	781	773	614	736	692	496	173	299	272	247	182	309	4	0	0	0	0
23.5E9.5N	55-607716?	6 through 8	0	0	0	0	0	0	0	0	1	224	0	189	57	488	4	4	311	0	4	128
PCX-1/22.5E9.3N	55-564426	6 through 9	0	0	0	0	0	0	1,416	2,225	1,767	2,082	1,350	2,056	1,964	1,907	1,909	2,110	1,871	1,629	1,927	1,927
MWC/MDWC	55-600523	2 through 6	52	53	102	119	112	127	118	114	128	138	113	101	99	87	3	95	95	103	89	92
22.4E09N	unknown	4 through 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SRIRSCC	N/A	4 through 7	164	164	150	175	151	160	148	69	132	149	145	145	124	129	145	157	117	131	142	139
I219A	N/A	1 through 3	0	153	118	175	0	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148
23.5E8.8N	55-607687	3 through 8	126	3	1	5	14	0	0	1	3	252	135	40	405	460	3	6	256	0	3	156
22.1E8.5N	55-607725	3 through 8	281	197	27	150	6	40	0	2	0	929	409	6	0	14	0	0	0	0	0	136
AWC11	55-608785	3 through 8	390	324	370	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AWC12	55-608784	3 through 8	462	347	326	331	626	459	631	518	442	589	628	563	611	595	705	773	772	811	665	671
AWC7	55-608782	6 through 8	147	644	764	807	713	648	363	426	568	581	525	419	436	325	336	86	78	99	120	300
AWC8	55-608781	1 through 8	691	797	782	794	444	649	515	705	608	557	264	532	404	612	559	485	696	672	622	540
COS2	55-626808	4 through 9	476	698	469	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AWC9	55-608783	5 through 8	827	244	186	260	400	430	450	343	317	409	615	406	321	303	254	529	768	422	495	452
AWC8A	55-536833	4 through 7	0	0	0	410	751	505	517	507	517	351	259	430	489	467	298	372	6	213	224	311
COS1	55-626837	1 through 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COS75A	55-546469	6 through 10	0	0	0	0	861	1,515	1,699	1,810	1,581	1,705	1,864	1,591	1,776	1,762	1,782	1,768	1,065	1,562	1,672	2,250
21.5E08N	55-617097	4 through 7	142	5	10	114	33	37	0	2	406	865	471	305	316	483	55	0	0	0	6	250
COS75	55-626541	1 through 8	0	0	10	698	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COS78	55-626537	4 through 8	1,901	1	2	1	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0
COS77	55-626538	4 through 8	0	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COS76	55-626539	4 through 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AREA7	Not Pumping	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0
COS70	55-626544	3 through 8	254	5	82	742	211	105	177	5	0	0	0	0	0	0	0	0	0	0	0	0
7-EX1and2	unknown	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AZCC	55-605798	3 through 4	5	0	1	0	0	0	0	9	9	9	14	8	0	31	0	10	23	0	0	9
7EX3MA	unknown	2 & 3	0	0	0	0	0	0	0	0	25	166	145	122	148	159	138	139	141	122	134	141
7EX4MA	unknown	2 & 3	0	0	0	0	0	0	0	0	24	110	97	57	68	53	36	42	24	23	37	55
COS6/23.3E7.5N	55-607686	1 through 8	298	46	0	68	91	366	320	470	193	118	195	153	263	169	3	3	333	0	0	124
COS74	55-626615	7 through 9	81	72	1,209	1,396	1,570	877	755	1,504	1,747	2,079	2,218	1,909	1,819	2,090	2,230	808	620	607	811	0
I4/SRIR4	N/A	3 through 5	115	15	0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1. ANNUAL GROUNDWATER PUMPING, NIBW SITE 5YR MODEL

PRODUCTION WELL	ADWR REGISTRATION NUMBER	MODEL SCREENED LAYERS	GROUNDWATER PUMPING, IN GALLONS PER MINUTE																			
			1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	FUTURE
COS31/23.3E7.3N	55-608435	3 through 9	0	2	42	1,916	30	2,326	1,853	938	1,744	1,423	1,871	2,076	1,939	984	1,573	1,067	588	1,247	10	371
COS73	55-626540	1 through 9	6	1,235	1,916	6	2	19	6	1	0	0	0	0	0	0	0	0	0	0	0	0
22.3E7N	55-607724	1 through 3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COS71	55-626543	1 through 8	0	0	12	956	447	2,144	1,823	1,802	1,202	1,499	1,928	822	1,455	1,216	738	1,572	937	1,326	1,379	1,440
COS72	55-626542	3 through 7	0	0	9	751	570	1,332	1,260	1,482	1,815	1,453	1,058	1,564	1,067	1,956	1,934	1,765	876	623	2,070	1,800
22.5E06N	55-608432	1 through 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23.6E06N/GR	55-617830	3 & 4	0	0	0	0	0	0	0	0	199	547	331	607	344	82	112	330	85	189	151	278
MEX1MA	55-566405	2 through 5	0	0	0	0	0	0	0	0	65	488	688	432	227	601	590	594	633	771	750	577
I105	N/A	1 through 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I106A	N/A	4 through 5	47	47	47	47	47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I106B	N/A	3 through 5	90	90	90	90	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22.5E5.5N	55-608363	1 through 6	0	0	0	0	0	0	0	0	0	0	235	503	0	0	0	0	0	0	0	74
I10/SRIR10	N/A	1 through 6	91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23.5E5.3N	55-608365	4 through 7	234	6	8	6	9	5	0	66	212	274	241	430	245	486	6	0	150	0	6	184
COS25	55-626824	4 through 7	496	380	93	922	1,050	461	49	17	0	0	12	30	28	29	18	48	30	28	24	25
COT6	55-628167	3 through 6	0	3	5	19	7	127	8	0	0	849	1,397	421	51	0	43	1	0	0	0	9
LAIRD	55-603767	2 through 6	16	3	3	2	3	3	9	3	16	19	0	0	0	0	0	7	7	1	1	4
IBGC	55-527102	1 through 3	133	113	125	127	117	152	144	131	1	54	124	133	120	125	112	121	121	133	113	116
COS69	unknown	1 through 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26E3.9N	55-617842	4 through 8	18	35	54	27	0	306	667	74	928	1,721	948	1,386	1,443	1,382	0	58	864	41	469	930
TRI	55-800535	3 through 4	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KACH	55-800560	4 through 5	0	2	1	2	9	9	6	0	0	2	3	3	0	3	0	0	0	0	0	1
NESB	55-628942	2 through 4	18	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25.5E3.5N	55-617114	1 through 6	340	22	16	15	6	185	576	28	1,547	498	690	1,886	1,040	714	11	0	0	27	241	573
APS-1	55-613078	1 through 5	0	0	0	0	0	0	0	0	0	0	0	0	0	191	0	111	114	25	88	58
APS-3	unknown	5 through 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
APS-2	unknown	4 through 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
APS-4	55-514735	7 through 8	299	405	364	461	395	425	608	739	939	1,246	1,381	651	0	199	0	193	241	173	161	416
COT	55-628165	1 through 3	0	2	1	2	1	0	8	0	0	850	1,398	421	51	0	43	1	0	0	0	276
24.3E03N	55-607744	2 through 7	51	23	16	47	9	29	16	37	21	0	0	0	0	0	0	0	0	0	0	0
25E3.1N	55-607746	2 through 7	186	47	107	182	24	176	403	17	548	1,099	845	1,451	1,413	1,194	64	53	0	23	469	761
7EX-1UA	unknown	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46
7INJ-1UA	unknown	1	0	0	0	0	0	0	0	0	0	0	0	-259	-399	-375	-369	-363	-389	-295	-340	-279
7EX-5MA	unknown	2 through 3	0	0	0	0	0	0	175	175	175	175	175	80	183	163	194	182	196	150	169	167

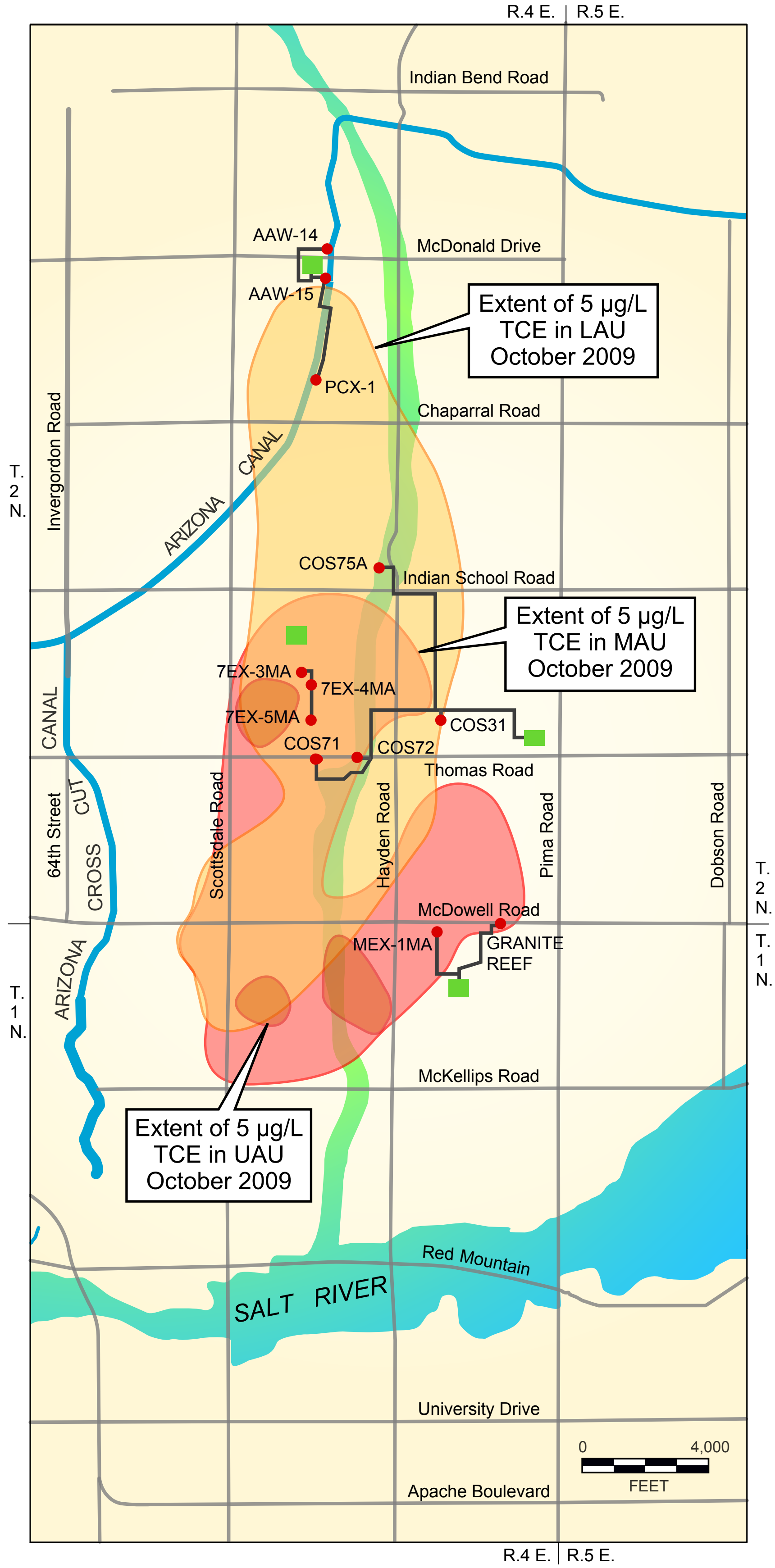
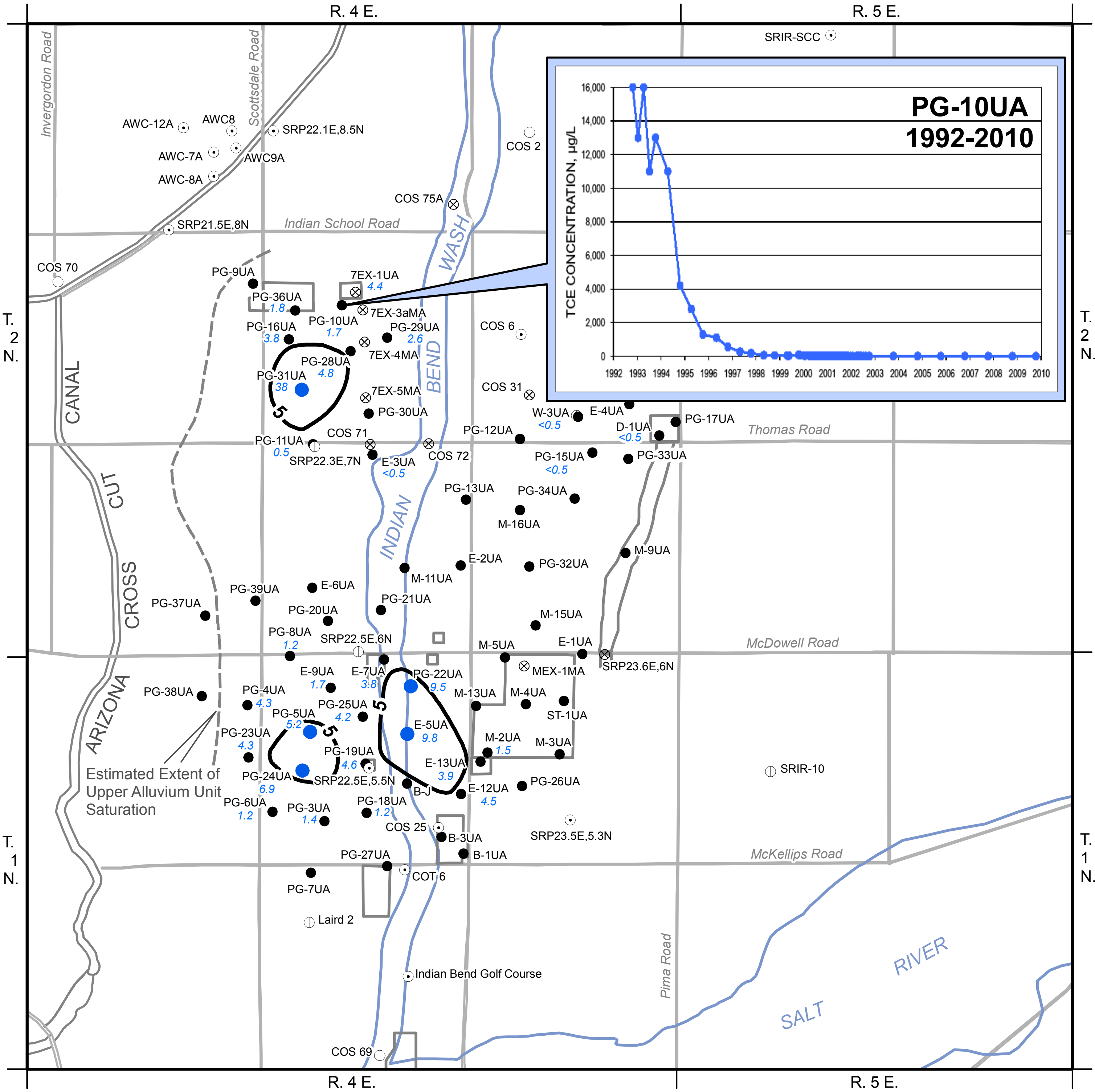


FIGURE 1. TCE PLUMES AND GROUNDWATER EXTRACTION SYSTEMS, NORTH INDIAN BEND WASH SUPERFUND SITE



EXPLANATION

PG-6UA ● 1.2	Upper Alluvium Unit Monitor Well Location and Identifier; Concentration of Trichloroethene, micrograms per liter
E-5UA ●	Upper Alluvium Monitor Well Location and Identifier, where TCE exceeds 5 micrograms per liter standard
COS75A ⊗	Extraction Water Well Location and Identifier
COS74 ⊙	Production Water Well Location and Identifier
SRP22.5E, 6N ⦶	Inactive Production Water Well Location and Identifier
COS69 ○	Abandoned Production Water Well Location and Identifier
—5—	TCE Concentration Contour, in micrograms per liter

0 3,500
Feet

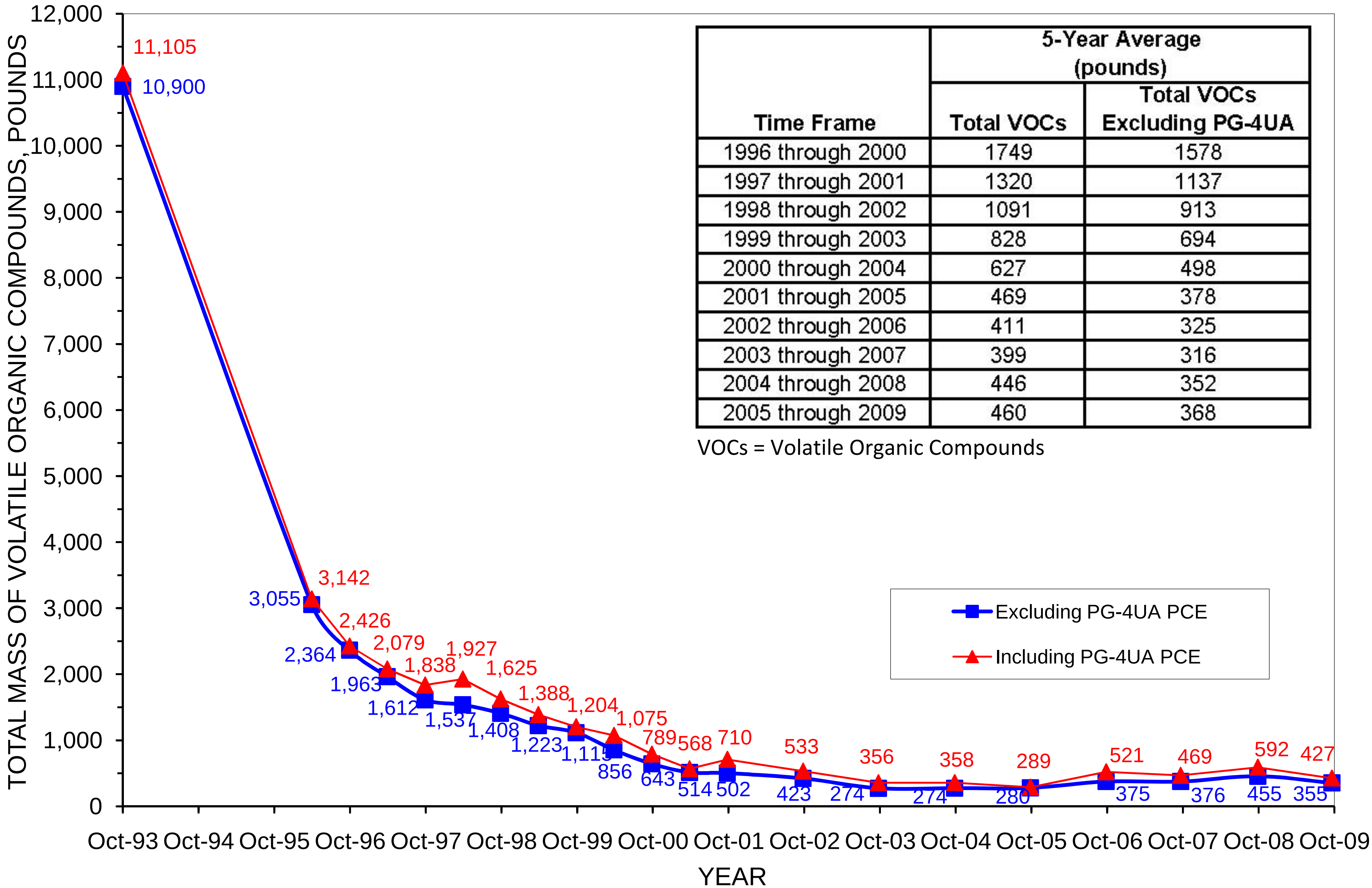
NORTH INDIAN BEND WASH AREA
MARICOPA COUNTY, ARIZONA

TCE CONCENTRATIONS
UPPER ALLUVIUM UNIT
OCTOBER 2009

North Indian Bend Wash Superfund Site

FIGURE 2

GIS-TUC\366.29\5YrReview_Dec2010\UAU_TceOct2009_5YrRpt_ltr\21Dec2010



Time Frame	5-Year Average (pounds)	
	Total VOCs	Total VOCs Excluding PG-4UA
1996 through 2000	1749	1578
1997 through 2001	1320	1137
1998 through 2002	1091	913
1999 through 2003	828	694
2000 through 2004	627	498
2001 through 2005	469	378
2002 through 2006	411	325
2003 through 2007	399	316
2004 through 2008	446	352
2005 through 2009	460	368

VOCs = Volatile Organic Compounds

FIGURE 3. TOTAL MASS OF VOLATILE ORGANIC COMPOUNDS IN SATURATED PORTION OF UPPER ALLUVIUM UNIT

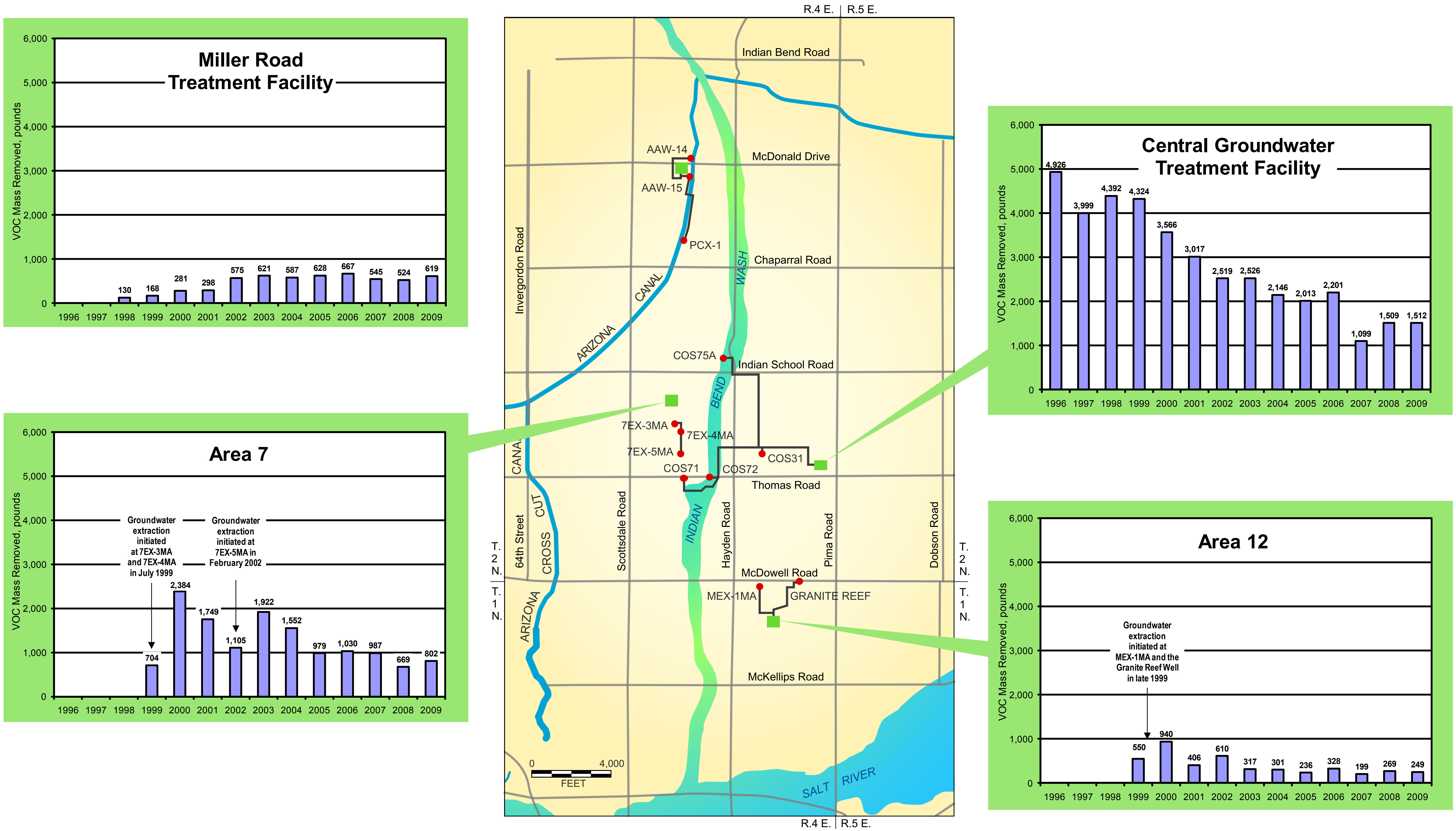
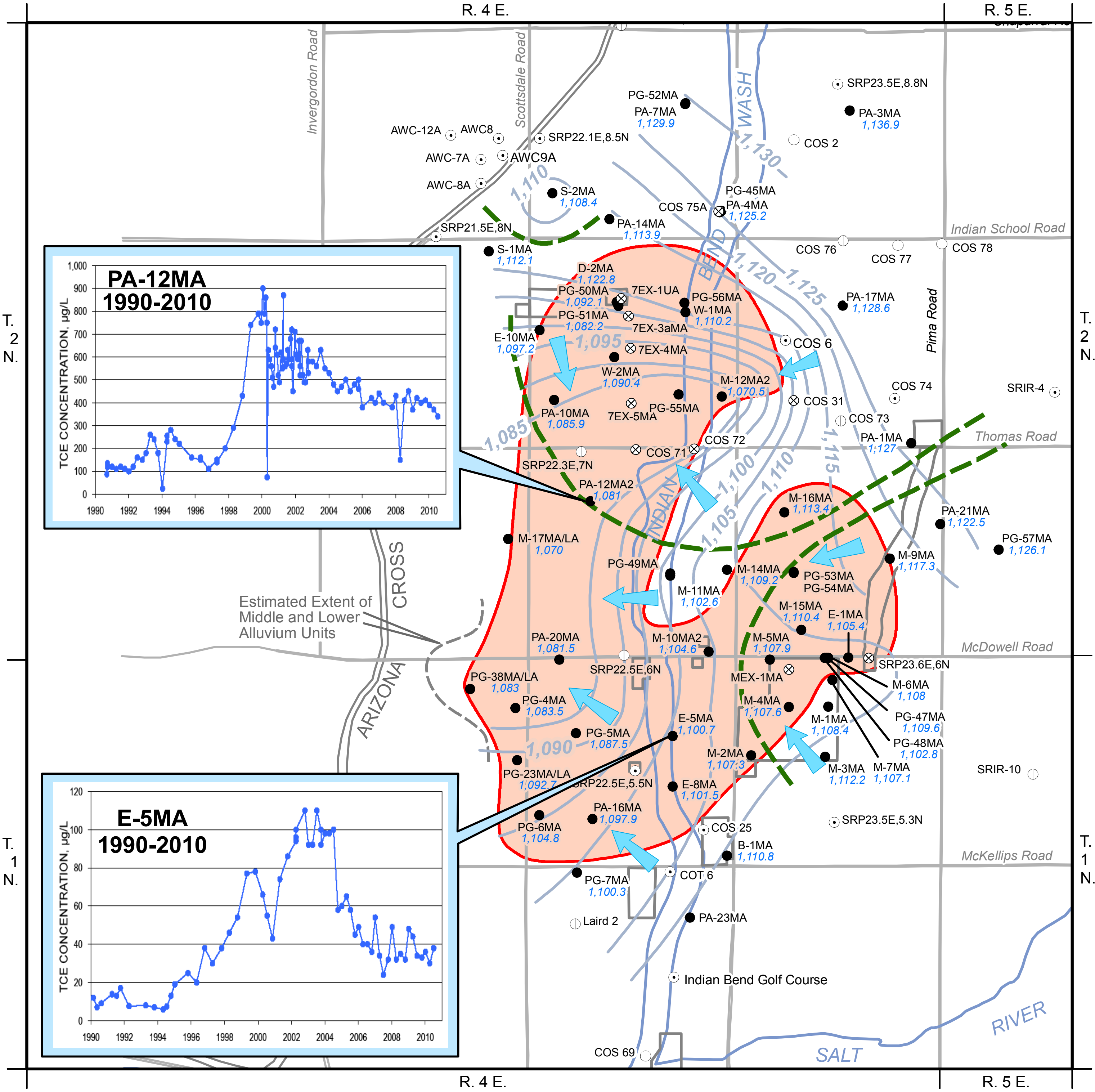


FIGURE 4. TOTAL ANNUAL TCE REMOVED BY GROUNDWATER EXTRACTION AND TREATMENT SYSTEMS, IN POUNDS

North Indian Bend Wash Superfund Site

GIS\366.29\5YrReview_Dec2010\366_ColorBaseMapFlat.ai\03Jan2011



EXPLANATION

PG-7MA 1,100.3 ●	Middle Alluvium Unit Monitor Well Location and Identifier
	Groundwater Level Altitude, in feet above mean sea level
COS75A ⊗	Extraction Water Well Location and Identifier
COS74 ⊙	Production Water Well Location and Identifier
SRP22.5E, 6N ⦶	Inactive Production Water Well Location and Identifier
COS69 ○	Abandoned Production Water Well Location and Identifier
—1,090—	Groundwater Level Altitude Contour, in feet above mean sea level
(arrow)	Direction of Groundwater Movement
(green dashed line)	Estimated Extent of Hydraulic Capture
(red outline)	Extent of 5 µg/LTrichloroethene Concentration in MAU

0 3,500 Feet

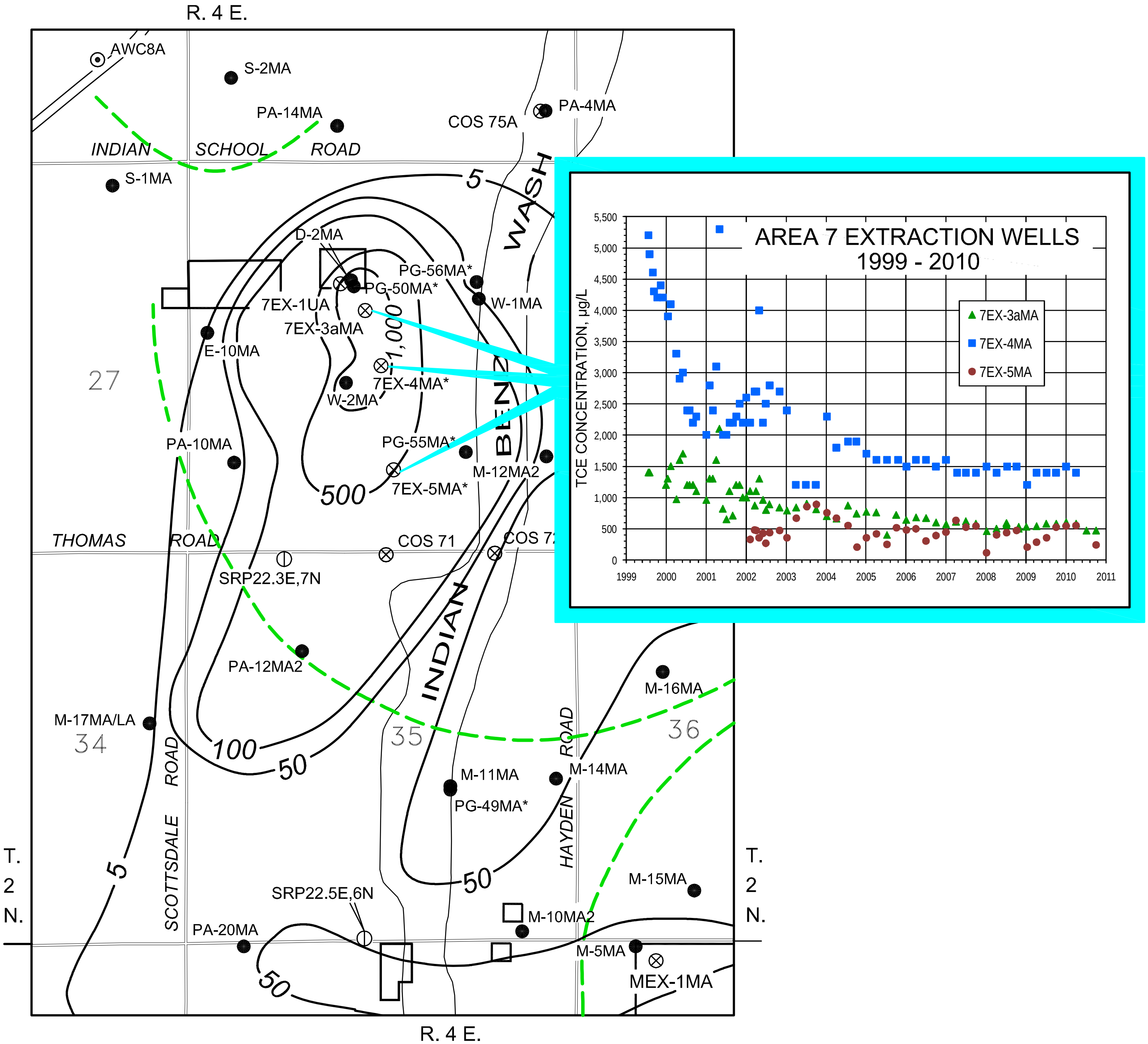
NORTH INDIAN BEND WASH AREA
MARICOPA COUNTY, ARIZONA

ESTIMATED HYDRAULIC CAPTURE MIDDLE ALLUVIUM UNIT OCTOBER 2009

North Indian Bend Wash Superfund Site

FIGURE 5

GIS-TUC\366.29\5YrReview_Dec2010\MAU_WLOct2009_Capture_5YrRpt\14Dec2010



EXPLANATION

—— 50 —— TCE Concentration Contour, in micrograms per liter

– – – – – Estimated Extent of Hydraulic Capture

0 1,000 2,000 3,000 4,000

FEET

N

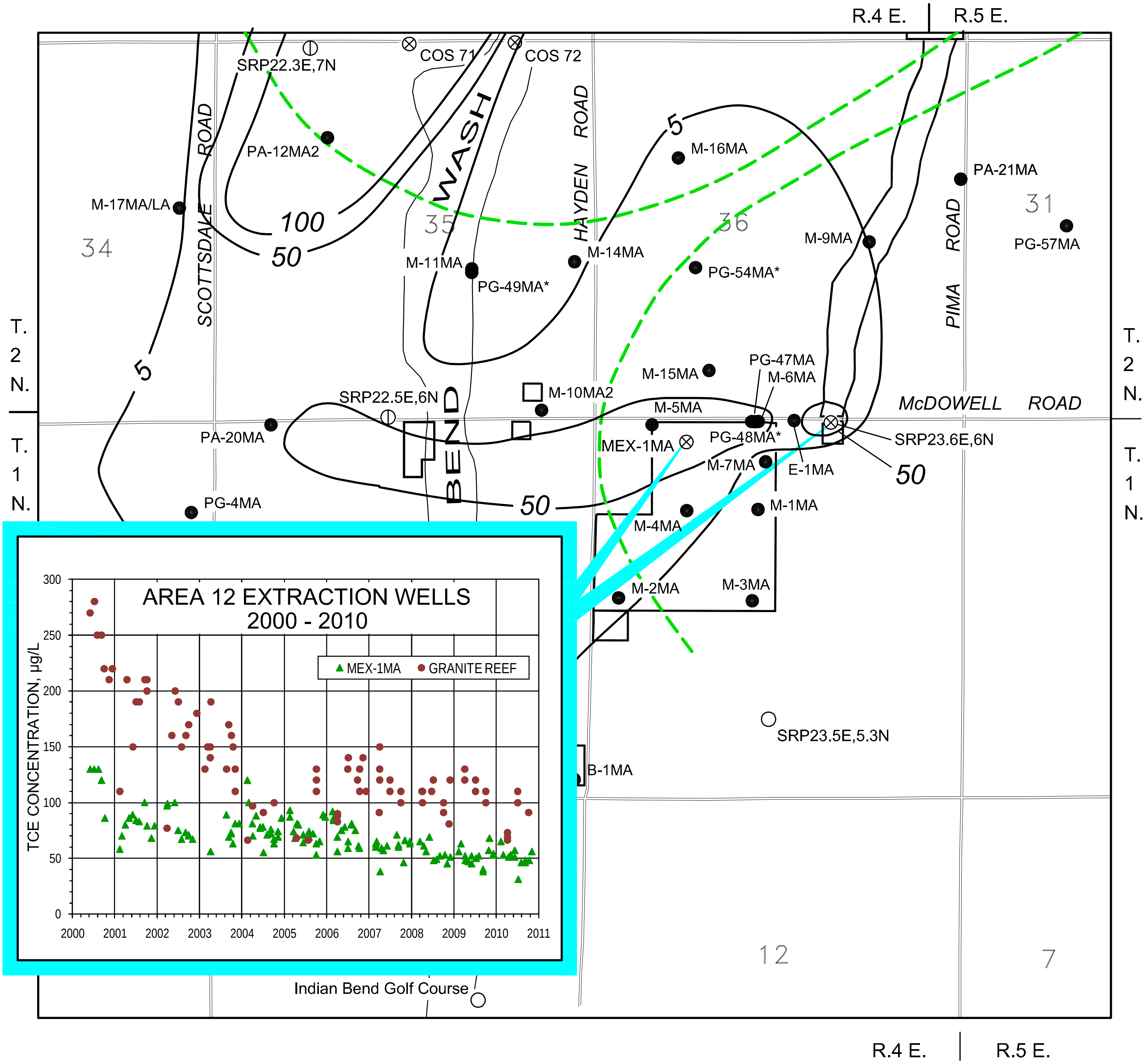
NORTH INDIAN BEND WASH AREA
MARICOPA COUNTY, ARIZONA

TCE CONCENTRATIONS AND
ESTIMATED HYDRAULIC CAPTURE
AREA 7 MIDDLE ALLUVIUM UNIT
OCTOBER 2009

North Indian Bend Wash Superfund Site

FIGURE 6

Drafting\366.29\5YrReview\Area7-UMAU-TCE_Capt_Oct09_Rev\03Jan2011



EXPLANATION

—— 50 —— TCE Concentration Contour, in micrograms per liter

– – – – – Estimated Extent of Hydraulic Capture

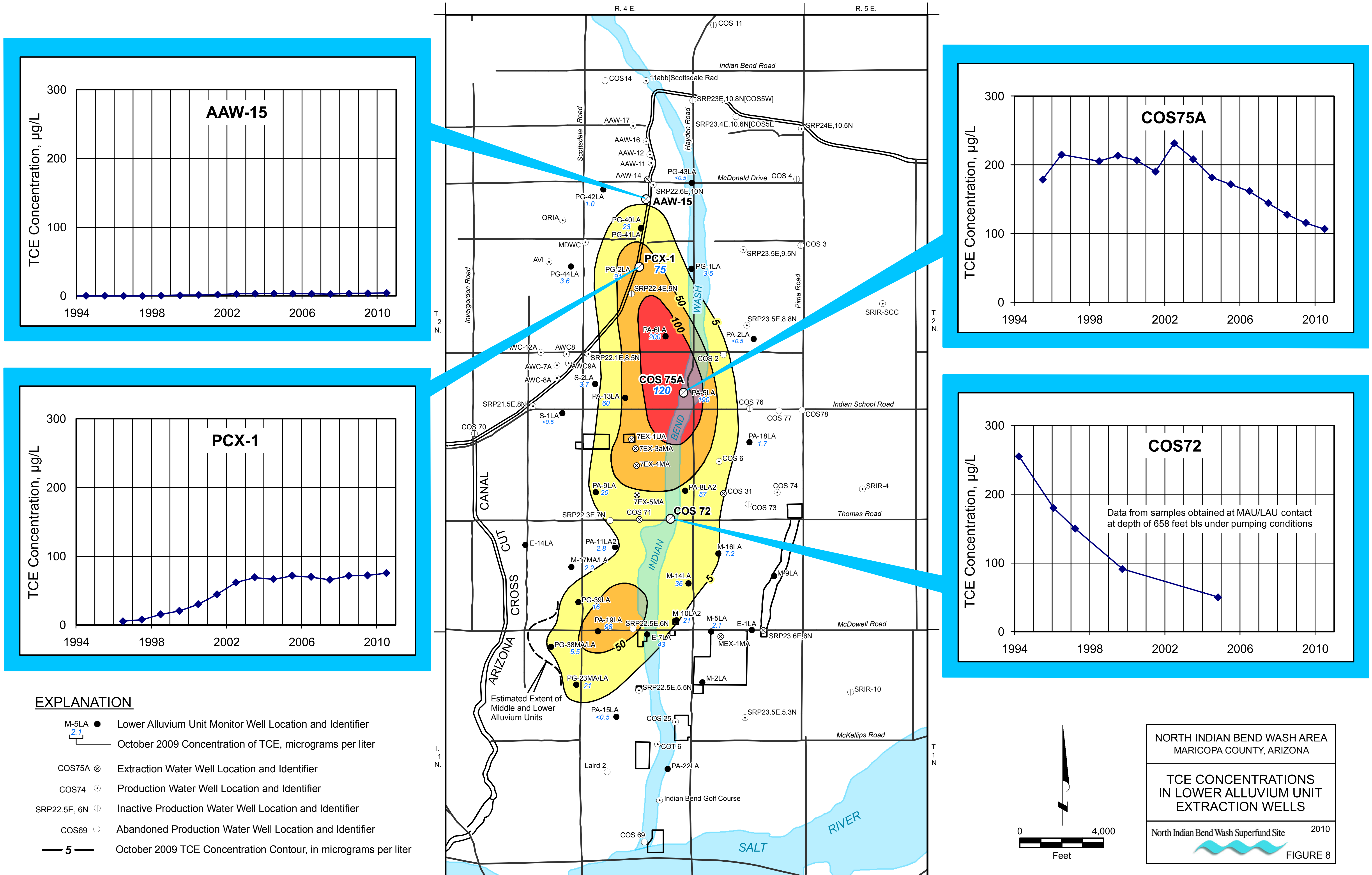
NORTH INDIAN BEND WASH AREA
MARICOPA COUNTY, ARIZONA

TCE CONCENTRATIONS AND ESTIMATED HYDRAULIC CAPTURE AREA 12 MIDDLE ALLUVIUM UNIT OCTOBER 2009

North Indian Bend Wash Superfund Site

FIGURE 7

Drafting\366.29\5YrReview\Area12-MAU-TCE_Capt_Oct09_Rev\03Jan2011



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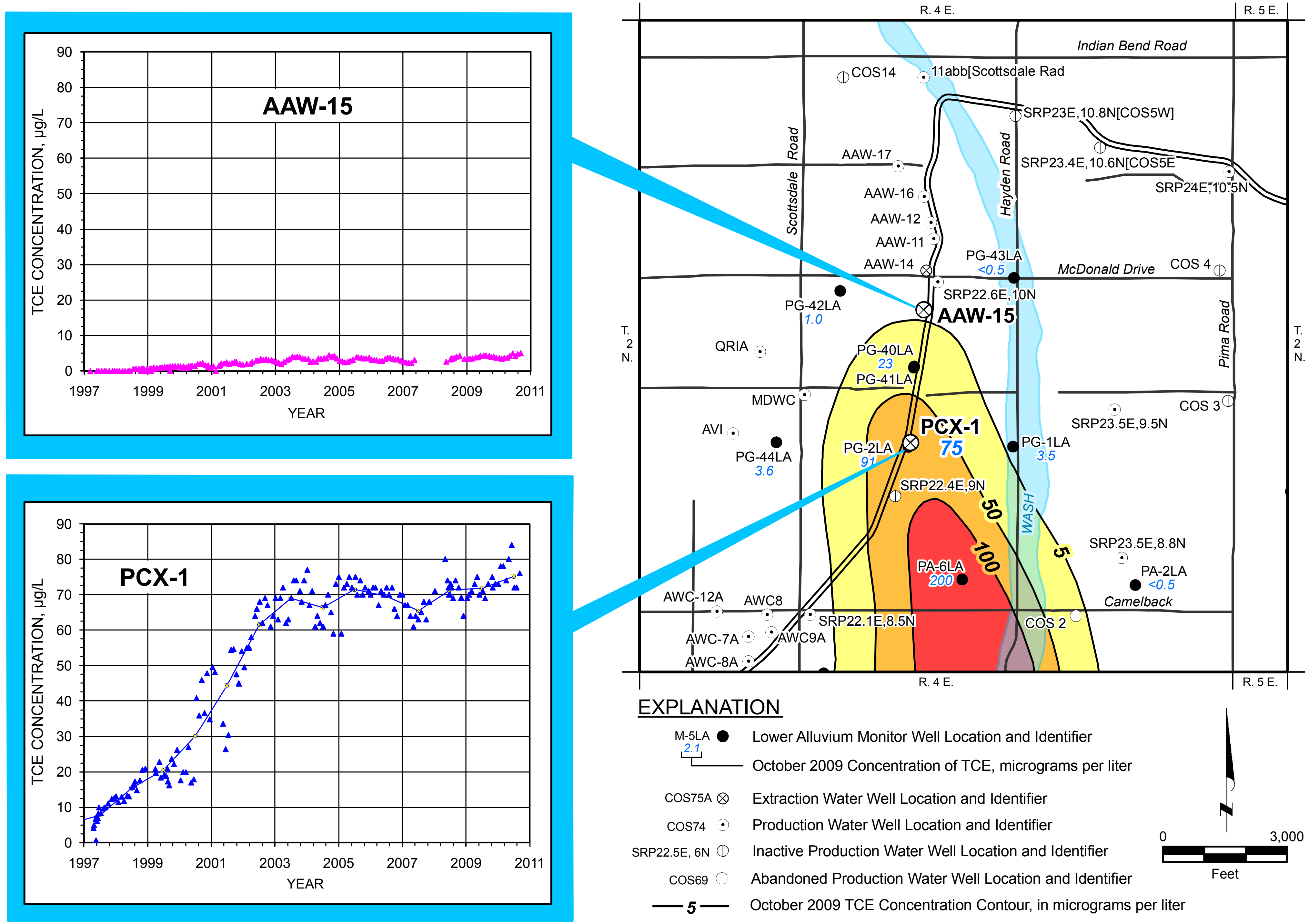


FIGURE 9. TCE CONCENTRATIONS IN NORTHERN LOWER ALLUVIUM UNIT EXTRACTION WELLS

GIS-TUC\366.29\5YrReview\TCE\2009\NorthernLAUdetail_TCEOct2009\21Dec2010

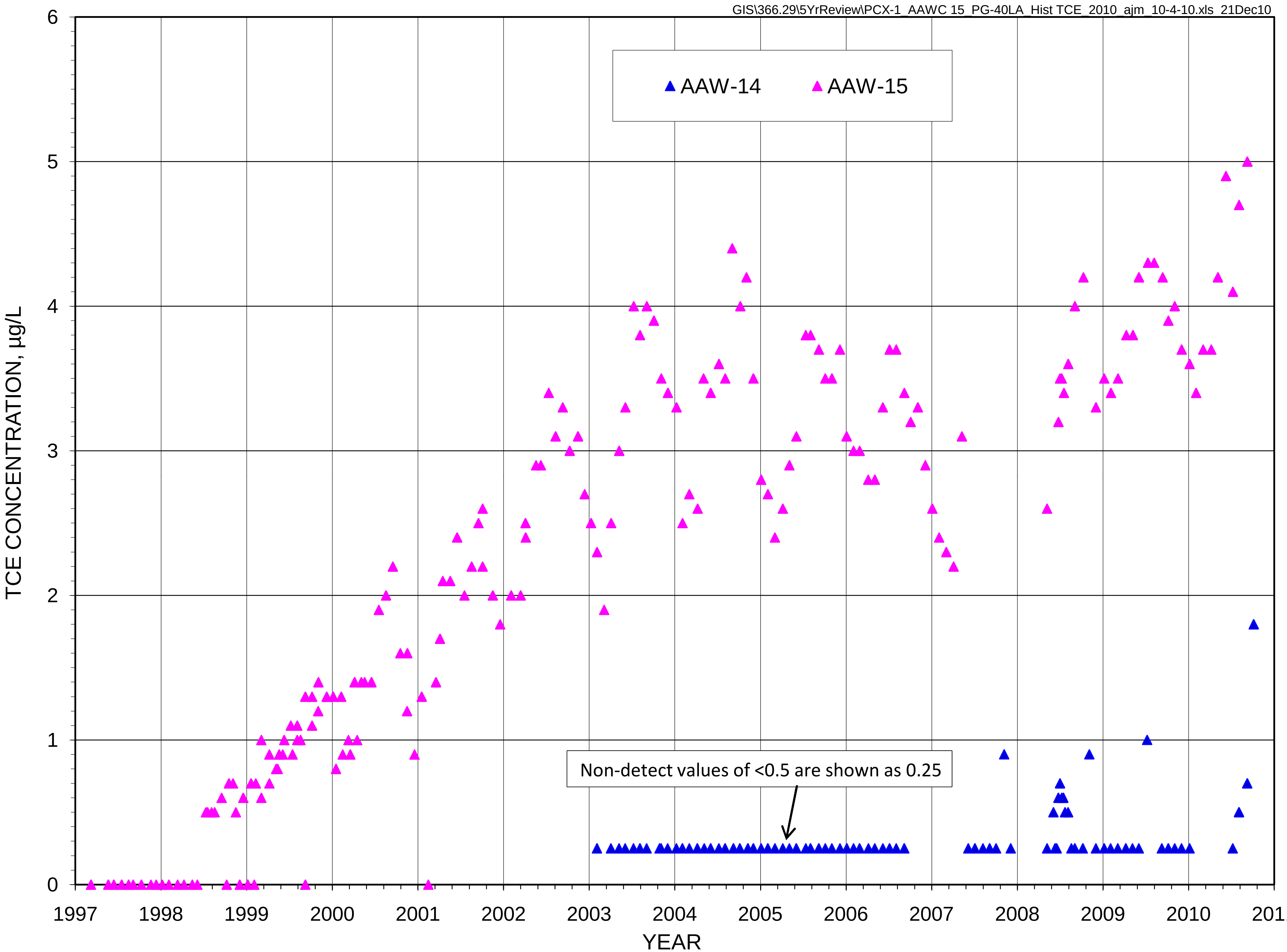
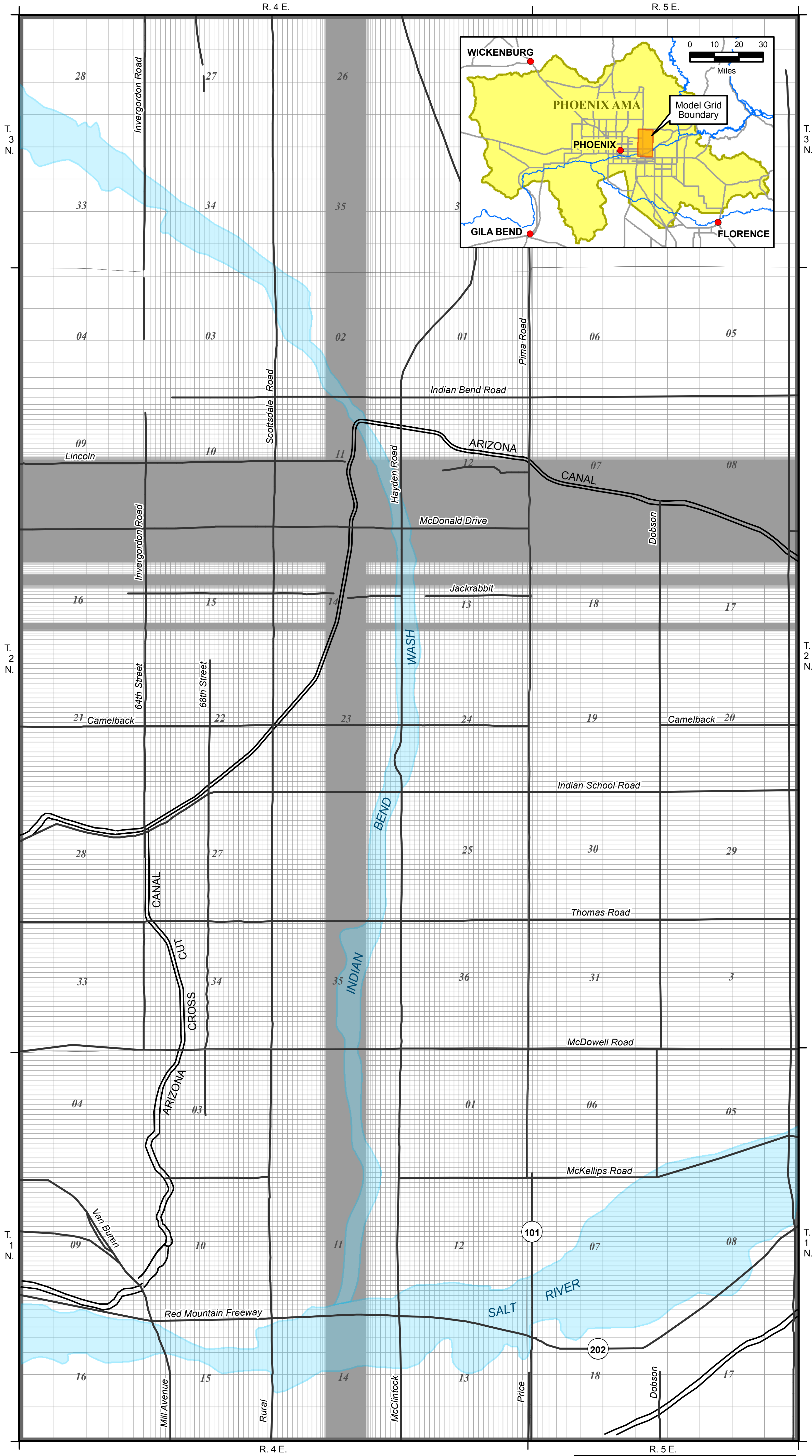


FIGURE 10. TCE CONCENTRATIONS AT LOWER ALLUVIUM UNIT EXTRACTION WELLS AAW-14 AND AAW-15, 1997 TO 2010

North Indian Bend Wash Superfund Site



R. 4 E. R. 5 E.

EXPLANATION

Model Grid Cell

0 4,000
Feet

NORTH INDIAN BEND WASH AREA
MARICOPA COUNTY, ARIZONA

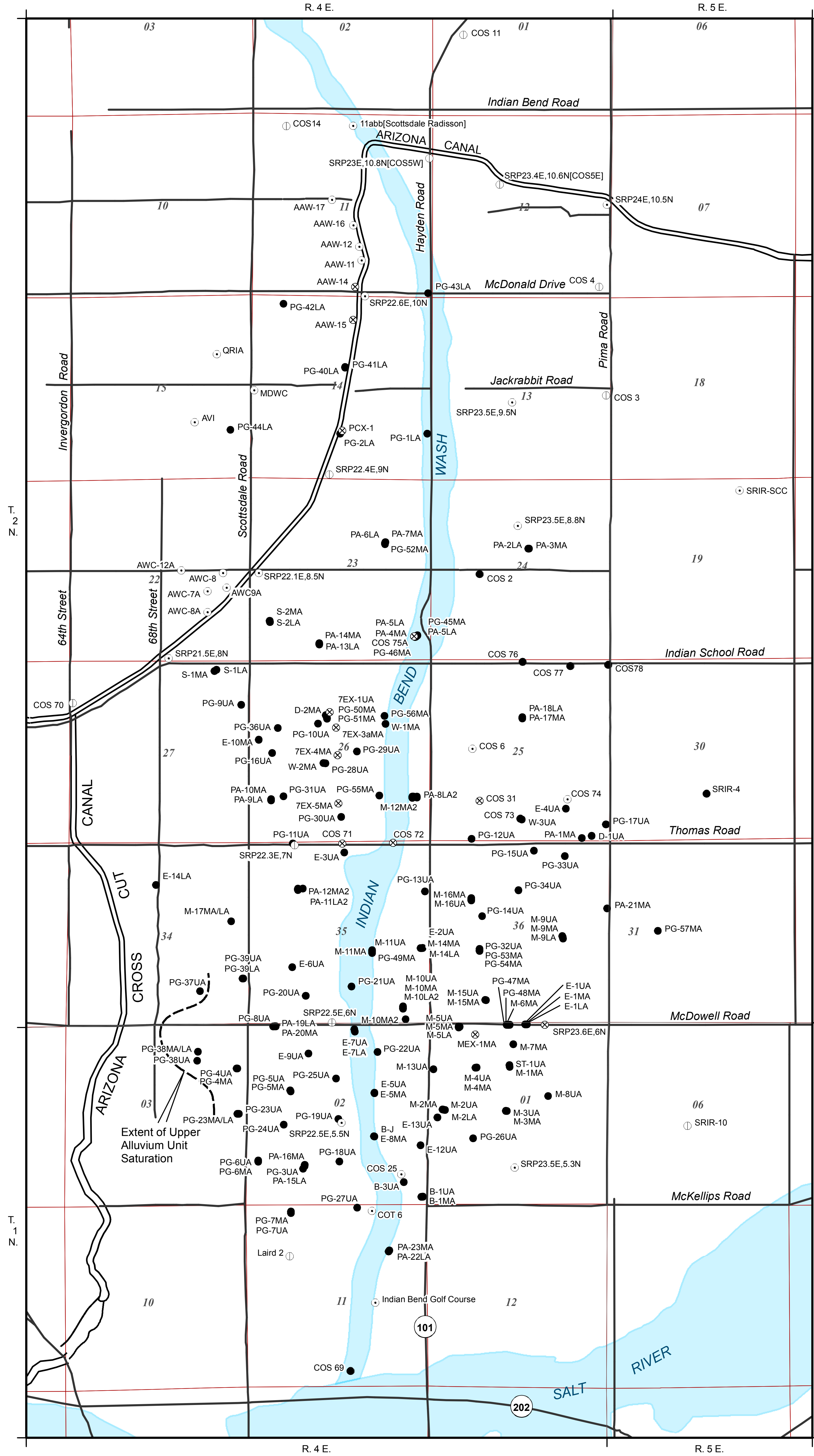
MODEL STUDY AREA AND GRID

North Indian Bend Wash Superfund Site

2010

FIGURE 11

GIS-TUC\366.29\ModelArea.mxd\21Dec2010



EXPLANATION

PA-15LA ● Monitor Well Location and Identifier

COS75A ⊗ Extraction Water Well Location and Identifier

COS74 ⊙ Production Water Well Location and Identifier

SRP22.4E, 9N ⦶ Inactive Production Water Well Location and Identifier

COS69 ◌ Abandoned Production Water Well Location and Identifier

0 3,000

Feet

NORTH INDIAN BEND WASH AREA
MARICOPA COUNTY, ARIZONA

WELL LOCATION MAP

North Indian Bend Wash Superfund Site

2010

FIGURE 12

GIS-TUC\366.29\ALL_WELLS_Locmap.mxd\21Dec2010

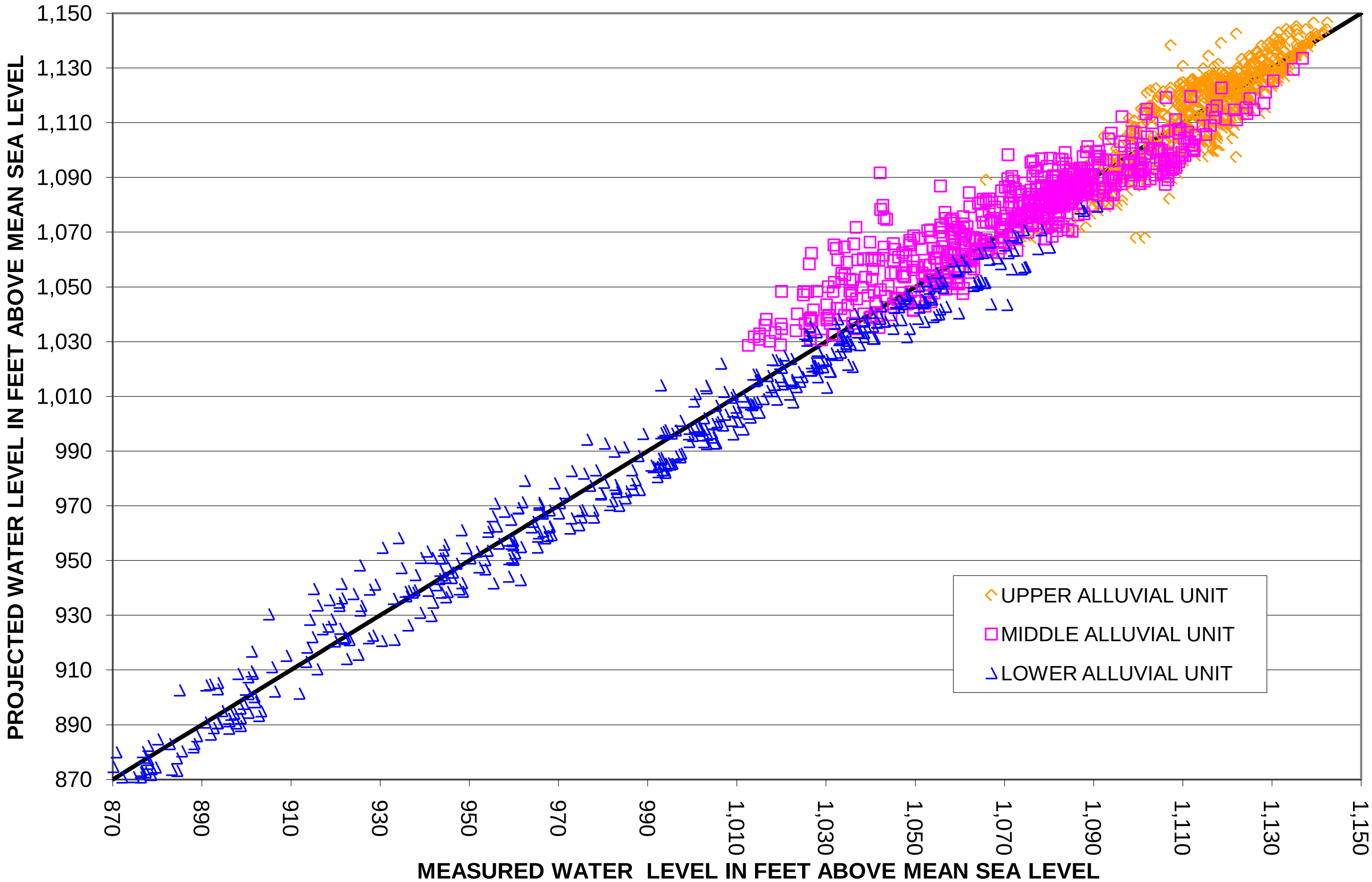
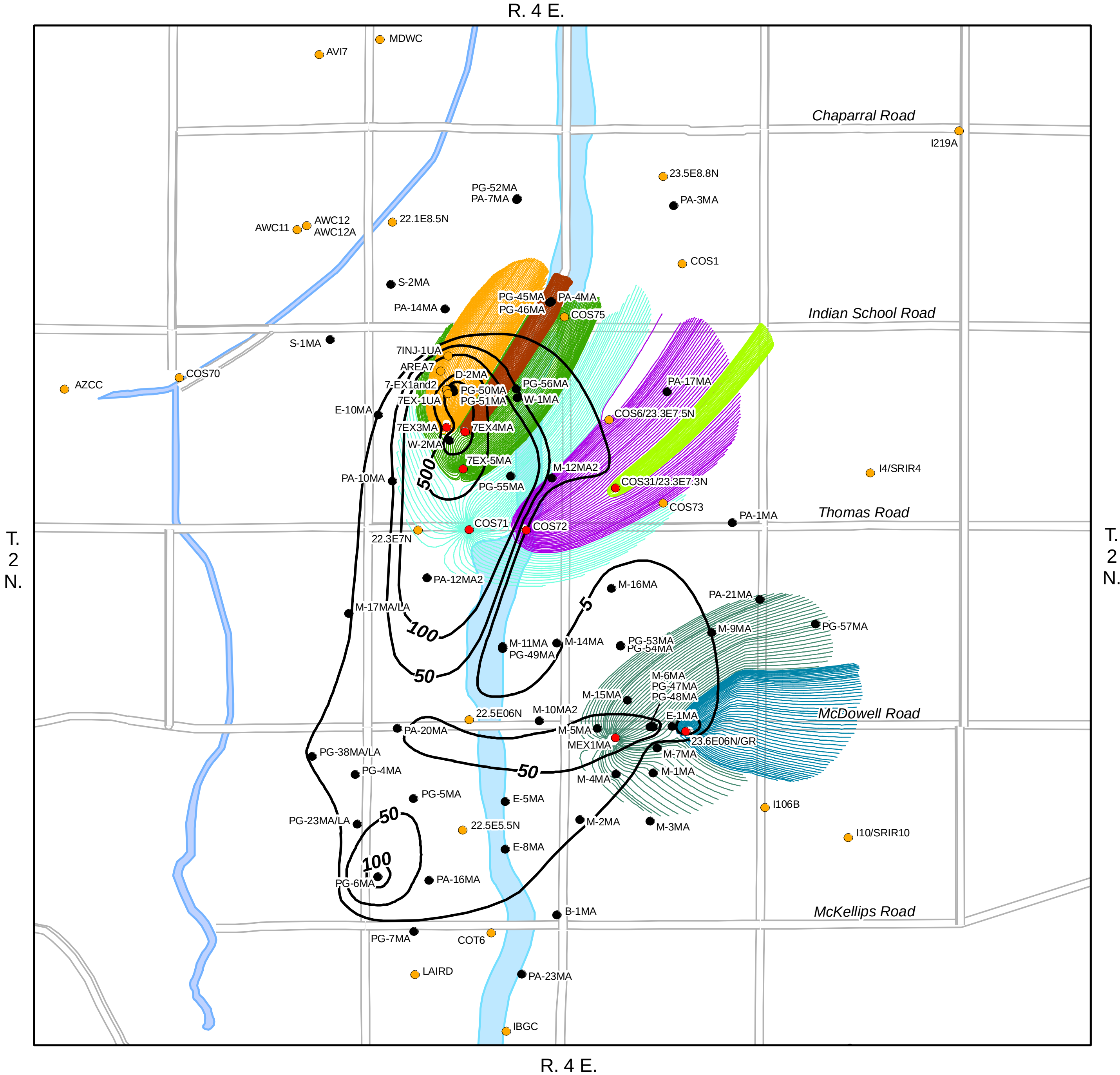


FIGURE 13. PROJECTED VERSUS MEASURED WATER LEVELS
5-YEAR REVIEW GROUNDWATER FLOW MODEL CALIBRATION
NORTH INDIAN BEND WASH SUPERFUND SITE



EXPLANATION

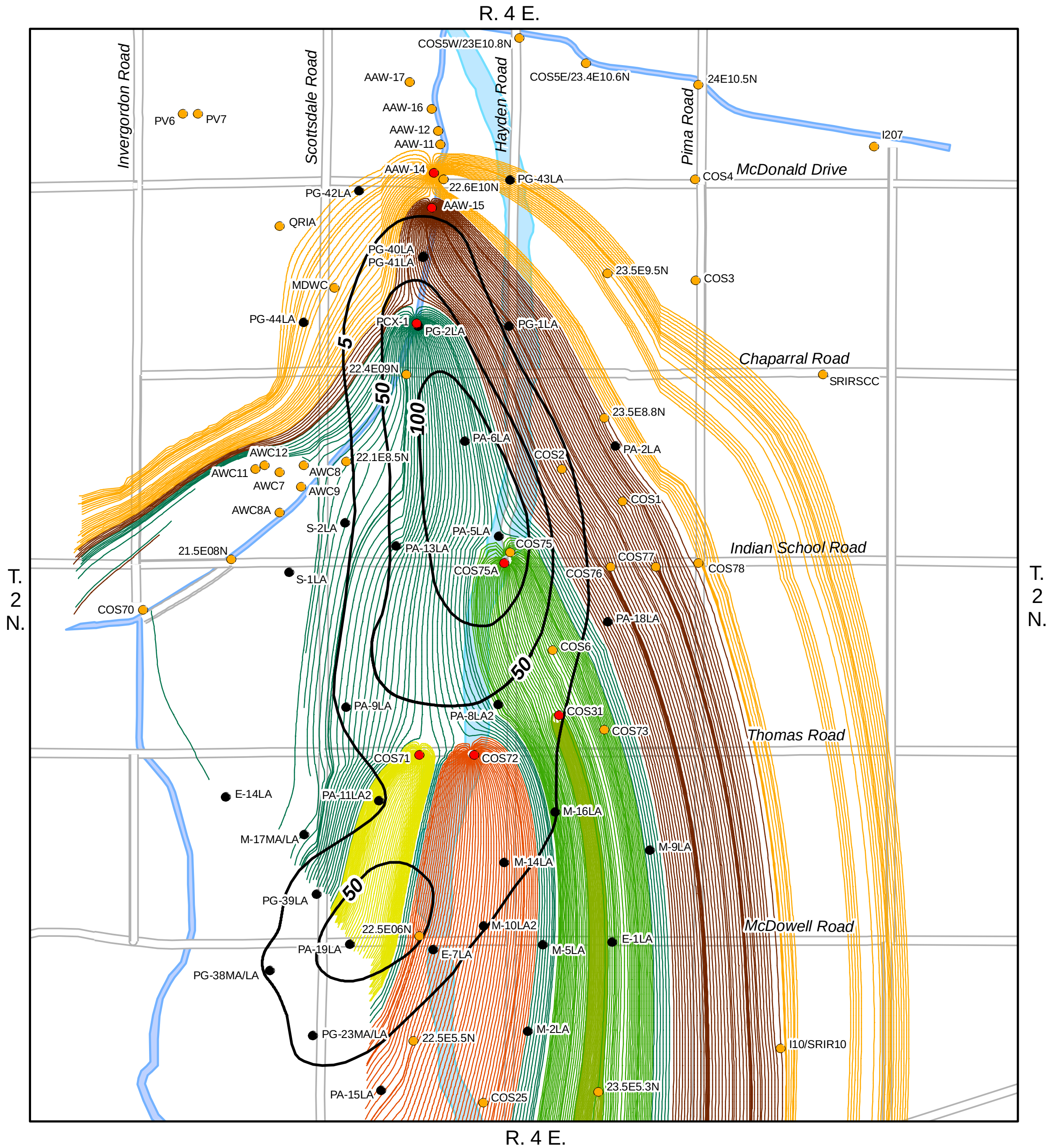
(black line)	October 2009 TCE Concentrations in MAU Groundwater (micrograms per Liter, µg/L)
(red dot)	Remedy Extraction Well
(orange dot)	Other Production Well
(black dot)	MAU Monitor Well
(double grey line)	Roads
(orange line)	7EX3MA Capture Zone
(brown line)	7EX4MA Capture Zone
(green line)	7EX5MA Capture Zone
(yellow-green line)	COS31 Capture Zone
(light cyan line)	COS71 Capture Zone
(purple line)	COS72 Capture Zone
(dark green line)	MEX1MA Capture Zone
(blue line)	23.6E06N Capture Zone

0 4,000
Feet

FIGURE 14. PROJECTED CAPTURE FOR MAU REMEDY EXTRACTION WELLS IN LAYER 3, RECOMMENDED PUMPING CONDITIONS

North Indian Bend Wash Superfund Site

GIS-TUC\366\13\5YR-Review_MAU-Cleanup.mxd 21Dec2010



EXPLANATION

- October 2009 TCE Concentrations in LAU Groundwater (micrograms per Liter, µg/L)
- Remedy Extraction Well
- Other Production Well
- LAU Monitor Well
- Roads

- AAWC14 Capture Zone
- AAWC15 Capture Zone
- COS75A Capture Zone
- COS31 Capture Zone
- COS71 Capture Zone
- COS72 Capture Zone
- PCX1 Capture Zone

0 2,250 4,500
Feet

FIGURE 15. PROJECTED CAPTURE FOR LAU REMEDY EXTRACTION WELLS IN LAYER 6, RECOMMENDED PUMPING CONDITIONS

North Indian Bend Wash Superfund Site

GIS-TUC\366\13\5YR-Review_LAU-Cleanup.mxd\21Dec2010

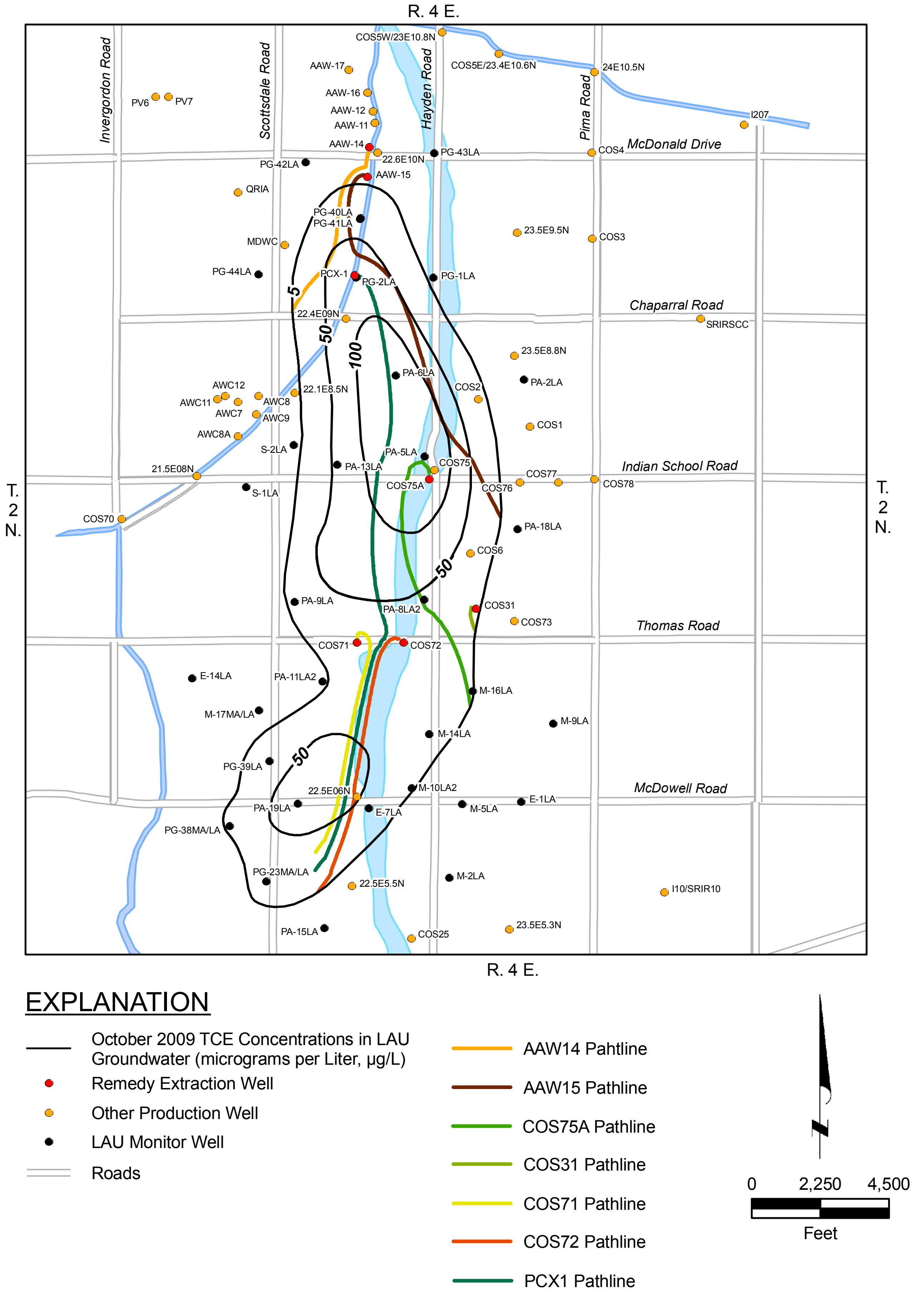


FIGURE 16. REMEDY EXTRACTION WELL LAYER 6 SELECTED PATHLINES RECOMMENDED PUMPING CONDITIONS

North Indian Bend Wash Superfund Site

GIS-TUC\366\13\5YR-Review_Layer6_Pathlines.mxd\21Dec2010

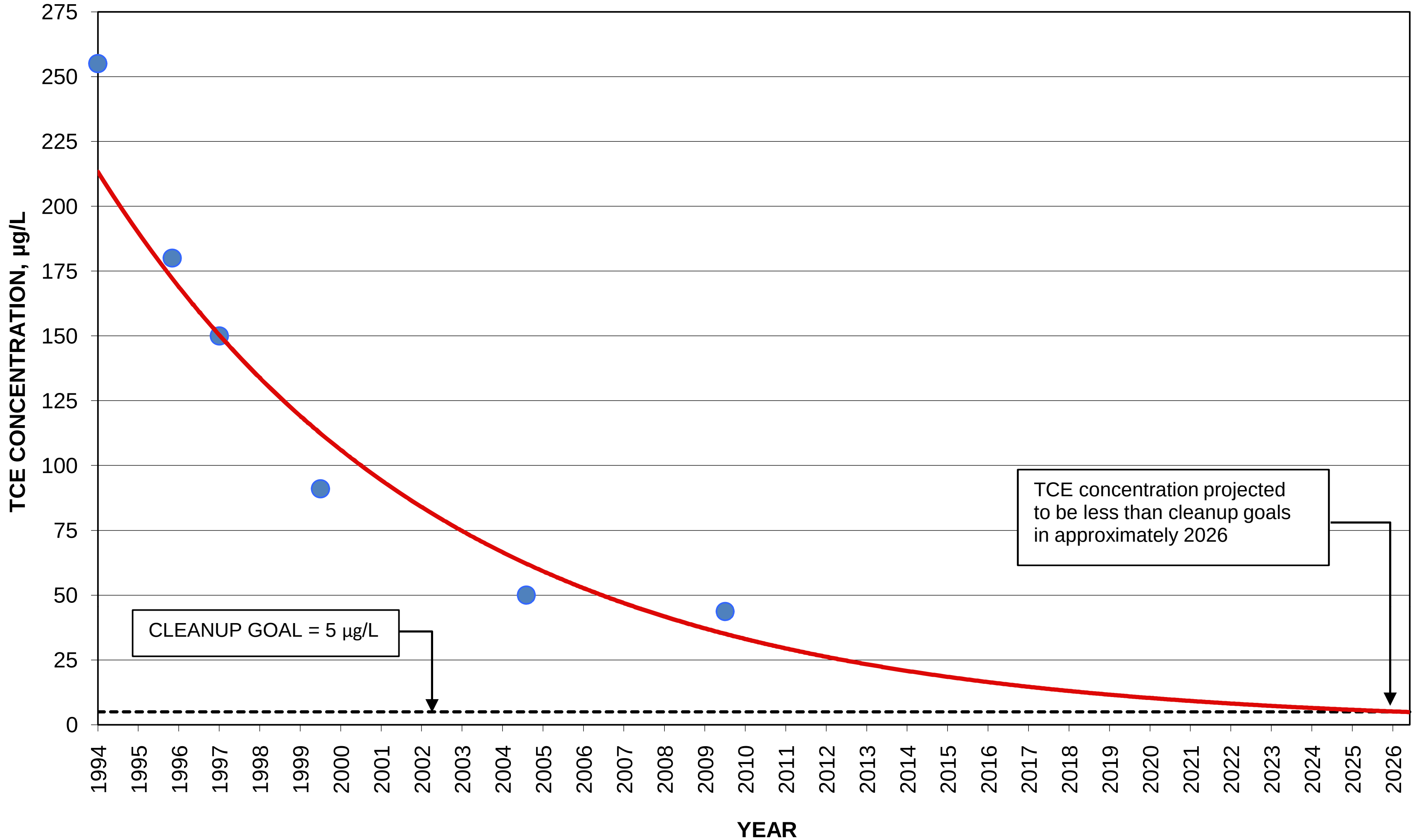


FIGURE 17. ANNUAL AVERAGE TCE CONCENTRATION AND EXTRAPOLATED DATA TREND FOR LOWER ALLUVIUM UNIT PRODUCING INTERVAL OF EXTRACTION WELL COS72

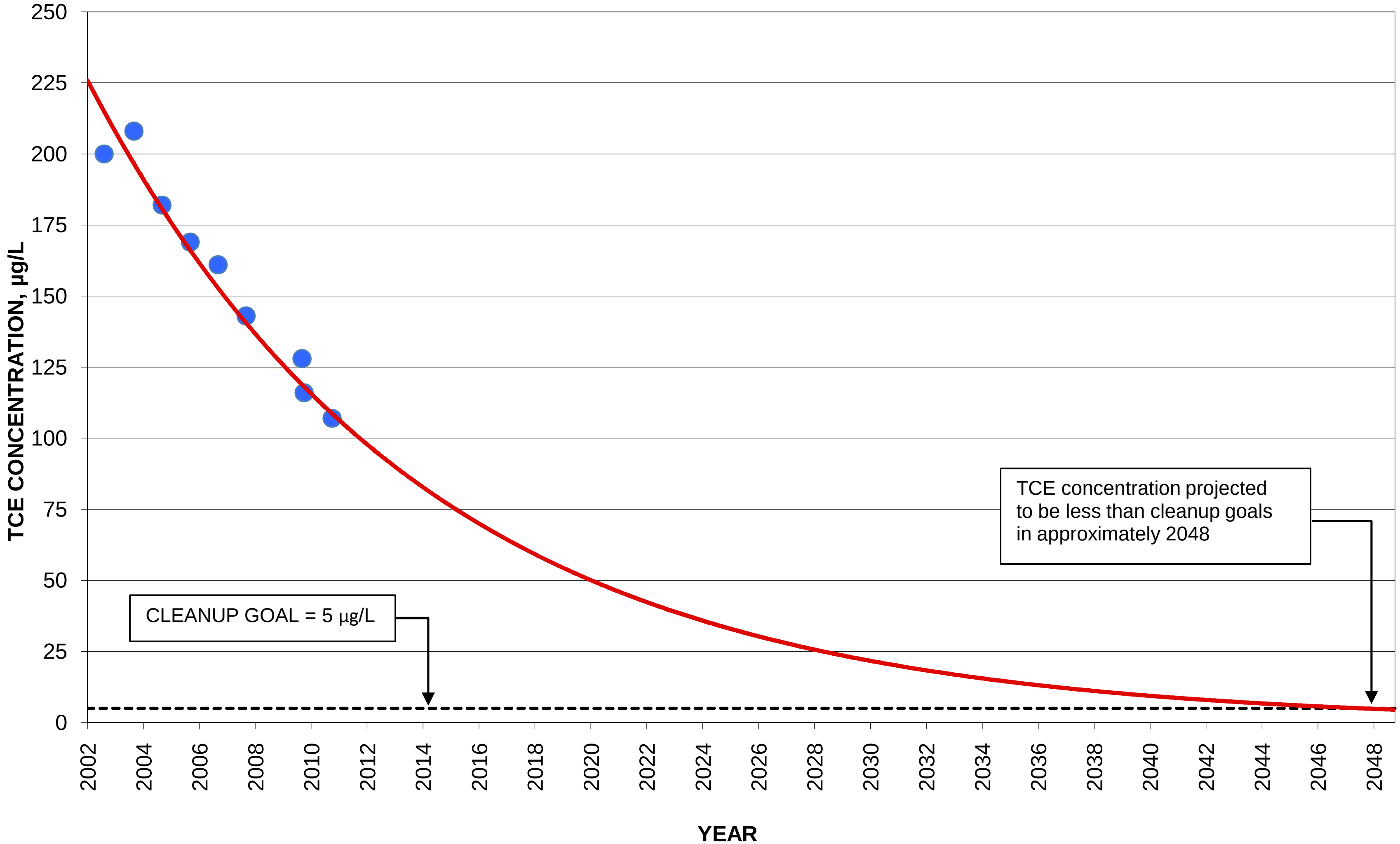


FIGURE 18. ANNUAL AVERAGE TCE CONCENTRATION AND EXTRAPOLATED DATA TREND FOR LOWER ALLUVIUM UNIT EXTRACTION WELL COS75A