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REMARKS:

This transmits the above-referenced revised final report. Per ADEQ's request, it incorporates changes related to use of vapor phase granular activated carbon in conjunction with the air stripping treatment alternatives. Based on the cost analysis, the use of only liquid phase granular activated carbon for VOC treatment is now being recommended for both the Reference and More Aggressive remedies. Please discard the 3 copies of the previous final version of the report dated Dec. 8. 2011.

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cc: Jamieson Schiff-Textron, Inc.

FINAL FEASIBILITY STUDY REPORT FOR THE SHALLOW GROUNDWATER SYSTEM

WEST OSBORN COMPLEX WQARF SITE PHOENIX, ARIZONA

Prepared for
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January 27, 2012

Project No. 2209.004

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APPENDICES

Appendix A Time Series Plots – WOC SGWS and NCP Wells
Appendix B Vendor Modeling Results for Liquid GAC and Air Stripping
Appendix C Discussion of WhAEM Modeling Results

LIST OF ACRONYMS

AS	Air Sparging
AAC	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
ADOT	Arizona Department of Transportation
ADWR	Arizona Department of Water Resources
ARS	Arizona Revised Statutes
ATC	Approval to Construct
AWQS	Aquifer Water Quality Standard
AZPDES	Arizona Pollutant Discharge Elimination System
BCC	Brown and Caldwell Consultants
bgs	Below Ground Surface
BHHRA	Baseline Human Health Risk Assessment
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cfm	Cubic Feet per Minute
COCs	Contaminants of Concern
COP	City of Phoenix
DCE	Dichloroethene
DO	Dissolved Oxygen
DSD	Development Services Department
EGA	East Grand Avenue
EPA	U.S. Environmental Protection Agency
ERA	Early Response Action
EVO	Emulsified Vegetable Oil
EW	Extraction Well
°F	Degrees Fahrenheit,
FS	Feasibility Study
ft	Foot; Feet
GAC	Granular Activated Carbon
GPL	Groundwater Protection Level
gpm	Gallons per Minute
hp	Horse Power
IRA	Interim Remedial Action
ISB	In-situ Bioremediation
IW	Injection Well
K	Thousand
lbs	Pounds
LC	Life Cycle
LGAC	Liquid-phase Granular Activated Carbon
LSGS	Lower Sand and Gravel Subunit
MCESD	Maricopa County Environmental Services Department
MCLs	Maximum Contaminant Levels
mg/kg	Milligrams per Kilogram
mg/L	Milligrams per Liter

µg/L	Micrograms per Liter
µg/m³	Micrograms per Cubic Meter
M	Million
MNA	Monitored Natural Attenuation
MW	Monitoring Well
NCP	North Canal Plume
NPV	Net Present Value
O&M	Operation and Maintenance
ORP	Oxidation Reduction Potential
PCE	Tetrachloroethene (also known as Perchloroethene)
P&T	Pump-and-Treat
PVC	Polyvinyl Chloride
RI	Remedial Investigation
ROI	Radius of Influence
ROs	Remedial Objectives
ROW	Right-of-Way
SGWS	Shallow Groundwater System
SRP	Salt River Project
scfm	Standard Cubic Feet per Minute
SVE	Soil Vapor Extraction
SVOCs	Semi-Volatile Organic Compounds
TCA	Trichloroethane
TCE	Trichloroethene
TDS	Total Dissolved Solids
UAU	Upper Alluvial Unit
UIC	United Industrial Corporation
VGAC	Vapor-phase Granular Activated Carbon
VOCs	Volatile Organic Compounds
WCC	Woodward-Clyde Consultants
WCP	West Central Phoenix
WGA	West Grand Avenue
WOC	West Osborn Complex
WQARF	Water Quality Assurance Revolving Fund

1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE OF THE FEASIBILITY STUDY REPORT

The West Osborn Complex (WOC) Water Quality Assurance Revolving Fund (WQARF) Site (WOC; WOC Site; the Site), located in Phoenix, Arizona (Figure 1-1), consists of two plumes: the Shallow Groundwater System (SGWS) plume and the Lower Sand and Gravel Subunit (LSGS) plume. This Draft Final Feasibility Study (FS) Report for the SGWS was prepared by GeoTrans, Inc. (GeoTrans) pursuant to: Arizona Department of Environmental Quality (ADEQ) letter dated July 3, 2007 (ADEQ, 2007); the ADEQ-approved FS Work Plan for the Site (GeoTrans, 2005); ADEQ March 8, 2011 final comments (ADEQ, 2011a) for the Draft SGWS FS Report that was prepared by GeoTrans and submitted to ADEQ on May 21, 2009 (GeoTrans, 2009); ADEQ decision regarding remedial alternatives for the SGWS FS (ADEQ, 2011b); and discussions with ADEQ.

This report was prepared in accordance with Arizona Administrative Code (AAC) R18-16-407 based upon the data and findings of the remedial investigation (RI) (GeoTrans, 2004) and additional investigations that have been conducted by United Industrial Corporation (UIC)[1] and others[2] from 1984 through 2010. The objectives of the FS are as follows:

1. Identity a reference and alternative remedies capable of achieving the Remedial Objectives (ROs) defined by the May 2005 Final Remedial Objectives Report, prepared by the ADEQ (ADEQ, 2005); and

2. Evaluate each of the identified remedies and recommend alternatives to address the ROs and comply with the requirements of Arizona Revised Statutes (ARS) §49-282.06, based on the GeoTrans' February 3, 2011 meeting with ADEQ and ADEQ comments letter dated April 5, 2011 (ADEQ, 2011).

Based on the objectives stated above, the FS presents a recommendation for the preferred remedy which:

1. Assures the protection of public health, welfare and the environment;

2. To the extent practicable, provides for the control, management, or cleanup of hazardous substances so as to allow for the maximum beneficial use of waters of the state;

3. Is reasonable, necessary, cost-effective and technically feasible; and

[1] UIC was later purchased by AAI Corporation, which was, in turn, acquired by Textron, Inc.

[2] Previous investigators include: the ADEQ as early as 1984 (WCC, 1987); Woodward-Clyde Consultants on behalf of Lansdale Semiconductor, Inc. in 1987 (WCC, 1987); and Brown and Caldwell Consultants, on behalf of Components, Inc. in 1991 and 1992 (BCC, 1992).

4. Addresses any well (used for municipal, domestic, industrial, irrigation or agricultural purposes) that could produce water that would not be fit for its current or reasonably foreseeable end use without treatment.

The FS was conducted in accordance with the ADEQ WQARF Remedy Selection Rule, as presented in Title 18, Environmental Quality, Chapter 16, Department of Environmental Quality Water Quality Assurance Revolving Fund Program, Article 4, Remedy Selection, R18-16-407, Feasibility Study.

1.2 REPORT ORGANIZATION

The FS report has been organized into the following sections:

Section 1.0 – INTRODUCTION: This section summarizes the purpose and scope of the FS Report.

Section 2.0 – SITE BACKGROUND: This section presents a summary of the Site and its SGWS, physiographic setting, nature and extent of contamination, and a risk evaluation.

Section 3.0 – FEASIBILITY STUDY SCOPING: This section presents the regulatory requirements of pertinent statutes and rules, delineates the remediation areas, evaluates contamination impacts from upgradient WQARF areas, and presents the ROs identified in the ADEQ May 2005 report.

Section 4.0 – EARLY RESPONSE ACTIONS: This section presents the Early Response Actions (ERAs) that have been undertaken at the Site.

Section 5.0 – IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES: This section presents an evaluation and screening of various remedial technologies related to contamination in groundwater, and lists the technologies that have been retained for inclusion into the reference and alternative remedies. In addition, it describes options for discharge of treated groundwater and end use of the water.

Section 6.0 – DEVELOPMENT OF REFERENCE REMEDY AND ALTERNATIVE REMEDIES: This section presents the selected reference remedy, a more aggressive remedy, and a less aggressive remedy. Each of the remedies identified includes a discussion of its associated strategy and measures for multiple remediation systems which comprise each remedy.

Section 7.0 – DETAILED COMPARISON OF THE REFERENCE REMEDY AND THE ALTERNATIVE REMEDIES, IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES: The three selected remedies are compared to each other based on practicability, permitting, source control, cost, risk, and benefit. Any uncertainties associated with each remedy are also discussed in this section.

Section 8.0 – PROPOSED REMEDY: This section presents:

1. The recommended remedy;

2. How the recommended remedy will achieve the ROs;

3. How the comparison criteria for the selected remedies were considered; and

4. How the proposed remedy will meet the requirements presented in ARS §49-282.06 and AAC R18-16-407.

Section 9.0 – REFERENCES. This section provides references cited in the report.

2.0 SITE BACKGROUND

This section presents a summary of the Site background, physiographic setting, nature and extent of contamination, and a risk evaluation. Additional details are available in the Final RI Report (RI Report) for the Site prepared by GeoTrans (GeoTrans, 2004).

2.1 SITE DESCRIPTION

The Site is located in Phoenix, Arizona, and consists of the WOC Facility and two groundwater plumes originating from it, the SGWS plume and the LSGS plume (Figure 1-1). The WOC Facility consists of three adjoining properties, located at street addresses of 3536 (East Parcel), 3600 (Middle Parcel), and 3640 (West Parcel), West Osborn Road, Phoenix, Arizona (Figure 2-1). The WOC Facility is bounded by the Grand Canal on the north, Osborn Road on the south, 35th Avenue on the east, and the extension of 37thAvenue on the west.

2.2 SITE REGISTRY

In 1982, trichloroethylene (TCE) was detected in City of Phoenix (COP) wells COP-70 and COP-71, located downgradient of the WOC Facility (Figure 2-2). Detected TCE concentrations exceeded the EPA Maximum Contaminant Level (MCL) of 5 micrograms per liter (μg/L).

In 1984, the Arizona Department of Health Services (ADHS) identified dissolved-phase VOCs in the on-site production well (hereafter called "the WOC irrigation well" or "the Pincus Well") located on the Middle Parcel. In 1987, Woodward-Clyde Consultants (WCC), under a contract with Lansdale Semiconductors, Inc. (occupant of the Middle Parcel at that time) collected 10 surface soil samples and one groundwater sample from the Pincus Well. Two soil samples were found to contain 285 and 2,020 μg/kg TCE, and the groundwater sample was found to contain 256 μg/L TCE, thus above the MCL of 5 μg/L.

The WOC Facility and the plumes originating from it were originally designated as the West Central Phoenix (WCP) WQARF Site in 1987. However, in 1998, the WCP WQARF Site was divided into five WQARF registry sites, one of which is the Site.

2.3 SOURCE AREA DEFINITION

The results of the extensive soil sampling consisting of about 150 samples indicate that the soil contamination at the WOC Facility was due to VOCs. Low levels of primarily TCE and even lower concentrations of 1,1-dichloroethene (1,1-DCE) and tetrachloroethene (PCE) were identified at the WOC Facility in the contents of and in native soil adjacent to various waste/wastewater disposal facilities (GeoTrans, 2004). The detected concentrations were all below Arizona Soil Remediation Levels (SRLs) (both residential and industrial), and with the exception of six samples, were below established Groundwater Protection Levels (GPLs). However, no specific location(s) were identified as the source(s) of the VOCs contamination in the unsaturated zone soils and SGWS. Based on these soil sampling results, an area in the north-northwest portion of the Middle Parcel appeared to have the largest mass of VOCs in the vadose zone. Therefore, an ERA consisting of soil vapor extraction (SVE) was implemented in the apparent source area. Follow-up vapor sampling and confirmation soil sampling verified that the SVE effectively removed approximately 449 pounds of VOCs from the vadose zone soils.

When the Grand Canal was lined in January 1998, groundwater levels at the WOC Facility immediately declined, and at the same time, concentrations of VOCs in monitor wells also declined for a period of time initially (see Table 3-1), but increased afterwards. VOCs (TCE, 1,1-DCE, and PCE) that were formerly in the shallow groundwater and in the capillary zone remained trapped in the vadose zone and may still be affecting groundwater quality, along with any other residual VOC contamination that may be present in on-site soils.

Based on extensive sampling/analytical testing for metals in septic tank contents and soil at the time septic tanks and piping were removed, heavy metals were not detected in soil in concentrations greater than SRLs and/or GPLs, except for a few samples with arsenic concentrations above the SRLs but still well below the GPLs. However, based on the results of the Baseline Human Health Risk Assessment (BHHRA; see Section 2.7 below) and the known history of manufacturing operations at the WOC Facility (including information obtained from employee interviews conducted by the ADEQ), arsenic was not considered a COC at the WOC Facility.

2.4 CHRONOLOGY OF SITE ACTIVITIES

The following outlines many of the events and investigative milestones for the project:

1987 — WCC reports that ADHS identified dissolved-phase VOCs in the on-site production well (hereafter called "the WOC irrigation well"[3] or "the Pincus Well") in 1984 (WCC, 1987). WCC collects 10 soil samples at the Lansdale facility on the Middle Parcel and analyzes them for VOCs. The results are reported in a preliminary site investigation for Lansdale.

1989 — Earth Technology Corporation (Earth Tech) begins regional groundwater investigations for ADEQ (Earth Tech, 1989; 1994; 1996).

ADEQ conducts site inspections of all three WOC Facility parcels (ADEQ, 1989 a,b,c) after the results of preliminary assessments recommended further investigations based on evidence of historic TCE usage at the WOC Facility. ADEQ conducts a soil-gas survey on all three parcels in conjunction with drilling operations as part of the site investigations.

1991 — Applied Environmental Consultants completes a Phase I RI/FS on the West Parcel of the WOC Facility on behalf of May Industries to identify any soil contamination.

July 1991 — WCC begins a preliminary site characterization of the WOC Facility (on behalf of Components, Inc.) that includes a geophysical survey and a

[3] This well was designated the WOC irrigation well based on its observed use for landscape irrigation in 1987, when environmental investigation was undertaken by WCC.

subsurface soil investigation. The results of the geophysical survey are used to identify subsurface utilities in order to select locations for the subsurface soil investigation. Five groundwater monitoring wells are installed into the SGWS at the WOC Facility (MW-1S thru MW-5S).

1996 UIC completes the Phase I and Phase II Soil Investigation, which includes the following:

- Excavation and sampling of test trenches and pits to locate waste disposal features, such as septic tanks, tile lines, and seepage pits;
- Removal of contaminated septic tanks as a source control measure;
- Drilling of soil borings in potential source areas to determine the horizontal and vertical extent of the VOC contamination; and
- Evaluation of potential releases from piping.

Ten groundwater monitoring wells (MW-6S, MW-7S, MW-2M, MW-3M, MW-4M, MW-6M, MW-7M, MW-4L, MW-6L and MW-7L) are installed in the SGWS (S-series wells), LSGS (M-series wells), and Middle Alluvial Unit (MAU; L-series wells) at locations designated in the 1996 Consent Decree and ADEQ-approved Work Plan. Monitoring and sampling of all groundwater monitoring wells installed by BCC begins.

1997 Nine groundwater monitoring wells (MW-100S, MW-l01S, MW-102S, MW-103S, MW-104S, MW-102M, MW-105M, MW-106M, and MW-13M) are installed in the SGWS and LSGS pursuant to ADEQ approvals. Monitoring and sampling of these wells begins, in addition to continued monitoring and sampling of the 15 wells already in place.

Additional monitoring wells are installed over the next 10 years to define the lateral extent of the TCE impacts to the SGWS and LSGS. All new wells are added to the groundwater monitoring network upon their completion.

January 1998 The Salt River Project (SRP) constructs the lining of the Grand Canal located adjacent north of the WOC Facility. Prior to 1998, the Grand Canal was unlined in the vicinity of the WOC Facility and served as a source of groundwater recharge.[4]

[4] The recharge created a water table mound, which acted as a groundwater divide between the North Canal Plume (NCP) WQARF Site and the Site. After the groundwater mound dissipated over time, many shallow wells near the Grand Canal dried up. In addition, groundwater flow north of the Grand Canal shifted to the south, allowing contaminants to migrate from the NCP onto the Site.

June 1999	An SVE system is installed as part of an ERA at the Middle Parcel of the WOC Facility and is initiated in August 1999.
September 2002	Confirmation soil borings and soil sampling are completed to evaluate the progress of the SVE remediation. Based on these results, the SVE system is decommissioned in October 2002. A total of approximately 449 pounds of VOCs are removed from the vadose zone between August 1999 and October 2002.
July 2004	GeoTrans issues the RI Report. As part of the RI, the WOC irrigation well is abandoned in accordance with Arizona Department of Water Resources (ADWR) regulations. ADEQ issues the Land and Water Use Report for the Site.
May 2005	ADEQ issues the RO Report for the Site.
2005- 2010	Groundwater sampling of SGWS monitoring wells is conducted in June 2005, September 2006, June 2007, December 2007, May 2008, September 2008, December 2008, March 2009, September 2009, and September 2010. Groundwater sampling of LSGS wells is conducted in July 2005, September 2006, September 2007, September 2008, March 2009, September 2009, and September 2010. This work is performed concurrently with additional downgradient characterization of contamination in the SGWS and LSGS, including the installation and sampling of wells MW-203S through MW-209S, and MW-203M.

All WOC groundwater monitoring wells used historically at the Site are shown in Figure 2-2, along with the COP and SRP production wells; groundwater monitoring well construction information is provided in Table 2-1. Other groundwater monitoring wells of interest in the WCP WQARF Site area are shown on Figure 2-2.

2.5 WOC FACILITY DESCRIPTION

The WOC Facility is located within the S1/2 of the SE1/4 of the NE1/4 of Section 27, Township 2 North, Range 2 East of the (Gila and Salt River Baseline and Meridian). It is bounded by the Grand Canal on the north, Osborn Road on the south, 35th Avenue on the east, and the extension of 37th Avenue on the west (Figures 1-1 and 2-1). The WOC Facility is approximately 15 acres in size and consists of three properties, the East, Middle, and West Parcels. Figure 2-1 shows each of the three properties and the locations of existing buildings and other pertinent features.

West Parcel – The West Parcel totals approximately 8 acres and is comprised of six individual parcels, as identified by the Maricopa County Assessor's Office. Seven buildings and asphalt parking lots are currently located on the West Parcel; two of the seven buildings are industrial buildings, and five are multi-tenant office buildings. Until 2000, the majority of the West Parcel, with exception to the northeastern-most parcel, was owned by Mr. Charles May and occupied by May Industries, Inc. (May Industries). The May Industries' portion of the property included one industrial building that housed a precision machine shop and 2.6 acres of land in the northwest portion of the West Parcel. The other building, located at the northeastern corner of the parcel, was occupied by Metal Joining, an affiliate of May Industries, Inc. The parcel transferred ownership to Elm Properties, LLC in February 2000. The northeastern parcel of the West Parcel was owned by Ms. Gloria Chestnut until April 2000, when it was sold to Elm Properties, LLC.

Middle Parcel – The Middle Parcel is approximately 3.9 acres in size and is partially enclosed with a chain-link fence. Structures on the Middle Parcel include a large main building and a small storage shed located north of the main building. There are three, relatively small, unpaved dirt areas located along the western and eastern boundaries of the Middle Parcel. The remaining exterior areas are paved, primarily with asphalt. The Middle Parcel is currently owned by Mr. Charles Delaney, who has owned the property since December 1992, when he purchased it from Lenore U. Pincus Family Trust. A mattress and furniture liquidation and used furniture auctioning and sales have been the tenants at the Middle Parcel since approximately December 1992. The Pincus Well was located in the northwest part of the Middle Parcel and was abandoned in July 2004.

East Parcel – The East Parcel is approximately 3.2 acres in size and is completely enclosed by a chain-link fence. One multi-tenant commercial/industrial building is located on the parcel. The driveways and parking areas are paved with asphalt. Till September 2002, the property was owned by Eugene and Laura Perri, and the main tenant was Western Dynex, Inc. Since September 2002, the East Parcel has been owned The Seven Angels, LLC. The East Parcel is currently occupied by Industrial Chassis, Inc.

2.6 WOC FACILITY HISTORY

Like most of the central part of the Phoenix metropolitan area, beginning in 1889, the WOC Facility and the surrounding area were used for agricultural purposes and irrigated with water from the Grand Canal. The history of development at the WOC Facility was previously provided by others (WCC, 1987; ADEQ, 1989 a,b,c; U.S. Environmental Protection Agency [EPA], 1989; and BCC, 1992) and summarized below.

In about 1957, the first building was constructed on what is now the East Parcel. A second building was added north of the first one between 1961 and 1964, and the two buildings were eventually connected with additions. Buildings on what is now the Middle Parcel were constructed between 1958 and 1961, and the West Parcel was not developed until after 1980.

The WOC Facility ownership history is shown in Table 2-2. According to the ADEQ, from 1957 to 1989, all entities operating at the WOC Facility were involved in the manufacturing of electronic components, their manufacturing processes were similar, and each used trichloroethene (TCE) as a solvent (ADEQ, 1989 a,b,c). The ADEQ evaluated manufacturing processes and solvent usage by conducting interviews with employees and former employees. ADEQ also obtained purchase records for solvents and disposal records for wastes, and asked former and present owners and tenants to fill out hazardous waste questionnaires. The results of these activities are summarized in the ADEQ's site investigation reports (ADEQ, 1989 a,b,c).

Topp Industries, Inc. purchased the property in July 1959; they merged with United Industrial Corporation (UIC) the same month, with UIC as successor in merger. Later that month, the deed was transferred from UIC to U.S. Semiconductor Products, Inc., a subsidiary of UIC. In May 1962, the property was acquired by Nucor Corporation, which sold the property to Components, Inc. (old) in October 1965. Components, Inc. sold the property in June 1971 to Corning Glass Works. Components, Inc. (new), a subsidiary of Corning Glass Works, operated at the WOC Facility between June 1971 and October 1976. Between 1976 and 1978, Corning Glass Works, through Components, Inc. (new), subdivided the WOC Facility into three separate properties (the East, Middle, and West Parcels) and sold them starting in October 1976. The ownership of the three parcels is presented in Table 2-2.

The East Parcel was purchased by Eugene and Laura Perri in November 1976. Western Dynex, Inc. operated at the East Parcel, and assembled computer disk drives from November 1976 through September 2002. The Middle Parcel was sold to Marbar Corporation (controlled by the Pincus family) in October 1976. Lansdale Transistor & Electronics, Inc., who produced transistors and semiconductors, operated on the Middle Parcel between November 1976 and February 1987, followed by Lansdale Semiconductor, Inc. The property was sold to Mr. Charles Delaney (current property owner) in December 1992. The West Parcel was sold to Mr. Charles May in June 1978 and operated as a multiple-tenant office and industrial park with many operating business that included, but are not limited to: May Industries, Inc., Metal Joining, Arizona Textile, and Aztec Chemical.

After the subdivision and sale, the WOC Facility continued to be used for electronics manufacturing and assembly. Lansdale Transistor & Electronics, Inc., and subsequently Lansdale Semiconductor, Inc., leased the Middle Parcel from approximately October 1976 through December 1988 for the manufacture of transistors. Western Dynex, Inc. assembled computer disk drives on the East Parcel from November 1976 through September 2002. According to the ADEQ, both of these facilities used solvents: TCE at Lansdale, and TCE and TCA at Western Dynex, Inc. May Industries began operations at the West Parcel in about 1980 and used TCA, along with other chemicals.

In 1982, TCE was detected in City of Phoenix (COP) wells COP-70 and COP-71, located downgradient of the WOC Facility, at concentrations exceeding the EPA Maximum Contaminant Level (MCL) of 5 micrograms per liter (µg/L). The WOC Facility and the plumes originating from it were originally designated as the West Central Phoenix (WCP) WQARF Site in 1987. However, in 1998, the WCP WQARF Site was divided into five WQARF Registry Sites, one of which is the Site.

2.7 RISK EVALUATION FROM RI REPORT

2.7.1 Baseline Human Health Risk Assessment

In February 2000, Roy F. Weston (currently Weston Solutions) prepared a BHHRA for the Site to evaluate potential chemicals of concern (COCs) (Weston, 2000):

- Soil: Arsenic and TCE at the WOC Facility; and

- Groundwater: TCE, PCE, 1,1-DCE, bromodichloromethane, and chloroform in groundwater at and downgradient of the WOC Facility.

The BHHRA was divided into the following exposure areas and evaluated separately:

- Surface soils at the WOC Facility;

- Four subsurface soil areas at the WOC Facility; and

- Five groundwater exposure areas.

The no-action alternative was evaluated based upon soil and groundwater use at the WOC Facility (on site) and groundwater use in the downgradient residential neighborhood (off site). The following exposure pathways were evaluated:

- Exposure to surface soils at the WOC Facility by current on-site industrial/commercial workers and trespassers;

- Exposure to groundwater by current residents of downgradient neighborhoods living above contaminated groundwater; and

- Exposure to subsurface soils at the WOC Facility by current on-site construction workers, future residents, and future industrial/commercial workers.

Intakes and risks were calculated under reasonable maximum exposure (RME) and central tendency (CT). The following is a summary of the RME results:

- Current On-site Trespassers:
  - *Total Carcinogenic Risk*: 1.7E-06, thus on the lower regulatory risk range set by EPA and the State of Arizona of 1E-06 to 1E-04; arsenic accounted for approximately 99% of the total cancer risk; and
  - *Total Hazard Indices (HIs)*: <1, thus below the benchmark of concern.

- Current On-Site Industrial/Commercial Worker:
  - *Total Carcinogenic Risk*: 8.9E-06, thus on the lower regulatory risk range of 1E-06 to 1E-04; arsenic accounted for approximately 99 percent (%) of the total cancer risk; and
  - *Total Hazard Indices (HIs)*: <1, thus below the benchmark of concern.

- Current/Future Off-Site Child and Adult Residents:
  - *Total Carcinogenic Risk*: 1.8E-4 (above the regulatory risk range of 1E-06 to 1E-04; majority of risk (51%) due to inhalation of VOCs during non-ingestion groundwater use, and groundwater ingestion (approximately 47%); 1,1-DCE accounted for about 80% of the risk; and
  - *Total HIs*: 4.1 for child and 2.8 for adult, thus above the benchmark of 1; TCE and chloroform accounted for approximately 94% of the total HI.

- Future On-Site Child and Adult Residents:
  - On-site Soil:
    - *Total Carcinogenic Risk*: 1.4E-07 to 1.8E-05, depending on the location; based on arsenic and/or TCE; and,
    - *Total HIs*: <1, thus below the benchmark of concern.
  - Groundwater:
    - *Total Carcinogenic Risk*: 3.5E-04; majority of risk (51%) due to inhalation of VOCs during non-ingestion groundwater use, and groundwater ingestion (approximately 47%); 1,1-DCE accounted for about 75% of the risk; and
    - *Total HIs*: 7.2 for child and 4.8 for adult; TCE accounted for about 94% of the Total HIs.

- Future On-Site Industrial/Commercial Worker:
  - On-Site Soil:
    - *Total Carcinogenic Risk*: greater than 1E-06 but lower than 1E-05; arsenic accounted for most of the risk; and
    - *Total HIs*: <1, thus below the benchmark of concern.
  - Groundwater:
    - *Total Carcinogenic Risk*: 4.4E-05, thus within the regulatory range; the majority of the risk (approximately 88%) was due to groundwater ingestion; 1,1-DCE accounted for approximately 76% of the risk; and
    - *Total HIs:* <1, thus below the benchmark of concern.

- Future On-Site Construction Worker:
  - *Total Carcinogenic Risk*: Less than 1E-06, thus below the regulatory risk range; and
  - *Total HIs*: <1.0, thus below the benchmark of concern.

2.7.2 Summary

The BHHRA calculations indicated TCE, 1,1-DCE, PCE, and/or arsenic to be the primary chemicals of potential concern. The BHHRA concluded the following:

- Receptors that are not exposed to total carcinogenic risks above the lower limit of the regulatory risks range of 1E-06 to 1E-04 and to total hazard index below 1, the benchmark of concern, are as follows:
  - On-site trespassers; and
  - Future on-site construction workers.

- Receptors that are exposed to total carcinogenic risks within the regulatory range of 1E-06 to 1E-04 and to total hazard index below 1, the benchmark of concern, are as follows:
  - On-Site Soil: Future on-site child and adult residents; and
  - On-Site Soil and Groundwater: Future on-site industrial/commercial workers.

- Receptors that are exposed to total carcinogenic risks above the regulatory range of 1E-06 to 1E-04 and to total hazard index above 1, the benchmark of concern, are as follows:
  - Groundwater: Future on-site child and adult residents; and
  - On-Site Soil and Groundwater: Future on-site industrial/commercial workers.

2.7.3 Conclusions

Because no direct domestic or municipal use of groundwater is currently occurring, and no future use is planned without treatment, it was concluded by GeoTrans that the groundwater exposure pathway is not complete for on- or off-site receptors. For this reason, the risks identified in the BHHRA are believed to be over-estimated for groundwater exposure at the Site.

Risk assessment calculations for exposure to arsenic in soils at the WOC Facility are based upon soil samples which include one anomalously high concentration of 120 mg/kg. This has resulted in an overestimated risk from arsenic in soils at the WOC Facility. Consequently, there is no need for remediation of on-site soils.

Thus, based on the BHHRA findings and the known history of manufacturing operations at the WOC Facility (including information obtained from employee interviews conducted by the ADEQ), it was concluded by GeoTrans that TCE, PCE, and 1,1-DCE are the only COCs for the Site.

3.0 FEASIBILITY STUDY SCOPING

3.1 REGULATORY REQUIREMENTS

According to ARS §49-282.06, the following factors must be considered in selecting remedial actions:

- Population, environmental and welfare concerns at risk;
- Routes of exposure;
- Amount, concentration, hazardous properties, environmental fate, such as the ability to bio-accumulate, persistence and probability of reaching the waters of the state and the form of the substance present;
- Physical factors affecting environmental exposure, such as hydrogeology, climate, and the extent of previous and expected migration;
- The extent to which the amount of water available for beneficial use will be preserved by a particular type of remedial action;
- The technical practicability and cost-effectiveness of alternative remedial actions applicable to a site; and
- The availability of other appropriate federal or state remedial action and enforcement mechanisms, including, to the extent consistent with this article, funding sources established under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), to respond to the release.

The Remedy Selection Rule R-18-16-407, Feasibility Study, states that an FS is a process to identify a reference remedy and alternative remedies that appear to be capable of achieving ROs and to evaluate the remedies based on the comparison criteria to select a remedy that complies with ARS §49-282.06.

3.2 CONCEPTUAL SITE MODEL SUMMARY

3.2.1 Site History

A detailed history of the Site, including documentation on timing of contamination, a Site timeline, and the significant events and their impact to the Site and associated contamination is presented in the RI report (GeoTrans, 2004).

Originally, the WOC Facility consisted of about 15 acres that are presently subdivided into three parcels: East, Middle, and West. Beginning in 1957, the WOC Facility was used by different owners to manufacture electronic components. Solvents, including TCE, were used in the manufacturing processes. When the WOC Facility was first developed, there was no municipal sewer service, and on-site systems, consisting of septic tanks and seepage pits, were used for wastewater disposal. Although the time period over which contamination occurred is unknown, and chlorinated solvent use at the WOC Facility occurred until after 1980, it is believed that TCE was introduced to the ground via drainage from seepage pits during the time period between 1957 and 1965. GeoTrans found five septic tanks and 17 seepage pits during a 1996 soil investigation, described in detail in the RI report. TCA contamination is believed to have occurred between 1978 and 1990, associated with its use on the West Parcel and East Parcel by May Industries and Western Dynex, respectively. Additionally, TCE contamination is believed to have impacted the LSGS aquifer via the WOC irrigation well, a 581-ft deep well located at the northern end of the Middle Parcel of the WOC Facility, subsequently abandoned in July 2004.

Upon being introduced to the soil, the chlorinated solvents began downward infiltration, driven by gravity, and periodic precipitation. They reached the SGWS aquifer, and began dissolving in the groundwater and flowing south, away from the Grand Canal. Some of the solvent likely remained in the soil as NAPL or sorbed to the finer-grained clays beneath the Site, which impeded their downward progress. Ultimately, the downward infiltration of solvents introduced to subsurface soils at the seepage pits was stopped by the higher clay content in the middle fine-grained unit, from which they likely continued to dissolve, contributing to the groundwater plume in the SGWS. In accordance with the RI/FS Work Plan that was incorporated into the Consent Decree, an interim remedy was implemented to achieve shot-term mass removal of VOCs from investigated sources. This remedy consisted of an SVE system, which operated in an area where former septic tanks and seepage pits were installed at the Middle Parcel to remove VOCs that would otherwise be susceptible to contaminating groundwater. The SVE system was installed in June 1999 and operated from August 4, 1999 through October 21, 2002. A total of approximately 447 pounds of VOCs were extracted from the subsurface and treated with vapor-phase granular activated carbon (VGAC) to remove VOC prior to discharge into the atmosphere.

On behalf of UIC, GeoTrans submitted a technical letter on September 11, 2001 to ADEQ, requesting ADEQ's approval to permanently shut-down the SVE system operation. Consequently, confirmatory drilling/sampling was conducted in September 2002. The results showed that no detectable VOCs were present in 39 subsurface samples collected from the SVE remediation zone. Based on these results, the justification specified in GeoTrans' September 11, 2001 letter was deemed satisfied by ADEQ, and the SVE system was shut down on October 21, 2002. The activities and the analytical results associated with the confirmatory soil drilling and sampling were all contained in the GeoTrans' report entitled *Confirmatory Drilling/Soil Sampling Results for Shut-Down of Interim SVE Remediation System, Middle Parcel, West Osborn Complex*, submitted on January 23, 2004. Currently, based on the results of the SVE confirmation borings, there is no continuing on-site source of VOCs to the shallow groundwater.

3.2.2 Site Hydrogeology

In 1993, the ADWR released the results of its modeling study of the Salt River Valley (Corkhill et.al. 1993). For modeling purposes, the ADWR defined three hydrogeologic units that are generally correlative with the hydrostratigraphic units defined by the United States

Bureau of Reclamation in 1976. These include: the Upper Alluvial Unit (UAU), the Middle Alluvial Unit (MAU), and the Lower Alluvial Unit (LAU). For this report, the ADWR's hydrostratigraphic nomenclature has been used. The wells that were drilled at the WOC were denominated with the suffixes S, M, and L. No wells at the WOC were completed in the LAU. The L-series wells were completed in the MAU, the M-series wells were completed in the deepest part of the UAU, and the S-series wells were completed in the upper part of the UAU. Therefore, the S-, M-, and L-series wells will be referred to as simply the shallow, intermediate, and deep wells.

In the vicinity of the WOC Facility, the aquifer units of concern include the UAU, and to a lesser extent the MAU. The UAU is the uppermost basin fill unit in the SRV and, where saturated in the West Salt River Valley, is the most prolific water producer. It is composed mainly of silt, sand, and gravel, but local, usually relatively thin, clay layers can be present. Near the WOC, the UAU is much finer-grained than approximately 1.5 miles to the south, closer to the Salt River channel. The UAU has been encountered in all of the previous wells that have been drilled in the West Central Phoenix WQARF Study Area. Most of these have been shallow water-table wells and have only penetrated the top approximately one-half of the Unit. However, the entire thickness was drilled at several locations for the WOC RI, and at most of these, three or four subunits of the UAU can be recognized. Of particular relevance are the SGWS, consisting of silts and sands, typically present at a depth of 70-130 feet bgs, the Middle Fine-Grained Unit (MFGU), typically consisting of silt and clay, and present beneath the SGWS, and the LSGS, a sand and gravel present beneath the MFGU. The LSGS is the most significant water-bearing zone in the vicinity of the WOC. Its distinctive geophysical signature is present on most of the well logs, and shows relatively good continuity between all wells that were drilled to a sufficient depth. Aquifer tests show that it also has the capacity to transmit large quantities of water (Section 5.0, RI Report; GeoTrans, 2004). It was the target zone for the M-series wells that were drilled for the RI.

3.2.3 Groundwater Flow and Contaminant Transport

Groundwater flow directions and gradients at the WOC Facility have varied based on aquifer characteristics. Prior to lining of the Grand Canal, groundwater flowed radially away from the canal within the underlying SGWS. At greater depth, the flow direction in the LSGS was slightly south of east to west. Groundwater recharge associated with the Grand Canal is believed not to have significantly influenced flow direction or gradient in the LSGS due to the presence of the middle fine-grained unit. Following lining of the canal, flow gradients in the SGWS decreased from 0.05 to 0.001 foot per foot (ft/ft). Although flow direction in the SGWS did not significantly change, the elevation of the water table declined at the WOC Facility area over time by approximately 40 feet from 1996 to 2011. At the LSGS wells, horizontal gradients have been consistently south-southwest, except in June 1997, when the SRP well was pumping. The value of the horizontal gradient in the area of the WOC Facility has ranged from about 0.005 to 0.01 ft/ft. Southwest and downgradient of the WOC Facility at the Site, between MW-107M and MW-110M, the gradient is about 0.002 ft/ft.

At present, groundwater contamination continues to move downgradient from the WOC Facility in the direction of groundwater flow. Based on groundwater monitoring results, the SGWS plume has impacted groundwater at MW-208S, which is the farthest well to the south in the existing WOC Site well network. The groundwater plume in the LSGS is believed to be delineated at the downgradient edge by MW-108M, which has typically been below the 5.0 microgram per liter (μg/L) AWQS for TCE. Water seepage velocities in the LSGS have been estimated in a range from 2 to 14 ft/day. TCE concentrations initially detected at MW-108M in 2003 have not significantly increased since, suggesting that the LSGS plume has stabilized.

A second chlorinated VOC groundwater plume has historically been present north of the WOC Facility and its associated plumes. The North Canal Plume (NCP) consists of similar contaminants, including TCE, PCE and 1,1-DCE, in different concentrations than those of the WOC plumes, in particular containing elevated concentrations of PCE not seen in the WOC plumes. Until the Grand Canal was lined in 1998, the NCP remained entirely north of the Canal and was prevented from moving southward past the canal by the mounded water infiltrating through the canal bottom. As the hydraulic mound of the leaky canal dissipated in the early 2000's, the NCP began flowing southward, co-mingling with the WOC plume, as indicated by increasing concentrations of PCE in the SGWS since the canal was lined. Concentrations of TCE and 1,1-DCE in the SGWS also began to increase following lining of the canal.

Additionally, following canal lining, PCE concentrations in the LSGS began increasing, suggesting a pathway from the SGWS to the LSGS. The annular space around the well casing of the WOC irrigation well (abandoned in 2004) is believed to have been the former pathway between the SGWS and LSGS, enabling contaminants from the NCP SGWS to infiltrate through the MFGU to the LSGS.

3.2.4 Hydraulic Communication Between SGWS and LSGS

Hydraulic communication between the SGWS and the LSGS is believed to be minimal. The hydrostratigraphic unit between the SGWS and LSGS consists of a thick sequence of silts and clays that act as an aquitard. Groundwater flow directions and potentiometric surface elevations are significantly different in the SGWS compared to the LSGS. As noted in the RI report, there are large vertical groundwater gradients at the WOC Facility noted between the two aquifers. Hydraulic stresses affecting one aquifer have minimal effect on the other. In particular, the set of data collected during the March 1997 through December 1997 time period reveals a direct correlation between large water level changes in the LSGS (MW-6M), likely due to regional pumping, with much smaller and slightly lagged-in-time responses in the shallow (MW-6S) and deep (MW-6L) monitor wells. While 30 to 35 feet of drawdown was observed in LSGS wells MW-2M, -3M, -4M,-6M, -7M, and the WOC irrigation well as a result of this pumping (at an estimated rate of 2,600 gpm), the observed drawdown in the shallow aquifer monitoring wells was generally 2 feet or less. The connection appears to be so poor that the two zones behave very differently in response to most aquifer stresses (e.g., canal recharge to the SGWS, or regional pumping in the LSGS). Although a poor hydraulic connection between the water table system (i.e., SGWS) and the LSGS appears to exist, no apparent changes in the gradient in the LSGS associated with the canal lining have been observed. This supports the interpretation of a poor hydraulic connection, and subsequent low vertical flux, between the SGWS and the LSGS subunit (GeoTrans, 2004).

For these reasons, the SGWS and LSGS are believed to represent aquifers for which the degree of hydraulic connection is extremely low. As a result, the two aquifers may be treated as though they are essentially hydraulically isolated and independent of each other for the purposes of remedial system design.

3.2.5 Baseline Human Health Risk Assessment

As discussed in Section 2.7, Weston prepared a BHHRA for the Site (Weston, 1999). In summary, the BHHRA calculations indicated TCE, arsenic, and/or 1,1-DCE to be the primary chemical of potential concern, resulting in the following:

- Receptors that are not exposed to total carcinogenic risks above the lower limit of the regulatory risks range of 1E-06 to 1E-04 and to total hazard index below 1, the benchmark of concern, are as follows:
  - On-Site trespassers; and,
  - Future on-site construction workers.

- Receptors that are exposed to total carcinogenic risks within the regulatory range of 1E-06 to 1E-04 and to total hazard index below 1, the benchmark of concern, are as follows:
  - On-Site Soil: Future on-Site child and adult residents; and,
  - On-Site Soil and Groundwater: Future on-Site industrial/commercial workers.

- Receptors that are exposed to total carcinogenic risks above the regulatory range of 1E-06to 1E-04 and to total hazard index above 1, the benchmark of concern, are as follows:
  - Groundwater: Future on-site child and adult residents; and
  - On-Site Soil and Groundwater: Future on-site industrial/commercial workers.

Weston also calculated Preliminary Remediation Goals for those scenarios where the total cancer risk exceeded 1E-06 or the total hazard index exceeded 1.

Because no direct domestic or municipal use of groundwater is currently occurring, and no future use is planned without treatment, the groundwater exposure pathway is not complete for on- or off-site receptors. For this reason, the risks identified in this assessment may be over-estimated for groundwater exposure at the WOC Facility and surrounding areas.

Similarly, risk assessment calculations for exposure to arsenic in soils at the WOC Facility are based upon soil samples which include one anomalously high concentration of 120 mg/kg. This is believed to have resulted in an overestimated risk from arsenic in soils at the WOC Facility.

3.3 DELINEATION OF REMEDIATION AREAS

According to the ADEQ-approved FS Work Plan (GeoTrans, 2005), no further remediation is required for the unsaturated zone at the WOC Facility based on the success of the on-site SVE system and the results of the subsequent confirmation borings. Therefore, for the purpose of the FS, only compounds whose groundwater concentrations have exceeded the relevant AWQSs are considered for the determination of the extent of contamination in SGWS groundwater. The following is a summary of the extent of Site SGWS contamination:

- Based on GeoTrans' review of the Site historical groundwater quality data and the groundwater quality data from December 2008 (presented in Table 3-1), TCE, PCE, and 1,1-dichloroethene (1,1-DCE) are the Site contaminants of concern (COCs); and

- The groundwater remediation area (Figure 3-1) is defined as the WOC portions of the SGWS with concentrations of COCs that, in December 2008, exceeded their respective AQWSs: 5 micrograms per liter (μg/L) for TCE, 5 μg/L for PCE, and 7 μg/L for 1,1-DCE.

3.3.1 Groundwater

A comprehensive understanding of the type and extent of contamination and fate and transport of the COCs is essential to define the nature and extent of contamination at the Site, meet the ROs, and determine the remedial alternatives.

3.3.1.1 Aquifer Characteristics

Average transmissivity values for the SGWS at the Site range from 350 ft^2/day at MW-7S to 7,500 ft^2/day at MW-6S. At MW-7S, recovery data are considered more representative than drawdown data. At MW-5S and MW-6S, drawdown and recovery data are considered approximately equally representative.

Results from the tests at MW-7S and MW-6S are reasonable and correlate with the lithologic characteristics of the screened intervals. Lithologic and geophysical logs show that MW-6S is screened across a coarser-grained part of the Upper Alluvial Unit (UAU)[5] than MW-7S.[6] The results from MW-7S are similar to results obtained from BCC's tests at on-site wells.

Results from MW-5S are considered to be under-representative, even though the test at MW-5S was the longest of any that were conducted at the Site (24 hours). The yield of the MW-5S well is low compared to observed yields at nearby wells, MW-100S and MW-101S. When MW-100S and MW-101S were developed after drilling, they could be pumped at rates of more than 10 gallons per minute (gpm) with only small drawdown. However, MW-5S could not sustain a pumping rate of 10 gpm during a pre-test, and the aquifer test was eventually

[5] The UAU is the upper hydrostratigraphic unit of the Salt River Basin. According to the ADWR, the UAU is typically 300 to 400 feet thick in the West Salt River Basin.
[6] MW-6S and MW-7S have gone dry.

conducted at 6 gpm. A possible explanation is that a portion of the fine-grained material present at the well screen depths was not completely removed during the well development process.

Based on the transmissivity range of 350 to 7,500 ft^2/day and a saturated thickness of 10 feet at MW-7S and 35 feet at MW-6S, hydraulic conductivities in the SGWS range from 35 to 210 ft/day. Based on borehole lithologic logs, these estimates are believed to be high for the SGWS in its entirety. However, they may be representative of select sand zones intersected by the wells.

3.3.1.2 Groundwater Movement

Complete results of water elevation measurements for the RI groundwater investigation at the Site are presented in the RI Report, Table 5-6 (GeoTrans, 2004b). During the period 1996 through 2003, significant changes were observed in the depth to groundwater, the direction of the horizontal gradient, and the values of the vertical and horizontal gradients. Most of the hydrogeologic changes that have been observed in the SGWS are directly related to the SRP water delivery system, which includes the Grand Canal (Figure 2-2). The Grand Canal was constructed in the early 1900's, and with the exception of a gunite lining placed by the SRP in January 1998, all of the present features were in place by 1950, before the WOC Facility was first developed. Prior to January 1998, the canal was lined east of the Eastern Parcel of the WOC Facility, but unlined to the west. With the lining of the Grand Canal, a significant source of recharge to the SGWS was greatly reduced.

As shown on Figure 3-2, presenting WCP WQARF Site SGWS groundwater elevations and flow direction for September 1995 (prior to the lining of the Grand Canal in January 1998), infiltration from the unlined canal had major impacts on the SGWS water levels, groundwater gradient, and flow direction. Water loss from the canal was great enough to create a recharge mound beneath the canal along the northern edge of the WOC Facility and westward. This recharge created a south or southeast flow from the WOC Facility, toward the future location of MW-202S. At this time, water-level data were very limited south of Thomas Road, and the direction of flow was poorly known further south. Contaminated water from the NCP did not flow beneath the WOC Facility because of the mound, but instead flowed either to the north or to the east. The water flowing to the east could flow beneath the lined canal east of the Site.

Figure 3-3, illustrating WCP WQARF Site SGWS groundwater elevations and flow direction for September 1999 (after the canal was lined), shows the mound seen two years earlier significantly dissipated. Water from the WCP could begin to move beneath the WOC Facility after the gradient reversal had dissipated. Flow from the WOC Facility was still toward the south-southeast, but appears to have a more westerly component south of MW-104S.

By September 2008 (Figure 3-4), a northeasterly trending trough in the water level data is present with an axis that passes near MW-203S and MW-202S. Flow from the WOC Facility is toward this trough, but does not pass past the trough axis. There is also flow from east of the trough to the trough. MW-201S and MW-204S appear to be located on a potentiometric ridge that parallels the trough on its southeastern side. The trough and ridge were shown on a map prepared by ADEQ using September 2003 data (Figure 3-5). Under the present flow field, these wells are sampling water flowing from the east or northeast. In the area between Encanto Drive and McDowell Road, the direction of flow is approximately to the southwest.

The SGWS groundwater elevations and flow direction did not change significantly between September 2008 and December 2008, as shown on Figure 3-6.

The declining water levels in the WCP SGWS are a result of lining of the Grand Canal, increased regional groundwater pumping, and a period of sustained drought. Although some amount of hydraulic communication appears to be present between the saturated material intersected by the SGWS and LSGS wells, the connection appears to be so poor that the two zones behave very differently in response to most aquifer stresses (e.g., canal recharge or regional pumping). Therefore, water-level elevation measurements from SGWS have been evaluated separately.

Measurements from SGWS wells have been used to calculate the direction of the horizontal component of the groundwater gradient at the water table. At the SGWS wells, horizontal gradients have been consistently south-southeast before the Grand Canal was lined adjacent to the WOC Facility. At the WOC Facility, the value of the horizontal gradient has ranged from about 0.0021 to 0.032 feet/foot (ft/ft). In the area of MW-201S, MW-203S, and MW-204S, the gradient is westward and has ranged from about 0.0062 to 0.015 ft/ft.

Horizontal groundwater seepage velocities in the saturated zone were estimated using the following relationship:

$$V_s = \frac{K_h \cdot i}{n_e}$$

Where:

K_h = horizontal hydraulic conductivity;
i = horizontal hydraulic gradient; and,
n_e = effective porosity (estimated at 0.2).

Prior to canal lining, the estimated horizontal seepage velocities in the SGWS ranged from about 4 to 13 ft/day.

3.3.1.3 Extent of SGWS Contamination

The estimated areal extent of the December 2008 SGWS WOC plume is presented on Figure 3-1. The lateral extent of the WOC portion of the plume has been drawn on Figure 3-1, assuming that the upgradient boundary of the WOC plume is at the WOC Facility's Middle and East Parcel northern property boundaries. However, as discussed in Section 3.3 below, this is not believed to be the case due the presence of other upgradient source(s) which extend the physical plume northward beyond the WOC Facility boundaries. The following summarizes the extent of SGWS groundwater contamination at the Site:

- Groundwater contamination in the SGWS by TCE at concentrations greater than 5 μg/L extends beyond the following monitor wells: MW-3SR to the north, MW-202S to the east, MW-206S to the southeast, and MW-208S to the southwest;

- Groundwater contamination in the SGWS by PCE at concentrations greater than 5 μg/L extends beyond MW-3SR to the north and WCP-207 to the south. Note that according to historical WOC Facility information, PCE was not used in manufacturing; therefore, it is assumed that PCE has migrated onto the Site from one or more upgradient sources; and

- Groundwater contamination in the SGWS by 1,1-DCE at concentrations greater than 7 μg/L extends beyond MW-3SR to the north and WCP-207 to the south. A detached 1,1-DCE plume also exists in the central area of the Site plume, extending from north of MW-103S to beyond MW-206S to the south-southwest.

3.3.2 Time Series Plots – WOC SGWS Wells

Time-series plots were generated to evaluate the effects of the lining of the Grand Canal and time on the concentrations of PCE, TCE, and 1,1-DCE in selected NCP wells and the Site wells MW-3S/MW-3SR, MW-4S, MW-5S, and MW-102S/MW-102SR (see Appendix A). Plots with data from multiple site monitoring wells extend through 2008, representing the last event in which all sites were collectively. Plots with solely WOC well data extend through the latest sampling round in September 2011. A discussion of the time-series plots is presented below.

3.3.2.1 NCP

Locations of NCP wells are shown on Figure 3-7. NCP wells exhibiting significant changes in PCE, TCE, and 1,1-DCE concentrations were plotted on Figures A-1, A-2, and A-3, respectively. Because concentrations did not co-vary in a given well, Figures A-1, A-2, and A-3 highlight different selected wells. PCE concentrations, as plotted on Figure A-1, showed large fluctuations overall, but generally decreased in all wells, with the exception of well WCP-227. TCE concentrations (Figure A-2) either increased or decreased significantly, depending on the area of the NCP site. However, in the wells immediately upgradient of the WOC Site, such as WCP-27, TCE concentrations generally decreased. 1,1-DCE concentrations also decreased across the NCP site (Figure A-3). A plot of PCE, TCE, and 1,1-DCE concentrations as a function of time at WCP-27 indicates a general decrease in contaminant concentrations since 2005 (Figure A-4). This observed decrease immediately upgradient of the WOC Site occurred long after the groundwater mound associated with infiltration from the unlined canal dissipated, thereby ruling out the possibility that the contaminants were stranded in a smear zone. The fact that the decrease was observed after the local groundwater gradient returned to normal regional flow suggests that the center of mass of the NCP has moved downgradient of WCP-27 and is now detected at MW-3SR and other downgradient WOC wells.

3.3.2.2 MW-3S/MW-3SR

Concentrations of PCE, TCE, and 1,1-DCE in monitoring well MW-3S, installed on the northern boundary of the West Parcel and thus immediately downgradient of the NCP and cross-gradient of the WOC Facility source area in the Middle Parcel, were below the laboratory detection limits prior to the lining of the Grand Canal (Figure A-5). Shortly after the canal was lined, water levels dropped and MW-3S went dry. A replacement well, MW-3SR, drilled in the immediate vicinity of MW-3S in October 2007 and screened deeper in the shallow aquifer, consistently contained concentrations of PCE, TCE, and 1,1-DCE well above the respective AWQSs. The dramatic increase in contaminant concentrations indicates impacts from the NCP plume by migrating into the WOC plume after the lining of the canal. As stated earlier, prior to lining, leakage from the canal created a groundwater divide which prevented or reduced transport of contaminants from the NCP to the south. As detailed earlier, prior to lining, leakage from the canal created a groundwater divide which prevented or reduced transport of contaminants from the NCP to the south.

3.3.2.3 MW-4S

After the lining of the Grand Canal, TCE concentrations in MW-4S decreased dramatically from 600 μg/L in May 1997 to 7.2 μg/L in May 1998 (Figure A-6). The observed decrease in TCE concentrations may be due to the rapid decrease in water levels, resulting in a smear zone, thereby stranding the contamination at shallower depths which were no longer saturated.

Concentrations of PCE and 1,1-DCE were below laboratory detection limits during both cited sampling events; however, it should be noted that the detection limits in May 1997 for both compounds were 25 μg/L in May 1997 and 0.50 g/L in May 1998 due to the dilution of the May 1997 sample. It is, therefore, possible that concentrations of both PCE and 1,1-DCE also decreased during this same time frame, but were not observed due to the relatively high detection limits in May 1997.

The last groundwater sample was collected in February 1999, after which the well went dry. Subsequent changes in contaminant concentrations at this location are not known, as the well was not deepened or replaced by another well.

3.3.2.4 MW-5S

Since its installation, concentrations of PCE, TCE, and 1,1-DCE decreased dramatically from a maximum of 480 μg/L TCE in November 1996 to 96 μg/L in February 1998 (Figure A-7). Concentrations of all three contaminants were monitored until March 2002, when the well went dry and was not replaced. Like MW-4S, the rapid decrease in the water levels may have created a smear zone in the vicinity of MW-5S, resulting in lower concentrations of contaminants observed in the well prior to the well going dry.

3.3.2.5 MW-102S/MW-102SR

Monitoring well MW-102S was installed and initially sampled immediately after the lining of the canal. TCE concentrations decreased from a maximum of 98 μg/L in May 1998 to 40 μg/L in February 1999 (Figure A-8). This decrease is also attributed to the formation of a smear zone. The well was not sampled again until June 2001, at which time the TCE concentration had increased to 59 μg/L. TCE concentrations continued to increase and reached a concentration of 120 μg/L in June 2003, after which MW-102S went dry.

In October 2007, a replacement well, MW-102SR, was drilled in the immediate vicinity of MW-102S and screened deeper in the SGWS. Since the installation of MW-102SR, TCE concentrations continued to increase to a maximum of 130 μg/L in December 2007. During the most recent sampling event in September 2011, TCE was present at a concentration of 91 μg/L. Concentrations of PCE and 1,1-DCE reflect similar trends at much lower concentrations. The gradual increase in concentrations of all contaminants over time suggests the migration of high concentrations from the upgradient NCP.

3.3.3 Flow and Transport of Contaminants

Based on the absence of TCE breakdown products (i.e., cis-1,2-DCE, trans-1,2-DCE, vinyl chloride, ethene, ethane), historic and future movement of the dissolved TCE and PCE groundwater plumes can largely be described by the advective movement of the groundwater. A gradual decrease in dissolved contaminant mass will naturally occur as the plume migrates downgradient. This decrease in concentrations is due to sorption to organic material and/or clay minerals within the aquifer, and dilution caused by dispersion.

3.3.4 Areas of Uncertainty

Migration of the dissolved-phase TCE, PCE, and 1,1-DCE plumes into the Site SGWS from the upgradient NCP WQARF site (see Section 3.3) will continue to occur. This continued migration may need to be addressed in the future by ADEQ. However, it is believed that the uncertainties related to the concentrations and fate and transport of the COCs into the Site SWGS do not preclude the selection of a preferred remedy.

3.4 EVALUATION OF IMPACTS TO THE SITE FROM OTHER WCP WQARF SITES

A complete record of groundwater quality monitoring for VOCs in the SGWS monitoring wells at the Site is provided in Table 3-1. A summary of general inorganic parameters in groundwater for select wells in included in Table 3-2. VOC concentrations in the Site SGWS wells for three sampling events (November 1996, September 2008, and December 2008) are presented graphically on Figures 3-8 through 3-10. The November 1996 sampling event was selected because it represents the earliest samples collected from the Site SGWS wells during a period before the Grand Canal was lined. The September 2008 sampling event was selected to display the most recent results for which both NCP and WOC data were available during the same sampling time frame. The December 2008 sampling event was selected as the most current snapshot of water-quality conditions at the Site.

Plume boundary maps for four WCP WQARF sites (WOC, NCP, North Plume, East Grand Avenue [EGA], and West Grand Avenue [WGA]), are shown on Figure 3-11. It should be noted that the NCP and WOC plumes are based on the most recent data, and the North Plume, WGA, and EGA are based on the January 2009 maps provided on the ADEQ website for these WQARF sites. Figures 3-12 through 3-15 illustrate the September 2008 concentration contours of the TCE, PCE, and 1,1-DCE plumes characterized at the NCP and the Site plumes. The plume contour maps illustrate the extent of the combined NCP-WOC plumes.

Maximum concentration plots (Figures 3-16 through 3-19) were also constructed to illustrate the highest concentrations of PCE, TCE, 1,1-DCE, and cis-1,2-DCE historically detected based on the available data from WOC, NCP, EGA, and WGA. While recent (i.e., through 2008) water-quality information was available from WOC, NCP, and EGA wells, wells associated with the WGA site have not been sampled since 2002. Therefore, wells located between WOC and Grand Avenue may not be representative of plume migrations over the last 7 years, particularly any downgradient plume migration from the WGA site.

The following sections compare the sources and observed migration of each contaminant from the four known source areas.

3.4.1 TCE Plume Boundaries

The TCE contour plot on Figure 3-12 indicates that there are currently two TCE plumes within the NCP: 1) an apparently detached TCE plume north of the Grand Canal, northwest of the WOC Facility source area in the Middle Parcel, that does not appear to be co-mingled with the WOC TCE plume; and 2) a plume that originates at NCP and extends underneath and south of the WOC Facility and has thus co-mingled with the WOC TCE plume.

An elevated concentration of TCE in the WOC plume (i.e., a hot-spot) was found in September 2008 at MW-3SR, which is located along the northern boundary of the West Parcel, thus immediately downgradient of the NCP and cross-gradient of the WOC Facility source area in the Middle Parcel. This hot-spot is thus assumed to be caused by the migration of the NCP. It should be noted that NCP wells to the north of MW-3SR had only slightly lower TCE concentrations in September 2008, as illustrated on Figure 3-13.[7]

The WOC TCE plume extends south-southwestward to MW-208S. Another hot-spot was observed in the MW-204S sample, collected in September 2008 in the central portion of the WOC plume. The concentration of TCE in this well is approximately twice that in wells immediately downgradient of the WOC Facility. The cause of this hot-spot is uncertain, but is possibly due to another upgradient source area towards the northeast. As discussed above, there is a hydraulic water-level trough that separates MW-204S from the WOC Facility; water flowing in the vicinity of MW-204S is believed to be coming from the northeast or east of the well.

Historical TCE hot-spots are evident in the northern portion of the WOC Site, the southern portion of the NCP site, the center of the WGA site, and the center of the EGA site (Figure 3-16). Mid-level concentrations of TCE have dispersed laterally and have moved downgradient from the known source areas. In addition, groundwater flow directions in the SGWS have changed due to the lining of the Grand Canal. Because of a shift in the

[7] In December 1999, WCP-14 contained 520 µg/L TCE, as shown on Figure 3-16.

groundwater flow direction in the vicinity of MW-202S from southerly to southwesterly, the hot-spot observed in the vicinity of MW-204S is likely the result of the downgradient migration of TCE from a source to the northeast of MW-204S. It is noted that both EGA and WGA are located upgradient from the well in this direction. High TCE concentrations have previously observed at the EGA source area (i.e., greater than 540 µg/L). It may also be important to note that, because the WGA wells located between the EGA source area and the WOC wells have not been sampled since 2002, the migration of contamination through the existing monitoring network may have been missed.

Elevated TCE concentrations have been observed since 1992 at the NCP, indicating that TCE was also used by the facilities within the NCP Site. However, TCE was not detected in MW-3S prior to the lining of the Grand Canal,[8] but was detected in MW-3SR since its installation in 2007. This well is located along the northern boundary of the West Parcel, thus immediately downgradient of the NCP, but cross-gradient of the WOC Facility source area in the Middle Parcel. The TCE contour plot indicates that the TCE plume boundary encompasses the NCP TCE plume. Therefore, it is believed that the NCP TCE plume has co-mingled with and has impacted the WOC TCE plume.

3.4.2 PCE Plume Boundaries

The PCE contour map on Figure 3-14 indicates the highest concentration of 420 µg/L PCE was encountered in 2008 at NCP's well WCP-213,[9] and that PCE concentrations generally decrease to the south (i.e., downgradient) of the NCP Site. The contour plot clearly indicates that the PCE plume originates to the north of the WOC Facility and extends southward across the Grand Canal and underneath the WOC Facility. A minor secondary PCE plume is evident to the south of the WOC Facility in the vicinity of MW-209S. Because none of the monitoring wells in the center of the Site TCE plume contain PCE above the AWQS and the PCE plume does not extend south to MW-209S, it is believed that the PCE detected at MW-209S originates from a different source area.

PCE hot-spots are evident in the southern and eastern portions of the NCP site and the center of the EGA site, as shown on Figure 3-17. Mid-level concentrations of PCE have dispersed laterally and have moved downgradient from NCP. Again, it is important to note that, because the WGA wells located between the EGA source area and the WOC wells have not been sampled since 2002, the migration of the plume through the interlying monitoring network may have been missed. The low concentration of PCE observed at MW-209S is disconnected from the known source areas and is likely the result of a release to the northeast.

It is believed that after the mound disappeared, PCE originating at the NCP migrated south of the canal and has appeared in the Site monitoring wells. This opinion is based on:

- The observed hot-spots of PCE concentrations at the NCP site;

[8] Shortly after the canal was lined, water levels dropped and MW-3S went dry. A replacement well, MW-3SR, was drilled in the immediate vicinity of MW-3S and screened deeper in the shallow aquifer.
[9] In December 1999, WCP-14 contained 690 µg/L PCE, as shown on Figure 3-17.

- Documentation indicating that PCE was not used at the Site (ADEQ, 1989 a,b,c); and

- Conclusions of the scientific community that TCE (which was used at the Site) cannot degrade to PCE by any in-situ reaction mechanisms.

3.4.3 1,1-DCE Plume Boundaries

The 1,1-DCE contour map on Figure 3-15 also indicates the presence of multiple detached plumes in the area. Like TCE, it appears as though there is another completely detached 1,1-DCE plume north of the Grand Canal, to the northwest of WOC Facility source area.

The second 1,1-DCE plume has the highest concentration of 1,1-DCE (63 μg/L) which was encountered in 2008 at NCP's monitoring well WCP-227[10], immediately upgradient of the WOC Facility. Like the PCE plume, this 1,1-DCE plume appears to originate at the NCP and extends downgradient, underneath the Grand Canal to the south of the WOC Facility. Another detached 1,1-DCE plume is also present in the area south and southwest of the WOC Facility, at groundwater monitoring wells MW-203S, MW-204S, and MW-206S. Again, because this downgradient 1,1-DCE plume is detached from the northern 1,1-DCE plume, it is also likely that the elevated concentrations of 1,1-DCE in this area are a result of a separate upgradient source area towards the northeast, most likely EGA.

As shown on Figure 3-18, historical 1,1-DCE hot-spots are evident throughout the NCP site, in the northern portion of the WOC Site, and in the center of the EGA site. 1,1-DCE has dispersed laterally and moved downgradient. The concentrations of 1,1-DCE are many-fold higher than in the wells immediately downgradient of the WOC Facility. The higher concentrations are possibly the result of the downgradient migration of the high 1,1-DCE concentrations (i.e., greater than 58 μg/L) previously observed at the EGA source area. Once again, it is important to note that, because the WGA wells located between the EGA source area and the WOC wells have not been sampled since 2002, the migration of the plume through the interlying monitoring network may have been missed.

In wells a short distance downgradient of the WOC Facility, the concentration of 1,1-DCE is approximately 4 to 7% of the concentration of TCE. In MW-204S, the percentage is higher, approximately 9 to 12% in September and December 2008, respectively. The proportionately higher, as well as actually higher, concentration in MW-204S suggests a source other than the WOC Facility.

Although 1,1,1-TCA (the parent-compound of 1,1-DCE) was reportedly used at the Site, water-quality data from the NCP prior to the lining of the Grand Canal in 1992 show concentrations of 1,1,1-TCA, thus indicating that 1,1,1-TCA was used at the NCP as well. Based on the observed hot-spots of 1,1-DCE at the NCP site and the apparent 1,1-DCE plume extending from NCP to WCP-207, it is believed that after the mound disappeared, 1,1-DCE migrated from NCP to the south and has appeared in Site monitoring wells. A separate

[10] In December 1999, WCP-14 contained 89 μg/L 1,1-DCE, as shown on Figure 3-18.

1,1-DCE plume appears to exist in the vicinity of MW-204S and MW-206S, but does not connect to the 1,1-DCE plume at the WOC Facility.

3.4.4 Cis-1,2-DCE Plume Boundaries

Cis-1,2-DCE concentrations are much lower than, and have not migrated downgradient as far as, the other contaminants, as shown on Figure 3-19. Concentrations of cis-1,2-DCE exceeding the AWQS of 7 µg/L have only been observed within the NCP site and the EGA site, and have not been observed within the WOC source area. Concentrations of cis-1,2-DCE below the AWQS have migrated downgradient and are occasionally detected in WOC wells.

3.5 SOIL GAS SAMPLING AT MIDDLE PARCEL

To evaluate remedial options and the potential justification for an additional source property remediation system, soil gas sampling was performed in 7 select wells at the WOC Middle Parcel in October 2008. The locations of these wells are shown on Figure 3-20; Table 2-1 provides well construction information, the month applicable wells went dry, historic high groundwater TCE concentrations, and the results of October 2008 soil gas sampling. In an effort to evaluate the degree of contaminant mass present in the vadose zone, detected soil gas concentrations were compared to calculated maximum soil gas concentrations that could result from the volatilization of TCE from groundwater using Henry's Law. The Henry's Law calculations used historic high groundwater concentrations in a given well to determine the maximum predicted soil gas concentrations. Actual soil gas concentrations appreciably above calculated maximum predicted soil gas concentrations would suggest the presence of either a nearby source of TCE in soil, and/or possibly dense nonaqueous phase liquid in the subsurface.

The results of October 2008 soil gas sampling are presented in Table 3-3. The actual soil gas concentrations detected in MW-4S (15,000 µg/m^3) and MW-5S (26,000 µg/m^3) were approximately an order of magnitude below the Henry's Law maximum predicted soil gas concentrations, implying significant source material is not present in the zones surrounding both of these dry monitoring wells. However, the actual vapor concentration detected in MW-100S (81,000 µg/m^3) is greater than the Henry's Law maximum predicted soil gas concentration for this well (29,600 µg/m^3), but it is less than an order of magnitude greater. Well WCP-207, sampled in December 2008, is close to MW-100S. In December 2008, the groundwater TCE concentration in WCP-207 was 88 µg/L, resulting in a Henry's Law calculated maximum soil gas concentration of 37,000 µg/m^3. This concentration is close to the current maximum predicted concentration of 29,600 µg/m^3 for MW-100S, suggesting that the degree of source material present in the area of MW-100S and WCP-227 is inconclusive. In other words, the soil gas concentration in the area of MW-100S and WCP-207S may be related solely to the volatilization of TCE from groundwater, or may have some minor contribution from residual source material.

The historical research of chemical use in manufacturing indicates that PCE was not used at the WOC Facility. However, PCE was detected in 5 of the 7 collected soil gas samples at the Middle Parcel (Table 3-3). The two samples in which PCE was not detected had elevated laboratory method detection limits, and therefore, it is reasonable to conclude that low concentrations of PCE were likely present in these samples. PCE is a known contaminant of concern that has impacted groundwater at the NCP site. The presence of PCE in soil gas samples provides compelling evidence that the NCP plume containing PCE has migrated south beneath the WOC, and has volatilized from groundwater into the unsaturated vadose zone.

Based on the results of the October 2008 soil gas sampling of the dry monitoring wells screened in the vadose zone, significant TCE source material does not remain in the zones surrounding the wells. However, it is clear that residual VOC mass is present in the lower portion of the vadose zone that was formerly saturated with contaminated groundwater prior to the lining of the Grand Canal and resulting water-table elevation declines at the Site. Furthermore, the presence of PCE in soil gas provides compelling evidence that the NCP groundwater plume has migrated beneath the WOC.

3.6 REMEDIAL OBJECTIVES

The ROs for the Site were developed by ADEQ pursuant to AAC R18-16-406 of the Remedy Selection Rule (the rule). ROs are established for the current and reasonably foreseeable uses of land and waters of the state that have been, or are threatened to be, impacted by a release of a hazardous substance. The rule specifies that the reasonably foreseeable uses of water are those likely to occur within 100 years, unless a longer time period is appropriate [RI 8-1 6-406(D)]. Reasonably foreseeable uses are those likely to occur based on information obtained from water providers, well owners, land owners, local governments, and the general public. Not every use identified in the Land and Water Use Report will have a corresponding RO; uses identified may or may not be addressed based on information gathered during the public involvement process and whether the use is reasonably foreseeable.

The ROs for the Site were formalized in the ADEQ's May 2005 Remedial Objectives Report (ADEQ, 2005), including comments received by the COP at that time. The ROs were developed with input from land owners, local governments, water providers, and the public and were originally documented in Appendix L of the Final Remedial Investigation Report, West Osborn Complex WQARF Site (GeoTrans, 2004). The Land and Water Use Report (ADEQ, 2004a) is documented as Appendix K of the Final RI Report. At that time, the established ROs for the Site were consistent with the COP's and SRP's Water Management Plans and General Land Use Plan. The ROs were established based upon the current and reasonably foreseeable uses of land and reasonably foreseeable beneficial uses of water at the Site for drinking water purposes by the COP, and for SRP irrigation wells.

The ROs were prepared for each listed use in the following terms:

- Protecting against the loss for impairment of each listed use that is threatened to be lost or impaired as a result of a release of a hazardous substance;

- Restoring, replacing, or otherwise providing for each listed use to the extent that it has been or will be lost or impaired as a result of a release of a hazardous substance;

- Time frames when action is needed to protect against or provide for the impairment or loss of the use; and

- The projected duration of the action needed to protect or provide for the use.

3.6.1 ROs for Land Use

The current zoning designation for the WOC Facility, as defined by the West, Middle and East Parcels, is A-2 Industrial (ADEQ, 2004a). Based on meetings with the COP Planning Department, GeoTrans understands that there are no foreseeable plans to alter the current zoning districts in the Site vicinity, and the area is expected to remain predominantly industrial (A-2) or light industrial (A-l). Based on the completion of remediation activities on the Middle Parcel, no restrictions to the current or foreseeable future land uses are present.

Soil remediation conducted at the Site, through the use of the SVE system, meets soil remediation standards established in ARS §49-152 and AAC R18-7-2. The soil analytical results presented in a letter report dated January 23, 2004 indicate no detections of TCE. The Residential Soil Remediation Level for TCE is 27 mg/kg. The minimum groundwater protection level (GPL) for TCE is 0.61 mg/kg. Based on this information, ADEQ granted a permanent shutdown of the SVE system at the Site on March 1, 2004.

Based on the above information, no ROs are needed for this use.

3.6.2 ROs for Groundwater Use

Four current and/or potential groundwater uses were identified within the Site: 1) the current and future use of groundwater for drinking water purposes by the COP; and 2) the current and future use of SRP irrigation wells. The COCs in the groundwater at the Site are TCE, PCE, and their degradation products.

3.6.2.1 COP Municipal Use

The COP is not currently operating any wells within a one-mile radius of the Site boundary. The following is a discussion of the COP wells currently or potentially impacted by the WOC SGWS plume. Two municipal wells, COP-70 and COP-71, were removed from service in 1982 due to TCE groundwater contamination at the Site. According to COP, loss of these wells has reduced Phoenix's overall well system capacity and ability to meet service area water demands, especially during droughts or temporary water system outages. COP-68 is located within the eastern edge of the WOC SGWS plume (Figure 3-1). This well has been inactive (but not capped) since 1986 due to high nitrates and total dissolved solids.

In August 2000, COP requested funding for an interim remedial action (IRA) for COP-70 and COP-71 pursuant to ARS §49-282 03. The IRA requested funding to recover the 1,500 gpm total well capacity lost due to the TCE contamination associated with the Site.

The RO for the COP current municipal use is:

> *To restore, replace, or otherwise provide for the COP groundwater supply that has currently been lost due to PCE and/or TCE contamination associated with the Site. This action is needed as soon as possible. This action is needed for as long as the need for the water exists, the resource remains available, and PCE and/or TCE concentrations in the water prohibits or limits its use.*

COP's continued interest in future well development in the Central Phoenix wellfields led COP to the development of computerized tools that would assist the City in evaluating the suitability of groundwater resources in the Central Phoenix area. The primary goal of the project was to aid the City in evaluating the general location and timing of future groundwater resources development for the COP public water supply. As part of the project, COP evaluated the entire water service area for future well development and assigned numerical score, based on established criteria. Based strictly on the statistical evaluation of the scores, COP indicates that areas with scores in at least the 75^{th} percentile (scores >81) may warrant consideration for future well development. The area where the WOC SGWS plume is located scored 80 to 85; therefore, it may be considered for future well development for drought protection. The area immediately downgradient of the WOC SGWS plume scored 78 to 80; therefore, it is not currently considered for future well development (after year 2010). However, in a letter received by ADEQ from COP dated May 12, 2005, COP indicated that site-specific considerations and operational/services needs may require the location of wells in lower scoring areas. COP's current analysis is that scores in the 78 to 80 range, or perhaps lower in certain circumstances, may indicate generally favorable well development conditions.

The RO for the COP future municipal supply use is:

> *To protect for the use of the COP municipal groundwater supply threatened by the PCE and/or TCE contamination emanating from the Site. According to the COP, this use may be needed by the year 2010. This action would be needed for as long as the level of contamination in the identified groundwater resource threatens or prohibits its use.*

3.6.2.2 SRP Municipal and Irrigation Use

SRP owns several irrigation wells in the area and will continue to need operational wells to supplement surface water supplies. A water treatment plant may be built in the Grand Canal sometime in the future, which would change the use of groundwater from irrigation to drinking water. However, at this time the use of any SRP wells affects the LSGS, rather than the SGWS. As such, the use of the SRP wells is not a focus of this FS.

The proposed RO for the SRP current and future municipal and irrigation use of the wells is:

> *To protect for the use of the SRP groundwater supply threatened by the PCE and/or TCE contamination emanating from the Site. According to SRP, this use may be needed as soon as is technically feasible. This action would be needed for as long as the level of contamination in the identified groundwater resource threatens or prohibits its use.*

4.0 EARLY RESPONSE ACTIONS

For the purposes of removing the source area and to prevent further aquifer contamination, the following three activities, including one ERA activity, were conducted at the Site:

- Removal of actual and potential sources of contamination:
  - Contents of five septic tanks, ST-1. thru ST-5 (as detailed in the RI Report); and
  - Four septic tanks (ST-l, ST-2, ST-3 and ST-5) and the associated piping connected to seepage pits;

- Installation and operation of an SVE system: (a formal ERA activity) to remove VOCs in the vadose zone; and

- Abandonment of the on-site irrigation well (Pincus Well).

The following is a description of these activities, which forms the basis of the FS for the WOC LSGS plume.

4.1 SEPTIC SYSTEM REMOVAL

The sampling, excavation and removal of the contents and/or tanks associated with ST-I through ST-5 occurred during the Phase I Soil Investigation and are described in detail in the Final RI Report, Section 4.3.1, and will not be discussed in detail here. However, their removal effectively removed the likely on-site source(s) of VOCs.

4.2 SVE SYSTEM INSTALLATION, START-UP, AND OPERATION

4.2.1 SVE System Installation and Start-Up

In accordance with the RI/FS Work Plan, an ERA using SVE was conducted at the Site to meet the short-term remedial action objective specified in the RI/FS Work Plan. The primary objective of this work was to reduce the mass of contaminants in the vadose zone to prevent further leaching to, and contamination of, groundwater.

The ERA SVE system at the Middle Parcel was installed in June 1999. Note that this ERA fulfilled the requirement in the Consent Decree for implementing an Interim Remedial Action. The SVE system consisted of three pairs of nested SVE wells, underground conveyance piping, a conventional extraction blower package, and vapor-phase granular activated carbon (GAC) treatment vessels. The general layout of the system is shown on Figure 4-1. The system was designed to remove residual TCE from the shallow and deep vadose zone in the area identified by ADEQ's soil vapor and by the only detections of VOCs in soil borings. The nested SVE wells were installed in the vicinity of the storage shed near the northwest (SVE-1 nest), southeast (SVE-2 nest), and south (SVE-3 nest) sides of the storage shed. Each nest consisted of two, 2-inch, polyvinyl chloride (PVC) wells installed in the same borehole, but screened at different depth intervals: the shallow SVE wells and deep SVE wells were screened from approximately 10 to 40 feet bgs, and approximately 65 to 110 feet bgs, respectively. Each SVE well was equipped with a 2-inch butterfly flow control valve and a monitoring port to allow measurement of the applied well vacuum and to collect samples of extraction vapor. Street-rated, flush-to-grade vaults were installed over the SVE wells.

A 7.5-horsepower SVE blower and related mechanical equipment were installed in a fenced equipment compound at the northwest end of the Middle Parcel. Two GAC vessels, each containing 400 pounds of coconut shell GAC, were used to abate VOC emissions. The GAC vessels were connected in series with a dual plumbing manifold to facilitate change-out of spent GAC and switching the primary and secondary GAC vessel positions.

Initial periodic testing of the SVE remediation system began on August 4, 1999, and official start-up began on August 5, 1999.

4.2.2 SVE System Operation

The ERA SVE system was operated from August 5, 1999 to October 21, 2002. During this operating period, a total of 25 influent and 25 effluent vapor samples were collected and analyzed by EPA Method TO-15. Analytical results indicate that the vast majority of contaminant mass in the extracted vapor was TCE, with trace amounts of PCE and 1,1-DCE.

The ERA SVE remediation system successfully remediated significantly more contamination than was originally anticipated. Table 4-1 and Figure 4-2 present SVE system performance data with respect to the cumulative VOC mass removal over time. Using average SVE flow rates, average analytical results, and system operation time, GeoTrans calculated that approximately 449 pounds of VOCs were removed from the subsurface during the 706 days of operation between August 4, 1999 and October 21, 2002. System downtime equated to approximately 167 days as a result of equipment repairs/maintenance, periodic power outages, and intentional shut-down periods for response tests and "pulse-mode" operations. Because the density of TCE is approximately 12 pounds per gallon, the 449 pounds of total remediated VOCs represents approximately 37.41 gallons of liquid TCE.

4.2.3 SVE System Shut-Down

On behalf of UIC, GeoTrans submitted a technical letter on September 11, 2001 to ADEQ requesting approval to shut down the SVE system permanently. Confirmatory drilling and sampling, conducted in September 2002, verified that VOC concentrations were below laboratory detection limits in all 39 subsurface samples collected from the SVE system area of influence. Based on these results, ADEQ approved the SVE system shut down, which occurred on October 21, 2002.

The activities and analytical results associated with the confirmatory soil drilling and sampling are contained in the GeoTrans' report entitled Confirmatory Drilling/Soil Sampling Results for Shut-Down of Interim SVE Remediation System, Middle Parcel, West Osborn Complex, submitted on January 23, 2004.

4.3 PINCUS WELL ABANDONMENT

The on-site irrigation well (Pincus Well) was believed to be the primary pathway for dissolved-phase TCE migration from the SGWS or surface activities, downward into the LSGS. Abandoning this well greatly reduced the potential for further migration of impacted groundwater from the SGWS to the LSGS.

The Pincus Well was abandoned in accordance with ADWR regulations on July 26 through 28, 2004, by perforating the casing from surface to a depth of 540 feet (confirmed with a video log) and pumping more than 23 cubic yards of neat cement into the well. Although the actual source of TCE in the LSGS was never identified, the proper abandonment of the Pincus Well is believed to have eliminated any potential for further migration of impacted groundwater from the SGWS to the LSGS.

5.0 IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES

Section 5.0 provides a detailed discussion of the identification and screening of remediation technologies for potential implementation at two main areas at the WOC Site. These locations include: 1) the upgradient portion of the plume, along the southern boundary of the WOC Facility to address contamination near the known historic source(s) of contamination; and 2) downgradient (to the south) of the WOC Facility to address the off-site, central portion of the plume (Figure 3-1). Note that the upgradient remedy is expected to have a simultaneous beneficial effect on the NCP, which has migrated to the WOC Facility.

5.1 TECHNOLOGY SCREENING

This section defines and describes remediation technology screening assumptions as well as treatment technologies for the SGWS considered acceptable by the ADEQ for achieving the ROs and to comply with the requirements of AAC Rl8-16-407. The following assumptions and system requirements will be used during the identification and screening of remedial technologies:

- Conservative contaminant concentrations derived from the upgradient portion of the SGWS plume (i.e., downgradient boundary of WOC Facility):
  - TCE at a concentration of 200 μg/L in groundwater;
  - PCE at a concentration of 15 μg/L in groundwater; and
  - 1,1-DCE at a concentration of 15 μg/L in groundwater.

These concentrations are based on the 2008 through 2011 groundwater sampling water-quality data for SGWS wells within the vicinity of the WOC Facility, including the estimated contribution of migrating contamination from the NCP.

- Conservative contaminant concentrations derived from the central portion of the SGWS plume (i.e., MW-206S vicinity):
  - TCE at a concentration of 180 μg/L in groundwater;
  - PCE at a concentration of 5 μg/L in groundwater; and
  - 1,1-DCE at a concentration of 25 μg/L in groundwater.

These concentrations are based on the September 2010 and 2011 groundwater sampling water quality data for SGWS wells within the central portion of the WOC Site.

- Remedial Efficiency – Should ultimately achieve drinking water standards for VOCs (MCLs and AWQSs).

- End Use – Depending on the remedial strategy, irrigation, reinjection to the aquifer, or no end use is proposed for the SGWS groundwater.

- Flow Rates – Depending on the remedial strategy for active remedies, flow rates involving SVE, in-situ air sparge (AS) injection, and pump-and-treat (P&T) technologies are evaluated. Capital, operation and maintenance (O&M), and present-value/life-cycle costs are compared based on each remedial scenario.

The list of potential remedies was developed from strategies and technologies that are used for remediating groundwater impacted by VOCs in environmental applications.

The appropriate remediation technologies for the impacted SGWS were identified and screened according to the following criteria:

- Contaminant treatment effectiveness;
- Constructability;
- Flexibility/expandability;
- O&M requirements;
- Operational hazards; and
- Cost-effectiveness.

The remediation technologies that pass the technology screening will be retained for use in development of the reference remedy and alternative remedies.

5.2 FLOW RATES AND DOSAGE RATES

5.2.1 Downgradient Margin of WOC Facility

The flow rates or dosage rates for active remedies will depend on the remedial strategy (Section 6.0). Flow rates for AS/SVE that have been screened for potential use at the downgradient margin of the WOC Facility, are approximated based on 1) vadose and saturated zone soil types at the WOC Facility; 2) conceptual remediation system designs; and 3) project engineering experience. A flow rate for potential P&T at the downgradient property margin (30 gpm) has been estimated using data from aquifer tests, and by computer modeling to evaluate capture zones induced by remedy pumping. Substrate dosage rates for the potential use of enhanced in-situ bioremediation (ISB) at the downgradient property margin have been estimated based on GeoTrans' project experience at similar sites.

5.2.2 Central Portion of Plume

Due to the relatively large geographic area that has been impacted by plume migration to the south of the WOC facility, P&T is the only active remedy that is being considered as practicable for this remediation. The P&T strategy is to pump groundwater from multiple extraction wells located along the central portion of the plume, where contaminant mass is highest. Pumping rates of either 300 gpm or 500 gpm have been modeled to evaluate capture zones for two different pumping strategies, as described in Section 6.0.

Monitored natural attenuation (MNA) has also been evaluated as a potential long-term strategy for plume remediation, particularly under the assumption that a non-exposure pathway will remain in the foreseeable future. An initial discussion of MNA is included in Section 5.7.1.

5.2.3 Contaminants

Historically, the principal contaminant of concern at the Site has been TCE, with much lower concentrations of PCE and 1,1-DCE intermittently identified in select wells. PCE has predominantly been observed in the northernmost SGWS wells, including MW-3SR, WCP-207, MW-4S, and MW-5S, as well as in the most southeastern well MW-209S. This PCE contamination is believed to be associated with upgradient sources, including the NCP, and possibly the WGA and EGA WQARF sites.

5.2.4 Mass Removal

Predicted contaminant mass removal rates for remediation of groundwater from the evaluated active remediation systems in this FS are presented below:

5.2.4.1 AS/SVE System - Option A

Operating at downgradient margin of the WOC Facility's Middle Parcel, 270 cubic feet per minute (cfm) AS injection; 550 cfm SVE:

- Estimated average extraction vapor influent concentration for first 30 days of operation: 100 mg/m^3 of total VOCs;
- Estimated average VOC mass removal rate, first 30 days of operation: 4.9 lbs/day[11]; and
- Assumed subsequent average VOC mass removal rate, first two years of operation: 0.50 lbs/day.

5.2.4.2 AS/SVE System - Option B

Operating at downgradient margin of the WOC Facility's West and Middle Parcels, 720 cfm AS Injection; 1,500 cfm SVE:

- Estimated average extraction vapor influent concentration for first 30 days of operation: 75 mg/m^3 of total VOCs;

[11] This is assumed to be the average mass removal rate during the first 30-days of AS/SVE operations, a period in which extraction vapor concentrations are expected to decline exponentially as is characteristic of SVE systems operating in areas without significant contaminant mass and/or NAPL.

- Estimated average VOC mass removal rate, first 30 days of operation: 10.1 lbs/day; and

- Assumed subsequent average VOC mass removal rate, first two years of operation: 0.75 lbs/day.

Note that the above contaminant mass extraction rates are, at best, highly uncertain. The only way to actually determine these rates is by monitoring an operating AS/SVE system during a typical start-up phase and over time.

5.2.4.3 Enhanced ISB System - Options A and B

Operating at downgradient margin of the WOC Facility (either on only the Middle Parcel, or both the West and Middle Parcels):

- Estimated conservative in situ groundwater concentrations: 200 μg/L of TCE, 15 μg/L PCE, and 15 μg/L 1,l-DCE; and

- Estimating a reasonably accurate VOC mass removal rate is not possible at this time; a pilot study would be required to determine an approximate in-situ biodegradation rate.

5.2.4.4 P&T Systems

P&T System operating at downgradient margin of WOC Facility's West, Middle and East Parcels, 30 gpm:

- Estimated conservative influent concentrations: 200 μg/L of TCE, 15 μg/L PCE, and 15 μg/L 1,l-DCE; and

- VOC mass removal rate: 0.083 pounds per day (lbs/day).

P&T System with three extraction wells operating at central area of downgradient portion of the plume (MW-206S Vicinity), 300 gpm:

- Estimated conservative influent concentrations: 150 μg/L of TCE, 5 μg/L PCE, and 20 μg/L 1,l-DCE; and

- VOC mass removal rate: 0.630 lbs/day.

P&T system with five extraction wells operating at central area of downgradient portion of plume (MW-206S Vicinity), 500 gpm:

- Estimated conservative influent concentrations: 135 μg/L of TCE, 3.5 μg/L PCE, and 20 μg/L 1,l-DCE; and

- VOC mass removal rate: 0.95 lbs/day.

A straight-forward calculation that utilizes the flow rate and influent concentrations as key factors was used to determine the above estimated VOC mass removal rates for P&T. Flow rates were determined by pumping and capture-zone modeling described in Sections 5.6.3.2, 5.7.2.1 through 5.7.2.3, and in Appendix C.

Flow rates for AS/SVE were estimated based on 1) engineering experience with AS/SVE pilot testing in similar soil types as those present at the WOC Facility; and 2) the conceptual AS/SVE system design described in Section 5.6.1.2. The estimated average 30-day extraction vapor concentration is based on soil gas sampling results in conjunction with vapor concentrations predicted using Henry's Law (Table 3-2), and the interim SVE system extraction vapor testing results after several months of operations (Figure 4-2).

5.2.5 Removal Efficiency

Due to the general drinking water-protected use classification for all Arizona aquifers (ARS §49-224), it is reasonable to conclude that the selected treatment technology, or combination of technologies, should ultimately achieve drinking water standards (Federal MCLs and Arizona AWQSs) for the COC. At the present time, the criteria for discharge of treated water into the SRP Grand Canal (an option being considered for one remedy discharge), a non-drinking water source, may be less stringent than MCLs and AWQSs. However, according to the SRP, there is a potential for use of the canal water as a drinking water source if a potable water treatment plant is installed on the Grand Canal in the future. Furthermore, the treated effluent concentrations would need to comply with Arizona Pollutant Discharge Elimination System (AZPDES) permit requirements, assuming the water was being discharged to either the Grand Canal or COP storm sewer.

5.2.6 End Use

The end use of the treated groundwater will be based on the remedial system discharge alternative. For this use, the selected technology and system design(s) must comply with all applicable Federal, state and local requirements. A detailed discussion of end use options is included in Sections 5.7 and 5.8. Note that domestic consumption from the COP municipal water system is not one of the proposed end uses for SGWS groundwater. This use has been considered only for the LSGS aquifer, which is presented in a separate FS.

5.2.7 Pre-Treatment

Removal of hardness (calcium and magnesium carbonates, such as $CaCO_3$) is not a treatment objective specified by the ADEQ. Hardness control was considered only in the context of treatment system O&M, as hardness may result in scaling problems with piping and equipment. High total suspended solids, manganese, and dissolved iron in groundwater can also cause problems with fouling of treatment media and/or equipment. Pre-treatment considerations are addressed in this FS based on the evaluated technologies that are most likely to be affected.

5.3 TREATMENT TECHNOLOGIES

Technologies are described below which are commonly used for treating the concentration levels of VOCs at the WOC Site, and the anticipated contaminant mass removal rates. The basic treatment mechanisms and the suitability and limitations of the technologies are discussed. The reasons a particular technology has been retained for further evaluation or eliminated from consideration are also discussed.

5.3.1 Carbon Adsorption

GAC is an appropriate treatment media for many organic compounds, including VOCs, semi-VOCs (SVOCs) and other non-VOCs. The VOC contaminants present in the WOC Facility vadose zone and SGWS plume (TCE, PCE, and 1,1-DCE) are amenable to treatment by GAC (EPA, 2000). Carbon adsorption is commonly used to remove VOCs present in either the vapor or liquid-phase. For water treatment, it is used as either a primary treatment mechanism or in combination with other treatment methods.

Carbon adsorption is a relatively low-cost, low-maintenance, and reliable alternative for treating non-polar organic contaminants, which can be removed from vapor or liquid by adsorption to GAC. Pre-packaged systems are available from multiple manufacturers and installation of modular components is relatively quick and easy. Carbon-use rates are a function of the influent concentration and the adsorptive capacity of the carbon for the specific contaminants. For VGAC, pre-treatment to remove humidity and/or to lower the vapor temperature can increase the carbon adsorptive capacity and reduce its use. For liquid-phase carbon treatment (LGAC), pre-treatment by air-stripping (AS) or advanced oxidation can reduce carbon use.

For both VGAC and LGAC treatment, system maintenance consists of periodic removal and replacement of the carbon when the adsorption capacity is reached. Maintenance for LGAC may also consist of periodic backwashing of the LGAC vessels when the pressure drop becomes excessive due to fouling with suspended solids, or either iron and/or carbonate (hardness) scale. Pretreatment with filtration and/or antiscalent chemicals can be performed to minimize these effects, but will add additional O&M costs. Carbon adsorption was retained as a treatment alternative for the Site.

5.3.2 Air Stripping

Air stripping is an effective treatment technology for removing VOCs and, to a limited extent, SVOCs from groundwater. Air stripping removes VOCs from the waste stream by transferring the compounds from the aqueous phase to the vapor phase (EPA, 1991). In a packed-tower air stripper, contaminated water flows downward by gravity through a circular or rectangular column filled with packing material. The packing material is designed to maximize the available surface area for contact between the water and process air, for volatilization of contaminants from the water. A blower delivers air into the tower, which flows upward through the packed bed countercurrent to the flow of water. Air stripping is a demonstrated technology with numerous systems treating groundwater reliably for decades. Packed-tower systems can treat high flows with low liquid pressure drop. Other types of air strippers typically used to treat lower flows include shallow cascading trays, bubble aeration, and aspiration (venturi-type strippers).

Air-stripping systems are simple, relatively inexpensive, and reliable. O&M costs are generally low, because systems can be operated unattended and associated labor and material costs are minimal. Prepackaged systems are available from numerous manufacturers and installation of modular components is relatively quick and easy. They are also commonly manufactured to meet specific requirements of each application. Computer models are available to design and optimize shallow-tray and packed-tower air strippers. Electrical power consumption is a function of the air-to-water ratio required for treatment and the system groundwater flow rate. O&M includes periodic inspections and servicing of the aeration blower. Depending on water characteristics, such as concentrations of dissolved iron, manganese, and hardness, the air-stripper internal structures, effluent piping, and/or internal packing typically require periodic cleaning. Concentrations of hardness in the SGWS groundwater range from about 100 to 350 milligrams per liter (mg/L) (see Table 5-1), which can be a problem, depending on how it precipitates. However, some fouling can be prevented with pre-treatment for hardness removal. Biological fouling can also be a problem with air strippers, if the untreated water contains sufficient organic matter to sustain biological growth. Biological fouling can be prevented by injecting disinfectants (e.g., sodium hypochlorite) to the untreated water with proper feed rates, to minimize the production of potentially harmful by-products, such as trihalomethanes.

Iron fouling of air strippers is another common problem. When ferrous iron comes in contact with oxygen during the stripping process; it is oxidized to ferric iron, forming an insoluble precipitate causing fouling. The concentration of dissolved iron (ferrous + ferric iron) in the SGWS groundwater is less than approximately 0.20 mg/L; therefore, the potential for significant iron fouling of air-stripper components is low.

Air stripping is often followed by carbon adsorption as a polishing step to remove residual contaminants from groundwater. Treatment of air-stripper off-gas could also be required, depending on effluent concentrations and corresponding mass discharge rates of VOCs into the atmosphere. Air stripping was retained as a treatment alternative for the SGWS plume.

5.3.3 Chemical Oxidation

Chemical oxidation is often used in water treatment to remove iron and manganese, control biological growth, and remove color, tastes, and odor. Chemical oxidants can also react with organic contaminants and oxidize the chemicals to harmless end-products. However, chemical oxidants are often highly selective, reaction rates are often slow, and competing reactions can reduce the effectiveness of oxidants for treating organic chemical contaminants. Therefore, use of common chemical oxidants is usually not cost-effective, in particular at the relatively low concentrations present in the WOC SGWS plume. Treatability testing would be required before chemical oxidation could be applied with confidence for treating VOCs in the extracted SGWS groundwater (Huling, 2006).

Chemical oxidation was not retained as a treatment option because the treatability of target contaminants by chemical oxidation is uncertain and treatment requires the use of hazardous chemicals (oxidants).

5.3.4 Ultraviolet Oxidation

Advanced oxidation, such as photo-oxidation, can be used to destroy all types of organic compounds and does not need off-gas treatment. Photo-oxidation uses high-intensity ultraviolet (UV) light to generate hydroxyl radicals from an oxidant, such as hydrogen peroxide. The hydroxyl radicals induce a chain of oxidation reactions that mineralize organic pollutants to bicarbonate, or ultimately to carbon dioxide. A potential advantage of UV oxidation is that contaminants are transformed into harmless end-products, eliminating the need for air emission treatment or disposal of sorbed contaminants. UV oxidation is effective in treating a broad range of organic contaminants, including some constituents that are not easily removed by other methods (e.g., 1,4-dioxane) (Trach, 1996).

UV/peroxide treatment has become more common for treating organic contaminants in water, and packaged systems are available from several manufacturers. Considerations for application include maintenance requirements, required pre- and post-treatment, and overall cost. Regular maintenance of UV systems is required to sustain transmittance and treatment efficiency. Pre-treatment for hardness removal can be required to minimize interference by carbonates and maintain light transmittance. Post-treatment by carbon is often used to minimize UV system requirements and to remove residual hydrogen peroxide and untreated contaminants.

The capital and O&M costs are typically higher for UV oxidation, compared to AS and GAC. Also, UV oxidation is considerably more likely to require pre-treatment for metals and/or solids to prevent fouling, compared to AS and GAC. UV oxidation is very sensitive to fouling and can result in poor performance due to increased turbidity, hardness, and iron and manganese content (Trach, 1996). For treatment of the relatively low concentrations of VOCs present in the SGWS at the Site (i.e., less than 300 µg/L total VOCs), UV oxidation is believed to be an inappropriate and impractical treatment alternative. Therefore, UV oxidation was not retained as a treatment option for pumped groundwater from the WOC SGWS plume.

5.3.5 Ion Exchange

Ion exchange removes ions from the aqueous phase by the exchange of cations or anions between the contaminants and the exchange medium. Ion exchange materials may consist of resins made from synthetic organic materials that contain ionic functional groups to which exchangeable ions are attached. They also may be inorganic and natural polymeric materials. After the resin capacity has been exhausted, resins can be regenerated for reuse (http://www.frtr.gov/matrix2/section4/4-49.html).

The most common application of ion exchange is for water softening. Target ions are adsorbed onto the medium in exchange for a loosely bound ion, such as sodium. Ion exchange is particularly effective for treating high-contaminant concentrations, especially with on-site regeneration. Ion exchange can also be appropriate for treating some constituents that are not effectively removed by GAC.

Treatment by ion exchange is contaminant-specific and not appropriate for treating process water that contains many constituents. Ion exchange is more expensive than GAC or AS for many of the common contaminants at typical concentrations found in groundwater (FRTR, 2002). Therefore, ion exchange was not retained as a treatment option for contaminated SGWS groundwater at the Site.

5.3.6 Membrane Filtration

Membrane processes include several different technologies, such as reverse osmosis, electro-dialysis, and ultra-filtration. In domestic water treatment, membrane processes are most commonly used in desalinization and for removing ions that are otherwise difficult to displace. Reverse osmosis and ultra-filtration can remove some dissolved organic compounds. However, membrane processes are generally not effective at removing low molecular weight compounds, such as those present in SGWS groundwater at the Site. Membrane processes are generally expensive and maintenance-intensive (FRTR, 2002). For these reasons, membrane processes were not retained as treatment alternatives for the WOC SGWS plume.

5.3.7 Biological

Ex-situ biological treatment can mineralize dissolved contaminants to the harmless end-products of carbon dioxide and water. It is often effective for treating constituents that are not easily removed by air stripping or GAC (e.g., ketones, ammonia). Chlorinated hydrocarbons have been successfully treated by aerobic biodegradation. However, aerobic biodegradation of chlorinated hydrocarbons typically requires a co-substrate, such as methanol or phenol. Biological processes are typically not used for treating drinking water because of concerns about transmitting microorganisms into the drinking water supply. Biological treatment is relatively operator-intensive compared to air stripping or GAC, and it generates solids that may need disposal (EPA, 2001). Therefore, ex-situ biological treatment was not retained as a treatment alternative for the COCs that are present in the SGWS. However, in-situ bioremediation has been evaluated as a potential remedial alternative for the Site as described in Section 5.6.2.

5.4 RETAINED TECHNOLOGIES

The treatment technologies retained for further evaluation, associated with the active remediation technologies screened in this FS, are GAC and AS. Treatment technology alternatives which were evaluated are as follows:

- Alternative 1: VGAC Treatment for AS/SVE;
- Alternative 2: Air Stripping Only Treatment for P&T;
- Alternative 3: Air Stripping with VGAC Treatment for P&T;

- Alternative 4: Air Stripping with LGAC Treatment for P&T;
- Alternative 5: Air Stripping with VGAC and LGAC Treatment for P&T; and
- Alternative 6: LGAC Only Treatment for P&T.

5.5 DETAILED EVALUATION OF TREATMENT TECHNOLOGIES

The retained technologies have been proven to be effective at treating the target VOCs that are present in soil and groundwater at the WOC Site. Below includes a detailed evaluation of treatment technologies for four alternatives with respect to contaminant treatment efficiency and O&M requirements.

5.5.1 Alternative 1 - VGAC Treatment for AS/SVE

This alternative pertains to the treatment of extraction vapor from an AS/SVE system operating at the downgradient margin of the WOC Facility. Note that a detailed discussion of AS/SVE, along with two other remedial technologies, considered for installation at this location is presented in Section 5.5. VGAC treatment is considered to be the best alternative for treating AS/SVE process vapor. It will be significantly less costly (in both capital and O&M costs) than installing and operating other types of treatment systems, such as resin-based systems, liquid scrubbers, and/or thermal or catalytic oxidizers necessary to safely remove extracted chlorinated VOCs.[12]

5.5.1.1 Treatment Efficiency

With proper management of VGAC, the treatment efficiency for VOCs present in the extraction vapor from an operating AS/SVE system could reliably exceed 99.5%. Before breakthrough of contaminants through the VGAC bed, the effluent concentration is generally zero and the treatment efficiency is 100%.

For an AS/SVE system operating at the downgradient margin of the WOC Facility, it is anticipated that the treatment process would consist of two VGAC vessels, configured in series, whereby one would serve for primary and the other would serve for secondary treatment. In order for the VGAC to achieve optimum performance (i.e., maximize adsorption capacity), both the relative humidity (RH) and temperature of the contaminant-laden vapor stream that passes through the VGAC should be controlled so as not to exceed ceiling levels. Although they are contaminant-specific, ceiling levels for RH and temperature would be approximately 45% and 95 degrees Fahrenheit (^{o}F), respectively. Based on GeoTrans' experience with SVE in Arizona, an effective approach to avoid exceeding these ceiling levels is to install the LGAC vessels on the pressure side of the SVE blower, and equip the SVE blower system with an air-cooled heat exchanger (i.e., an after-cooler). The heat of compression by the blower will control the RH to below 45%, while the heat exchanger will cool the process vapor during summer months to approximately 95^{o}F. During winter months

[12] Hydrochloric acid gas is generated as a by-product of combustion when using thermal destruction technologies for treating chlorinated VOCs. A scrubbing step to remove the HCL gas is typically required to protect process equipment and remove the HCL gas prior to discharge into the atmosphere.

when the process vapor through the blower is cooler, the heat exchanger can simply not be operated.

5.5.1.2 O&M

Series-configured VGAC treatment consists of a primary (lead) and secondary (lag) treatment vessel. Breakthrough monitoring of vapor concentrations exiting the VGAC vessels is required for O&M. The typical protocol is to periodically monitor the outlet port of the primary VGAC vessel using a portable photoionization detector (PID). When the PID measures low-level concentrations of VOCs exiting the primary vessel, this indicates that contaminant breakthrough has occurred. PID readings of the treated vapor discharge from the secondary VGAC vessel should also be monitored to document that no detectable VOC concentrations are present. When breakthrough of the primary VGAC vessel occurs, the vessel which had originally served for secondary treatment is switched to the position of primary. Then, either a vessel with new or re-activated VGAC is connected to serve for secondary vapor treatment. This procedure is repeated for on-going O&M of the VGAC treatment process.

In addition to performing VGAC breakthrough monitoring with a PID, samples of the untreated extraction vapor and treated discharge are normally collected for laboratory analysis of VOCs. The vapor sampling and analysis requirements will be specified by the Maricopa County Air Quality Department permit. Results of this sampling, in combination with the AS/SVE process data (i.e., vapor flow, temperature, and pressure), are used to calculate VOC mass removal rates from the subsurface, as well as the treatment efficiency of the VGAC.

5.5.2 Alternative 2 – Air Stripping Only Treatment for P&T

This alternative pertains to the treatment of extracted groundwater from P&T systems that would be installed to control and remediate groundwater from either the downgradient margin of the WOC Facility, or from the central, downgradient portion of the plume.

5.5.2.1 Treatment Efficiency

The design treatment efficiency for air stripping of the VOCs present in the SGWS groundwater can exceed 99%. Air strippers are designed to achieve the air-to-water ratio required to attain the target removal efficiency. However, stripper size and power consumption must increase to achieve a higher removal efficiency. Therefore, air strippers are generally designed to meet minimum design requirements, In this case, the design criterion is to attain Arizona AWQS and Federal drinking water MCLs for the VOCs in the treated effluent from the air stripper with a factor of safety over 2 (e.g., design air-stripper effluent PCE, TCE, and 1,1-DCE levels of <2.5 μg/L).

5.5.2.2 O&M

Air strippers typically have relatively low maintenance requirements and are reliable, assuming significant scaling problems difficult to control do not frequently occur. Periodic inspections (such as twice weekly) are recommended to confirm proper operation. Routine maintenance would include servicing the aeration blower, checking ancillary equipment and controls, and cleaning as necessary to mitigate fouling. The air stripper will likely require periodic treatments to remove scaling associated with hardness and iron present in the SGWS groundwater. To reduce the frequency of treatments, dosing the air stripper influent with an antiscalent sequestering agent via the use of a chemical feed pump should be considered. The appropriate concentration and dosage rate of the sequestering agent can be determined from a pilot study during the start-up phase of the air stripper system.

Using the concentrations and flow rates described in Sections 5.1 and 5.2 above, the total calculated mass of VOCs in the influent to the air stripper for a given P&T system would range from 0.083 lbs/day at 30 gpm, to 0.95 lbs/day at 500 gpm. Assuming 100% mass transfer to air, and pursuant to the Maricopa County Health Services Department Air Pollution Control Regulations, Rule 200, emissions do not need to be treated when the potential to emit VOCs is less than 3.0 lbs/day. Therefore, there would be no Maricopa County regulatory requirement for equipping an air stripper with off-gas treatment at the Site. However, the SGWS plume area encompasses predominantly residential neighborhoods; consequently, there may be political and/or public perception concerns that would warrant consideration for using off-gas treatment. Furthermore, ADEQ may require the use of VGAC in conjunction with air stripping as a matter of its own internal policy.

Carbonair has performed model calculations of the efficiency of its shallow-tray air strippers given the assumed VOC influent concentrations. Copies of the model runs are included in Appendix B. The results indicate the following for achieving MCLs and AWQS in the treated discharge:

- At a flow rate of 30 gpm, a system using 6 trays and a 3-horse power (hp), 150 cfm air blower provides a removal efficiency greater than 99% for total VOCs (i.e., PCE, TCE, and 1,1-DCE);

- At a flow rate of 300 gpm, a system using 5 trays and a 25-hp, 2,100 cfm air blower provides removal efficiency greater than 99% for total VOCs; and

- At a flow rate of 500 gpm, a system using 5 trays and a 40-hp, 3,500 cfm air blower provides removal efficiency greater than 99% for total VOCs.

5.5.3 Alternative 3 – Air Stripping with VGAC Treatment for P&T

This alternative pertains to the treatment of extracted groundwater from P&T systems that would be installed to control and remediate groundwater from either the downgradient margin of the WOC Facility, or from central, downgradient portion of the plume.

5.5.3.1 Treatment Efficiency

As described for Alternative 2 above, the treatment efficiency for removal of VOCs from groundwater by air stripping can exceed 99% with proper design. In addition to groundwater treatment, this alternative assumes that ADEQ would require VGAC treatment downstream of the air stripper discharge vent to provide a high degree of public protection against potential exposure to VOCs in air. Compared with other off-gas treatment technologies, VGAC would definitely be the most reliable and cost-effective technology to abate the low-concentration air-stripper emissions. With proper monitoring and management of the VGAC, the treatment efficiency would be greater than 99% removal of VOCs prior to discharge into the atmosphere.

5.5.3.2 O&M

The O&M considerations for Alternative 4 are similar to those described for Alternative 2 (Section 5.5.2), except that additional O&M associated with VGAC performance monitoring and periodic change-outs of spent VGAC would be necessary. To improve the VGAC adsorption capacity (and frequency of change-out), a duct heater could be used in the plumbing between the air stripper and VGAC units to reduce RH in the VOC-laden vapor. Another option would be to plumb the air blower in an induced draft arrangement whereby the air would flow upwards through the aeration trays under negative (vacuum) pressure rather than positive pressure. This arrangement raises the vapor temperature on the pressure side of the blower to reduce RH. Regardless of the blower plumbing arrangement, O&M of the off-gas treatment would involve monitoring concentrations and sampling emissions, and replacing spent VGAC.

A portion of the operating costs associated with Alternative 3 will be VGAC replacement. For typical VGAC systems, the lead (primary) vessel is replaced within an optimum time-frame after breakthrough occurs, and manifold valving is then switched, so that the lag (secondary) vessel serves as the lead vessel. Post-air stripping VGAC usage isotherms were provided by Prominent Systems, Inc. (Prominent) and Siemens Water Technology (Siemens), both reputable vendors of GAC treatment systems. Inputs to the isotherms (i.e., vapor concentrations and temperature, air flow rates, temperature, relative humidity, etc.) were provided to the vendors by GeoTrans, based on data derived from an air stripper modeler that demonstrated greater than 99% removal efficiency of VOCs from the groundwater by the air stripping process.[13]

- For 30 gpm air stripping, approximately 5.25 lbs/day of VGAC usage is predicted, based on performance of a Bisco Model 2131 ShallowTray® air stripper operating at 300 standard cubic feet per minute (scfm);

- For 300 gpm air stripping, approximately 33 lbs/day of VGAC usage is predicted based on performance of a Bisco Model 31241 ShallowTray® air stripper operating at 1,800 scfm; and

- For 500 gpm air stripping, approximately 48.5 lbs/day of VGAC usage is predicted based on performance of a Bisco Model 41251 ShallowTray® air stripper operating at 2,400 scfm.

[13] GeoTrans used output from Bisco/NEEP Systems ShallowTray® Modeler V6.12e to obtain simulated air stripper performance data, including air flow rates, number of trays, VOC removal efficiencies, and VOC off-gas concentrations.

Note that the above VGAC usage rates represent average rates of the Prominent and Siemens isotherms.

5.5.4 Alternative 4 – Air Stripping with LGAC Treatment for P&T

This alternative pertains to the treatment of extracted groundwater from P&T systems that would be installed to control and remediate groundwater from either the downgradient margin of the WOC Facility, or from the central, downgradient portion of the plume.

5.5.4.1 Treatment Efficiency

Air strippers are often designed with subsequent LGAC units to "polish" the effluent down to non-detectable levels, and protect against any loss of treatment efficiency due to mechanical/electrical failure, unusual influent characteristics, or fouling. This alternative assumes use of LGAC, but not VGAC with air stripping.

Although a well-designed air stripper alone could achieve high removal efficiency (greater than 99% VOC removal from groundwater), LGAC polish treatment is an option to achieve an even higher degree of treatment efficiency and supplemental safety factor to protect receiving waters.

5.5.4.2 O&M

The O&M considerations for Alternative 4 are similar to those described for Alternative 2 (Section 5.5.2), except that additional O&M associated with LGAC performance monitoring and periodic change-outs of spent LGAC would be necessary. Furthermore, it is recommended to install either bag filters or cartridge filters for pre-treating the influent groundwater upstream of the air stripper and LGAC. The purpose of filtration would be to enhance the adsorption capacity and longevity of the LGAC by removing fine sediments. It may also benefit by reducing the scale potential of the water during the air stripping process. O&M for filtration involves periodic monitoring of the pressure drop across the filter vessels, and replacing the filter media (i.e., filter bags or cartridges) on an as-needed basis.

5.5.5 Alternative 5 – Air Stripping with VGAC and LGAC Treatment for P&T

This alternative pertains to the treatment of extracted groundwater from P&T systems that would be installed to control and remediate groundwater from either the downgradient margin of the WOC Facility, or from the central, downgradient portion of the plume.

5.5.5.1 Treatment Efficiency

As described for Alternatives 3 and 4 above, the treatment efficiency for removal of VOCs from groundwater by air stripping can exceed 99% with proper design. Under this alternative, both VGAC and LGAC would also be used to provide off-gas treatment and effluent polish, respectively. The combination of VGAC and LGAC used downstream of the air stripper would provide the highest degree of treatment efficiency, capable of removing VOCs below standard levels of laboratory detection. This alternative also provides the greatest safety factor to ensure that treatment criteria are met and that potential exposure from VOCs is minimized.

5.5.5.2 O&M

The O&M considerations for this alternative involve the collective activities and information described for air stripper Alternatives 2 through 4 above. Air stripping with LGAC and VGAC would involve the most labor intensive and costly O&M of the air stripping options. However, as described above, it provides the highest degree of treatment efficiency and greatest safety factor for air stripper operations.

A significant portion of the operating costs associated with Alternative 5 will be both VGAC and LGAC replacements. Estimated carbon usage rates for post-air stripping VGAC and LGAC are described above in Sections 5.5.3.2 and 5.5.4.2, respectively. The procedures for monitoring, switching vessels, and replacing spent carbon are essentially the same, as described above.

5.5.6 Alternative 6 – LGAC Only Treatment for P&T

This alternative pertains to the treatment of extracted groundwater from P&T systems that would be installed to control and remediate groundwater from either the downgradient margin of the WOC Facility, or from central, downgradient portion of the plume.

5.5.6.1 Treatment Efficiency

LGAC-only treatment systems can reliably achieve high removal efficiency. Dissolved organic contaminants that pass through a LGAC vessel are completely removed until the contaminant breaks through, first at low concentrations. If the carbon was not replaced, effluent concentrations would increase until they equaled the influent concentration. Before breakthrough, the effluent concentration is generally zero and the treatment efficiency is 100%.

The adsorption capacity of LGAC for a particular contaminant is characterized by an empirical adsorption isotherm. The isotherm is described by an equation that defines the capacity of the carbon for the sorbed contaminant and the strength of the attraction. For a given LGAC vessel, the isotherm is used to estimate the time to breakthrough for a specific contaminant and mass loading rate, allowing the carbon-use rate to be calculated.

5.5.6.2 O&M

Carbon-adsorption systems are reliable and typically require little routine maintenance. Routine operation consists of periodic checks of pressure drop across the LGAC vessels and monitoring for contaminant breakthrough in the vessel effluent. Increased pressure could result from sediment accumulation. Bag filters (typically 10 to 25 microns) or similar performance cartridge filters are often installed upstream of the LGAC vessels to minimize the degree of sediment accumulation in the carbon. If pressure buildup occurs, the LGAC vessels are backwashed to remove sediment and restore the carbon's permeability. For this FS, it is assumed that the LGAC would be backwashed once per quarter. Typical backwash water contains sorbed contaminants and sediment, which is collected in a sedimentation tank. Supernatant water is pumped through the treatment system and collected solids are characterized and treated off site. Once the carbon capacity is reached and contaminant breakthrough occurs in the first vessel, in a typical two-vessel lead/lag configuration, the spent carbon requires replacement. By changing valve positions, the second vessel becomes the first in the series, and the first vessel is replaced. Carbon-use rates are also dependent on contaminant and hydraulic load changes via the possible addition of other extraction wells.

Parallel LGAC systems are typically configured to allow independent operation of each leg of the parallel system. This configuration allows an individual system to be isolated for backwash or carbon exchange with minimal disruption of groundwater pumping.

Carbon-only treatment systems are simple, quiet, and produce no emissions. The largest readily available units contain 20,000 pounds of GAC and treat up to 1,000 gpm. For treating flows greater than approximately 1,000 gpm, the treatment system typically includes two pairs of series-configured units (i.e., lead/lag vessels) arranged in parallel.

A main operating cost associated with LGAC systems is carbon replacement. LGAC in the lead (primary) vessel typically is replaced within an optimum time-frame after breakthrough occurs, and manifold valving is then switched, so that the lag (secondary) vessel serves as the lead vessel. LGAC usage was modeled by Prominent and Siemens; both entities are reputable vendors of GAC treatment systems. Siemens and Prominent used safety factors of 1.75 and 1.85 in their LGAC usage rates estimates, respectively. These safety factors account for the impact of natural organic matter and other unknown organic compounds that would adsorb to the LGAC. The average results of Siemens and Prominents isotherm models to predict LGAC usage based on the estimated VOC influent concentrations presented in Section 5.1 are:

- Approximately 7 lbs/day of LGAC usage at 30 gpm;
- Approximately 62 lbs/day of LGAC usage at 300 gpm; and
- Approximately 108 lbs/day of LGAC usage at 500 gpm.

Copies of the two vendors' isotherm model output sheets are included in Appendix B.

5.5.5 Recommended Treatment Alternative for P&T

A cost analysis has been performed for the five P&T groundwater treatment alternatives using a design flow rate of 300 gpm (see Tables 5-1 through 5-5). The analysis excludes capital costs for extraction wells, submersible pumps, and conveyance pipeline installations, since these costs would be the same for each of the alternatives. Air stripper performance and LGAC usage is based on estimated influent concentrations of 150 µg/L TCE, 5 µg/L PCE, and 20 µg/L 1,l-DCE. At these concentrations and the 300-gpm flow rate, the estimated 30-year life-cycle (LC) and net present value (NPV) costs for the multiple groundwater treatment alternatives are:

- Alternative 2, Air Stripping Only: $3.1 million (M) LC; $1.5M NPV;
- Alternative 3, Air Stripping with VGAC; $3.7M LC; $1.8M NPV;
- Alternative 4, Air Stripping with LGAC: $4.1M LC, $2.06M NPV;
- Alternative 5, Air Stripping with VGAC and LGAC; $4.2M LC; $2.1M NPV; and
- Alternative 6, LGAC Only: $3.0M LC, $1.6M NPV.

Based on the cost analysis, LGAC only (Alternative 6) would be the recommended treatment alternative for groundwater derived from pumping at the central portion of the downgradient plume. This is the least costly alternative, with simplistic O&M, and no noise or off-gas emissions compared with all the air stripping alternatives.

5.6 REMEDIAL TECHNOLOGY ALTERNATIVES CONSIDERED FOR WOC FACILITY

This section provides an analysis of potential remedial technology alternatives for groundwater near the WOC Facility. As described in Section 4.0, the presumed sources of SGWS contamination were multiple septic tanks and seepage pits historically in use at the WOC Middle Parcel. Note that there have been several remedial actions undertaken at the Middle Parcel, including: 1) the removal of multiple septic tanks and associated drain lines that received discharges of TCE in wastewater (Section 4.1); 2) installation and operation of an SVE system (Section 4.2); and 3) abandonment of the Pincus well. However, although historical concentrations of VOCs in multiple shallow monitoring wells at the Middle Parcel (that went dry) decreased, levels remained above AWQSs.[14] Furthermore, concentrations of TCE in wells nearest to the downgradient margin of the Middle Parcel (i.e., wells WCP-207, MW-102S (now dry), and MW-102SR) either remained, or presently are, at concentration levels of approximately 100 μg/L TCE (Table 3-1). The magnitude of these concentrations is approximately 20 times the TCE AWQS of 5 μg/L.

Some degree of soil and groundwater contamination remains from the historical releases at the WOC Middle Parcel. With respect to soil contamination, Section 3.4 includes a discussion of October 2008 soil gas sampling performed at the WOC Middle Parcel to evaluate remedial options and the potential justification for an additional source property remediation system. The results of model calculations indicate that residual soil contamination is likely to be less than applicable GPLs, and therefore, soil remediation would not be required. However, it is likely that distributed VOC contamination remains that is not readily removed, particularly contaminant mass that remains in soil water as a result of the declining water table. These VOCs are susceptible to remobilizing to groundwater by infiltration, a rising water table, or via soil gas.

[14] Specifically, VOCs in wells MW-4S, MW-5S, and MW-100S decreased prior to going dry (Table 3-1). The decline in concentrations correlates to the decline in water levels after the Grand Canal was lined.

COCs in groundwater (including PCE and TCE) are known to have migrated south from the NCP into the Site, both within and beyond the WOC Facility boundaries (see Section 3.3 and Figure 3-10). In the absence of implementing a hydraulic barrier and/or groundwater containment remedy at the NCP, contamination will continue to migrate south from the NCP into the Site.

This section considers installation of a barrier or containment remediation system that would operate at the downgradient margin of the WOC Facility along Osborn Road. It would include the use of remediation wells installed from east-to-west across either solely the south end of the Middle Parcel, or across the south end of both the Middle and West Parcels. The purpose of the system would be to reduce or cut-off the supply of contaminants emanating from the WOC and NCP to the downgradient portion of the plume. The expectation is that use of the system would reduce the overall timeframe to complete groundwater remediation by decades. This FS considers the following remedial alternatives:

- Alternative 1 – AS with SVE;
- Alternative 2 – Enhanced In-situ Bioremediation (ISB); and
- Alternative 3 – P&T with LGAC.

For the selection of the above three alternatives, a general screening process was performed to determine technologies that would be both technically viable and considered practical for installation and operation of barrier containment/remediation systems at the WOC Facility. Information from the Federal Remediation Technologies Roundtable (FRTR) Screening Matrix was reviewed (http://www.frtr.gov/matrix2/section1/toc.html). Additional viable technologies screened included in situ chemical oxidation, passive/reactive treatment walls, and slurry walls. However, the aforementioned wall technologies were generally considered cost-prohibitive due to the depth of contamination (greater than 100 feet) and related construction challenges. Chemical oxidation was considered cost prohibitive as well due to the depth and large number of injection wells or boreholes that would be required to achieve contaminant contact with oxidants, and high anticipated oxidant/application costs.

5.6.1 Alternative 1: AS with SVE

5.6.1.1 Technology Description

AS is a technique in which air is injected into the saturated zone below or within the areas of contamination through a system of AS injection wells. As the injected air rises through the formation, it volatilizes and removes adsorbed VOCs in soils, as well as stripping dissolved contaminants from groundwater. AS is most effective at sites with homogeneous, high-permeability soils and unconfined aquifers contaminated with VOCs (EPA, 1997). SVE is commonly used with AS to remove the VOCs that are transported in the vapor phase to the vadose zone from the AS process. A typical SVE system is comprised of multiple extraction wells to capture and remove vapor-phase VOCs to the surface, where they are treated using a standard off-gas treatment system.

5.6.1.2 Conceptual Design

AS/SVE System at Middle Parcel – Option A

For application at the Site, a line of AS/SVE remediation wells could be installed from east-to-west across the southern boundary of Middle Parcel of the WOC Facility (Figure 5-1). The total length of the AS/SVE conceptual barrier would be approximately 300 linear feet. Based on measurements in well WCP-207 in September 2010, depth-to-water in the area where remediation wells would be installed is approximately 139 feet bgs. The total depth of each AS boring would be 185 feet bgs, to coincide with the approximate depth of VOC contamination characterized during depth-specific sampling when MW-3SR was installed. MW-3SR is located near the Grand Canal on the north central side of the West Parcel (Figure 2-2). Based on the current depth to water (approximately 139 feet bgs), the saturated thickness within each AS borehole would be approximately 46 feet.

The AS wells would be installed as nested pairs within single boreholes. The purpose for using nested pairs (two AS wells per borehole), rather than a single air AS well per borehole, would be to provide more effective sparging remediation of the heterogeneous shallow aquifer.[15] In addition, if water levels continue to decline at the Site, the shallow sparge points could go dry, while the deeper points would remain functional/saturated. Each nested AS well could consist of one deep and one shallow 2-inch diameter, schedule 40 PVC sparge well. The deep sparge well of each nested pair would be screened from 180 to 185 feet bgs, and the shallow sparge wells would be screened from 160 to 165 feet bgs. Therefore, there would be 20 feet of separation within the aquifer between each nested pair of AS wells. The screen interval of the AS wells would be comprised of 0.010-inch slot aperture PVC screen surrounded by a silica sand filter pack. A continuous bentonite seal would be placed between the top of the lower AS well screen and bottom of the upper AS well screen. Another bentonite seal would be placed above the top of the upper AS well screen, followed by a neat cement grout seal to the surface. Flush-mount, street-rated vaults would be installed over each nested AS well to protect the wellheads and provide access to pressure gauges. Conveyance lines to each AS well pair would be connected to provide sparge air from an AS compressor installed above ground in a fenced equipment compound.

A rotary-screw, air-compressor system would be used to furnish air to the AS well network. The capacity of the air-compressor system would be based on an estimated design flow rate of 15 cfm per well. Plumbing manifolds with valves, rotameters, and pressure gauges would be installed for use with controlling the flow rate and injection pressure to each individual AS well. At a minimum, the AS compressor would be equipped with a safety interlock to shut off the AS process whenever the SVE blower shuts off. This control feature, typical of all properly designed AS/SVE systems, serves to prevent the production of uncontrolled VOCs in the subsurface that could result in a health and/or safety hazard.

Given the heterogeneous nature of the aquifer, including the presence of fine-grained clays, silts, and silty sands, a preliminary estimate for the AS radius of influence (ROI) would be

[15] Based on borehole lithologic logs from MW-3SR and MW-102SR, the aquifer material consists of alternating layers of clayey silt, clayey sand, both fine and well-graded silty sand, and clay.

17.5 feet. However, only AS/SVE pilot testing would provide the data necessary to estimate the actual ROI. Therefore, if this option is considered for implementation at the WOC Facility, conducting an AS/SVE pilot test is strongly recommended as a basis for system design. For purposes of this FS, the assumed AS ROI is 17.5 feet; therefore, the nested AS wells would be installed 35 feet apart across the barrier distance of 300 linear feet, representing 9 nested pair AS wells. Therefore, 18 individual sparge points receiving 15 cfm per point represents a demand of 270 cfm from the AS compressor system.

It is assumed that new SVE wells would consist of 4-inch diameter, schedule 40 PVC casing and 0.020-inch slot aperture screen. They would be installed in the vadose zone to a depth of approximately 145 feet bgs, also along the southern (downgradient) margin of the Middle Parcel of the WOC Facility (Figure 5-1). The SVE well screen intervals would extend from a depth of 100 to 145 feet bgs to coincide with the approximate historical 1996 and September 2011 water table depths, and extending approximately 5 feet into groundwater at the southern margin of the WOC Facility.[16] This screen interval will serve not only to extract VOCs derived from the saturated zone via the AS process, but also to extract residual contamination present above the current water table, which had adsorbed to soil as the water table declined over time at the WOC Facility. Drilling/installing each new SVE well to an additional 5 foot depth within the SGWS groundwater is recommended to provide some contingency depth in the event of future continued water level decline at the Site. Given the heterogeneous lithology of the lower vadose zone (silty sand, sandy silt, clay, and traces of gravel), a conservative estimate of the SVE ROI would be approximately 40 feet; therefore, SVE well spacings of 80 feet are considered a reasonable estimate. Note that several existing wells could be readily connected to the SVE system well network, including MW-5S (135 ft deep), MW-100S (137 ft deep), and MW-101S (140 ft deep). Therefore, for ROI coverage across a 300 linear feet barrier distance, the SVE system could utilize 3 existing wells (Figure 5-1).

The conceptual SVE system would include a positive displacement blower system with a total extraction capacity of approximately of 550 cfm, representing a flow-balanced system of approximately 110 cfm per each of the 5 SVE wells. Therefore, for capture and control of VOCs from the AS process, the SVE system (550 total cfm; 110 cfm per SVE well) would involve extracting approximately twice the amount of flow than the AS injection system (270 total cfm; 15 cfm per each of the 18 AS points). VGAC vessels would be used on the pressure side of the blower to remove VOCs from the extraction vapor prior to discharge into the atmosphere. The VGAC vessels would consist of two series configured pairs (i.e., lead/lag configurations) arranged in parallel with a pipe and valving manifold to facilitate proper change-out and optimum use of the VGAC. In addition, the blower system would include either air or liquid-cooled after-cooler to lower the temperature of the extraction vapor, particularly during summer months, into an optimum range for VOC adsorption onto the VGAC.

[16] Wells MW-5S and WCP-207 are located at and close to southern property boundary of the WOC Middle Parcel, respectively. The depth-to-water in MW-5S was 97.98 feet bgs in November 1996. The depth-to-water in WCP-207 was 142.31 feet bgs in December 2008.

AS/SVE System at Middle and West Parcels – Option B

This option would expand upon Option A to include AS/SVE wells across the southern boundary of both the Middle and West Parcels of the WOC Facility (Figure 5-2). The total length of the AS/SVE conceptual barrier would be approximately 800 linear feet. There would be 24 nested pairs of AS wells, and 12 SVE wells, including the three dry existing monitor wells that could be used as SVE wells. The air injection capacity of the AS compressor system would be 720 cfm representing 48 individual sparge points receiving 15 cfm air per point. The vapor extraction capacity of the SVE blower system would be approximately 1500 cfm, representing a flow-balanced network of 125 cfm per each SVE well. Due to the increased capacity of the AS/SVE system, the mechanical, electrical, and plumbing systems would be larger for Option B compared to Option A. The VGAC treatment system would also need to be designed to accommodate the higher SVE flow rate.

5.6.1.3 Remediation Equipment Compound and Operations

It is assumed that the AS/SVE remediation system equipment/treatment compound would be constructed at the northwest end of the Middle Parcel, at the same location as previous interim SVE system. A 230/460 volt, 3-phase, minimum 200 amperage electric power supply would need to be provided by the utility company (SRP) to operate the system. It is also assumed that access agreements to install and operate the system would be obtained from the current affected land owners of the Middle Parcel (for Options A and B), and West Parcel (for solely Option B).

Depending on the remedial performance goals and COP zoning requirements, the AS/SVE system could operate continuously, in a pulsed mode, or during day-time hours only. Consideration would need to be given to the fact that residential apartments exist on the south side of Osborn Road, within close proximity to the WOC Facility. Therefore, the SVE blower and AS compressor packaged systems would need to be equipped with noise suppression features, and perhaps be installed within a ventilated cargo container, trailer, or small building.

5.6.1.4 Permitting

Drilling permits from the ADWR would need to be obtained to authorize and register the AS/SVE remediation wells. This is required for wells that terminate in an aquifer (AS wells) and wells that terminate in the vadose zone to depths greater than 99 ft bgs. The COP will require a building permit from the Development Services Department (DSD), and a special use permit from the Zoning Department to allow installation and operation of an environmental remediation facility. It is estimated that the AS/SVE system will have the potential to emit greater than 3 lbs/day of total VOCs before any emission controls/abatement (Section 5.5.2.2). Therefore, a Maricopa County Air Quality Department permit would need to be obtained to authorize treated discharges of extraction vapor from the AS/SVE system into the atmosphere.

5.6.1 5 Estimated Costs

Estimated costs for installation and O&M of the conceptual AS/SVE systems, including Options A and B are presented in Table 5-4. Costs assume that the AS/SVE mechanical equipment would be installed within a small building at the northwest end of the Middle Parcel. For Option B, the greatest capital costs would be associated with drilling and construction of the numerous remediation wells. The most uncertain component of the cost is the estimated duration that the system would be operated at the WOC Facility. For purposes of this FS, a LC of up to 15 years has been used. Note that any remedies implemented for groundwater at the NCP Site could have a significant influence on the LC of any of the remedial alternatives being considered for a barrier system at the WOC Facility.

5.6.1.6 Advantages and Disadvantages

When properly designed and operated, AS/SVE is a proven technology for the timely and safe removal of VOCs from soil and groundwater. The rate of VOC mass transfer/removal is also superior to P&T. AS/SVE also has a particular advantage over P&T in that both groundwater and soil can be simultaneously remediated. The SVE component of the system would remove residual VOCs trapped in the lower 40 feet of the vadose zone, which historically had been saturated with contaminated groundwater. The removal of VOCs from this portion of the vadose zone, within the ROI of each SVE well, would mitigate the susceptibility for contaminants to remobilize to groundwater by infiltration, a rising water table, or via soil gas. However, based on the results of soil gas sampling at the Middle Parcel (Section 3.3), model-calculated concentrations of VOCs in soil are considerably lower than the Arizona GPLs. Therefore, remediation of vadose zone soils would not be necessary.

A disadvantage compared with the two other alternatives is the production of noise from the AS/SVE mechanical equipment, particularly under Option B. However, it is believed that noise generation can be sufficiently controlled by installing the equipment within a small building, incorporating noise suppression features on the mechanical equipment, and/or potentially operating the system during daylight hours only. Another effective option would be to locate the AS/SVE equipment compound at the northwest end of the Middle Parcel, which would be over 500 feet away from the nearest residential apartment buildings.

5.6.2 Alternative 2: Enhanced ISB

5.6.2.1 Technology Description

Enhanced in-situ anaerobic bioremediation is defined in Principal and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents (AFCEE, 2004) as:

> *the delivery of an organic substrate [electron donor] into the subsurface for the purpose of stimulating microbial growth and development, creating an anaerobic groundwater treatment zone, and generating hydrogen through fermentation reactions. This creates conditions conducive to anaerobic biodegradation of chlorinated solvents dissolved in groundwater [Biostimulation]. In some cases, organisms may need to be added, but only if*

the natural microbial population is incapable of performing the required transformations [Bioaugmentation].

The microbes associated with anaerobic biodegradation of chlorinated solvents (chloroethenes) are from the genus *Dehalococcoides*. Organic substrate serves as an energy source for the microbial population. *Dehalococcoides* respirate the chlorine atoms from the chlorinated solvents. The position of the respired chlorine atom is replaced with a free hydrogen atom from substrate. This process is generally termed dechlorination, and the biotic process of dechlorination is as follows:

PCE → TCE → DCE (typically cis-1,2-DCE) → Vinyl Chloride → Ethene

Various substrates used to enhance reductive dechlorination of VOCs include methanol, lactate, molasses, emulsified vegetable oil (EVO), hydrogen gas, and other commercially available formulations. Injections wells (IW)s or re-circulation wells completed in the affected aquifer are used to deliver the substrates. Successful ISB depends on physical contact of the microorganisms with the substrate and dissolved contaminants. Laboratory treatability studies with microbial and geochemical testing of representative samples of contaminated groundwater and aquifer matrix are typically performed to assess the performance of enhanced ISB with the various substrates.

A biobarrier application is being examined as part of this study. A biobarrier application of ISB requires the development of a reduced, biologically active zone (as discussed above), throughout the saturated thickness and target length (perpendicular to groundwater flow) of the impacted aquifer. The developed treatment zone must be of sufficient width (parallel to groundwater flow) to ensure contaminant residence time is long enough to achieve complete dechlorination.

5.6.2.2 Treatability and Pilot-Scale Testing

A pilot test should be conducted to evaluate enhanced ISB at the site. As part of the pilot test, baseline groundwater sampling and treatability studies are typically conducted to identify geochemical background conditions at the site and to select a suitable substrate for the application.

The baseline groundwater samples should be analyzed for total organic carbon, nitrate, sulfate, dissolved oxygen (DO), oxidation-reduction potential (ORP), and pH, as well as VOCs. The concentrations of these inorganic and organic parameters are used to determine the hydrogen demand (donor demand) to reduce the aquifer to reducing conditions and dechlorinate the contaminants. The groundwater should also be submitted for genetic testing to determine if an endemic population of halo respiring bacteria (*Dehalococcoides*) is present in the aquifer.

Soil samples should be collected from the boring of the pilot test injection well. Useful soil testing include treatability studies, grain size distribution, soil-bacteria count, oil retention capacity, and pH buffering capacity to evaluate site characteristics for electron donor, bacteria, and pH adjustment needs.

Baseline groundwater and soil results should be reviewed to determine if a treatability study is necessary. Substrates evaluated as part of the treatability study should include soluble substrates (lactate, methanol, and molasses), viscous fluid substrates or oil-based substrates (HRC and EVO), and solid substrates. Additionally, pH-adjusting substrates or additives can also be assessed as part of the study.

If a treatability study is not necessary, an EVO substrate will be recommended as the organic substrate (electron donor) based on past experience and success with the substrate. These products contain 40% to 60% emulsified soybean oil, which serves as a slow-release electron source, and 5% sodium lactate, which is a readily consumable electron donor that quickly initiates aquifer conditioning.

The overall objective of the pilot test is to determine if ISB can effectively reduce the concentration of dissolved-phase chlorinated solvents in the aquifer along the southern property boundary of the West and Middle Parcels.

Specific objectives of the pilot test are:

- Determine if biostimulation alone could achieve complete dechlorination of TCE to ethane;

- Determine if bioaugmentation would be required at the Site and if it could achieve complete dechlorination;

- Determine optimal electron donor and geochemical adjustment amendments quantities and dose rates for a full-scale application of this technology; and

- Determine the optimal residence time to achieve complete dechlorination.

The pilot test conceptual design includes one injection well (IW-1), two performance monitoring wells (PMW-1 and WCP-207), and a control well (MW-3SR) upgradient of the pilot test treatment area. The location of the injection well and monitoring wells are depicted on Figure 5-3. This layout utilizes two existing site wells. The injection well will consist of well couplets within one borehole, and would be constructed of 2-inch diameter, schedule 40 PVC casing and 0.020-inch slot continuous-wrap screen. The well screen intervals would extend from a depth of 142 to 162 feet bgs (A interval) and 165 to 185 feet bgs (B interval). The split injection well screen interval reduces the effects of preferential flow into shallower portions of the screen due to hydrostatic pressure. Figure 5-4 shows an injection well detail. The performance monitoring well would be constructed of 2-inch diameter, schedule 40, PVC casing and 0.010-inch mill slot screen. The well screen intervals would extend from a depth of 145 to 185 feet bgs. This allows for sampling at multiple depths to monitor the variability of treatment in the vertical direction, which can provide important information that can be used to optimize the full-scale design. Figure 5-5 shows a monitoring well detail.

The pilot test layout is intended to determine if a single well (IW-1) could achieve complete dechlorination within a 7.5-foot treatment radius. PMW-1 would be located 10 feet downgradient of IW-1, which will be located 40 feet upgradient of the existing monitoring well, WCP-207. This layout will allow for the observation of treatment that occurs beyond the targeted treatment radius, should it occur. Also, the two downgradient monitoring wells will allow for the observation of the transport regime of degradation products. Based on the contaminant concentrations present, existing geochemical data, and groundwater velocity at the site, an electron donor quantity of approximately 2.4 drums, or 1,000 pounds of donor will be applied to each injection well (half in the A-shallow and B-deep intervals) at a 5% solution (2,600 gallons of solution) for the pilot test application.

Electron donor would be delivered into the injection well using a water-powered dosimeter and municipal water supply. A backflow preventer and meter will be placed on the municipal water supply (likely a hydrant) as a safety precaution and to determine water usage. The donor would be mixed with municipal water and injected at a rate of 7 gpm. The municipal water source should be sampled prior to the initiation of the donor application to determine if trihalomethanes (common water treatment and disinfectant byproducts) are present. If trihalomethanes are present, water should be pre-treated with a flow-through GAC filter. For the purposes of this analysis, it is assumed that municipal water pre-treatment will not be necessary.

Pilot test performance monitoring following injection of substrates normally involves monthly monitoring of geochemical parameters, VOCs, and bacterial count (presence of *Dehalococcoides* genus) for a two- (or three-) month period. If the results indicate that biostimulation can establish a population of *Dehalococcoides* and achieve complete dechlorination, semi-annual samples would be collected to investigate longevity of the substrate for a one-year period from pilot-scale injection. If the performance monitoring data indicate that biostimulation cannot achieve the desired results, bioaugmentation would be completed. Bioaugmentation can be completed once the geochemical parameters of the groundwater indicate sulfate-reducing and slightly methanogenic environment exists (typically an ORP of -100 is desirable). Several bioaugmentation cultures that contain *Dehalococcoides* are currently available (KB-1, Bio-Dechlor INOCULUM, BAC-9, BCI). Bioaugmentation would consist of the injection of approximately 2.5 liters of a culture into each of the injection well screen intervals. Performance monitoring would continue monthly for two or three months to demonstrate the bacterial population has increased; then monitoring would transition to the semi-annual longevity. Pilot test data will be evaluated to design the full-scale application.

5.6.2.3 Conceptual Full-Scale Design and Implementation

A final full-scale design would be based on the pilot test results and performance monitoring analytical data at the WOC Facility. Specific design requirements for the full-scale application include a treatment zone to intercept and treat VOCs along the southern property boundary of the WOC Facility to eliminate off-site migration.

For conceptual purposes, we have developed two options (Options A and B) for a full-scale design based on our experience at similar sites. The following sections describe these conceptual designs.

Enhanced ISB Barrier at WOC Middle Parcel – Option A

The conceptual full-scale design consists of a row of 21 injection wells (including IW-1) which would be similar in construction to IW-1. An additional performance monitoring well would also be installed downgradient of the bio-barrier, to be used in conjunction with existing well WCP-227 to monitor the effectiveness of enhanced ISB. A layout of the conceptual design injection and monitoring wells is shown on Figure 5-6. The injection wells, oriented perpendicular to groundwater flow, would be spaced approximately 15 feet apart. EVO substrate is the organic substrate (electron donor) selected for the conceptual full-scale application.

Following the installation of the injection and monitoring wells and before application of the donor, a baseline sampling event will be completed on several of the injection well couplets and the performance monitoring wells. Similar parameters which would be analyzed in the pilot test baseline sampling event will be analyzed for the full-scale baseline sampling event.

Electron donor would be delivered into the injection wells using a water-powered dosimeter and municipal water supply. A backflow preventer and meter will be placed on the municipal water supply as a safety precaution and to determine water usage. Water should be pre-treated with a GAC filter, if municipal water is found to contain trihalomethanes during the pilot test phase. A fenced equipment compound would be constructed to secure substrate tanks or drums and a power supply.

Based on the quantity calculated for the pilot test, 45 drums (55-gallon) of emulsified soybean and sodium lactate donor has been calculated for the Option A conceptual full-scale design. It should be noted that quantities and formulations may vary based on the results of the testing completed during the pilot test phase. Preliminary calculations suggest that approximately 2.25 drums of electron donor would be applied to each injection well (half in the A-shallow and B-deep intervals) at a 5% solution (2,480 gallons of solution). This would be followed by approximately 10,000 gallons of water to spread the donor to the desired ROI. Life-span of the first application is assumed to be two years, based on the past experience with the substrate. The dosing rates and total quantity of substrate will also be revaluated based on pilot test results.

If necessary, bioaugmentation would be applied to the site three months after the full-scale injection, assuming conditions are optimal by that time.

Enhanced ISB Barrier at WOC Middle and West Parcels – Option B

A layout of the Option B conceptual design showing the injection and monitoring wells is shown on Figure 5-7. The design would expand the Option A barrier to the west, to include the installation of injection wells also across the southern margin of the West Parcel. There would be 53 injection wells (including IW-1), similar in construction to IW-1.

Following the installation of the injection and monitoring wells, and before application of the donor, a baseline sampling event will be completed on select injection well couplets (10% of the 53, or 5) and the three monitoring wells. Similar parameters which would be analyzed in the pilot test baseline sampling event will be analyzed for the full-scale baseline sampling event.

A quantity of 126 drums (55-gallon) of emulsified soybean and sodium lactate donor has been calculated for the conceptual full-scale design based on the quantity calculated for the pilot test. Approximately 2.4 drums (or 1,000 pounds) of electron donor would be applied to each injection well (half in the A-shallow and B-deep intervals) at a 5% solution (2,600 gallons of solution). This would be followed by 11,600 gallons of water to spread the donor to the desired ROI. Life-span of the first application is assumed to be two years, based on the past experience with the substrate. The dosing rates and total quantity of substrate would also be revaluated based on pilot test results

If necessary, bioaugmentation will be applied to the site three months after the full-scale injection, assuming conditions are optimal by that time.

5.6.2.4 Performance Monitoring and Maintenance Injection

Injection and monitoring wells should be sampled to determine remedial performance in the near and far vicinity of the biobarrier. The sampling events would be conducted in general accordance with the EPA Low Flow (minimal drawdown) Groundwater Sampling Procedures (April 1996), when possible. Low-flow sampling allows for discrete-depth groundwater sampling in the longer-than-typical screens in the injection wells and performance monitoring wells. A multi-parameter, water-quality meter equipped with a flow-through cell would be used to monitor the field parameters, including temperature, pH, specific conductance, ORP, DO, and turbidity. Samples would be collected in most instances when field parameter measurements are stable. Laboratory samples would be collected for VOCs, methane, ethane, and ethene, TOC, *Dehalococcoides* bacteria counts, dissolved iron, nitrate, and sulfate.

Performance monitoring would commence one month following the application of electron donor, and continued monthly for a 3-month period. If the site requires bioaugmentation, it would occur during the third month after the donor application. Monthly performance monitoring will be continued for two months. Thereafter, monitoring will be continued on a semi-annual basis for two years.

A maintenance injection of electron donor is expected to be needed every two years, and performance monitoring would be continued on a semi-annual basis to evaluate the remedial progress at the Site. Preparation of annual performance monitoring reports would commence one year following the initial installation.

5.6.2.5 Permitting

A well used for the injection of bioremediation agents into the subsurface for the purpose of remediation are considered Class V injection wells under the EPA Region 9 Underground Injection Control program. More specifically, a well used for this purpose is defined as an aquifer remediation well under that program. The EPA Region 9 does not recognize the State of Arizona as having primacy regarding underground injection control; therefore EPA Region

9 is the permitting body. Class V Aquifer remediation wells are permitted by rule, but the EPA Region 9 requires an injection well inventory be complete for their review (Attachment 1). Although the ADEQ does not have a Underground Injection Control program recognized by the EPA, there may be additional permitting requirements for the state (refer to the ADEQ Aquifer Protection Program (http://www.azdeq.gov/environ/ water/permits/app.html).

5.6.2.6 Estimated Costs

Estimated costs for the two enhanced ISB options are included in Table 5-4. Total costing for the entire project is divided into subcategories that include pilot-scale feasibility testing, full-scale implementation, maintenance substrate injection, and performance monitoring. The highest portion of the capital cost, by far, would be for drilling and installation of the injection wells. The most uncertain component of the cost is the estimated duration that the system would be operated at the WOC Facility. For purposes of this FS, a life cycle of up to 15 years has been used. Note that any remedies implemented for groundwater at the NCP site could have a significant influence on the life cycle of any of the remedial alternatives being considered as a barrier system at the WOC Facility. In addition to the drilling cost, substrate cost is a significant contribution to the total cost, because it would be necessary to apply maintenance donor injection every two years. Even though costs for the bioaugmentation are included into the total cost, bioaugmentation may not be required during the application based on the microbiological population present at the Site.

5.6.2.7 Advantages and Disadvantages

Advantages

Enhanced ISB would involve either minimal or no construction of any permanent aboveground infrastructure.[17] With the exception of maintenance injections estimated to be required every two years, there would be little to no O&M associated with enhanced ISB. Another advantage is that the technology can completely mineralize contaminants *in situ*, as opposed to transferring contaminant mass to another phase.

Disadvantages

Incomplete degradation and intermediate production of toxic degradation products (cis-1,2-DCE and vinyl chloride) are a concern with enhanced ISB. Microbial growth can cause undesirable impacts on water quality and aquifer conditions downgradient of the treatment zone, such as biofouling (reduces hydraulic conductivity), production of organic acids (lowers pH), redox changes, methane production, and nutrient removal. Given the depth to water, methane production and vapor intrusion are not likely to be a significant disadvantage. Biobarriers must be maintained as long as there is a source of influent contaminants. Aquifer conditioning and maintaining an optimal environment for the target bacterial population and competition with non-target populations can be a challenge. When

[17] If desired, a small fenced compound could be installed for storage of minimal required equipment and supplies to support groundwater monitoring of ISB performance, and for substrate injections estimated to be required once every two years.

there is a limited naturally occurring population of *Dehalococcoides*, the time required to establish an adequate population to achieved complete dechlorination can be several months to years, especially if bioaugmentation is not performed.

Due to its limited length of only approximately 300 linear feet, the Option A design would provide only partial barrier protection against the continued migration of VOCs downgradient of the WOC Facility. Option B provides significantly more

5.6.3 Alternative 3: P&T with LGAC

5.6.3.1 Technology Description

P&T is a common method for timely plume containment, with slow to very slow remediation of groundwater contamination over time. It typically involves the use of one or more extraction wells (EWs), each equipped with a submersible pump, to pump groundwater and deliver it to the surface, where it is treated to remove contaminants. Design of a P&T system is typically based on the results of aquifer (pump) tests to determine key aquifer properties, including hydraulic conductivity, transmissivity, specific yield, and storativity. These data are used in calculations and/or models to determine effective pumping rates and extraction well locations to enable capture of a contaminant plume. After the EWs are installed and the P&T system is operating, monitoring of drawdown in observation wells surrounding the pumping well(s) is required to confirm the effectiveness of plume capture.

5.6.3.2 Conceptual Design

Extraction Wells and Pumping Rates

Figure 5-8 provides a conceptual layout of a P&T system with three EWs installed along the southern margin of the West and Middle Parcels. It is assumed that the EWs would be constructed of 6-inch diameter, schedule 40 PVC casing and 0.020-inch slot aperture PVC screen. The screen intervals would be placed from a depth of 140 to 185 feet bgs, to coincide with the estimated thickness of VOC contamination.[18] Appendix C includes a discussion of WhAEM code modeling to predict capture zones of pumping wells installed at the WOC Facility's southern property. Based on the modeling results, it is estimated that a P&T system consisting of three EWs could be operated to contain the approximate full width of the SGWS plume at the WOC Facility (see Appendix C and Figure 5-9).

WhAEM model simulations using a hydraulic conductivity of 1.5 ft/day and a pumping rate of 10 gpm per well, predict that three EWs spaced approximately 330 feet apart would be adequate to achieve plume capture. The basis of these conceptual designs are data obtained from aquifer tests performed on MW-6S and MW-7S at the Site, an aquifer test performed on WCP-227 at the NCP site, and previous groundwater model reports by GeoTrans (HSI, 2000) and the ADWR (ADWR, 1994).

[18] Based on depth-specific sampling during installation of replacement monitoring well MW-3SR, which is located at the north end of the WOC Facility West Parcel.

Treatment Plant and Operations

For purposes of estimating costs, it is assumed that the extracted groundwater would be treated to remove VOCs using bag filtration for particulate removal and LGAC only for VOC removal. The treated water would be discharged to the Grand Canal located directly north of the WOC Facility. During the SRP's annual dry-up period for maintenance of the Grand Canal, it is assumed that the treated water would be diverted to the COP sanitary sewer. It is also assumed that the treatment compound would be located in the northwest corner of the Middle Parcel, at the location of the former interim SVE system equipment compound. Each of the groundwater EWs would be individually connected to the treatment compound using underground high-density polyethylene ethylene piping. These pipelines would stub-up to the surface within the equipment compound and connect to a common manifold. Each pipeline would be equipped with a gate valve, a flow/totalizer meter, and a sample valve.

The groundwater treatment system would include a pair of bag filter units plumbed in parallel between the common manifold and tray air stripper. The purpose of the bag filters would be to remove fine sediment and other particulates from groundwater to optimize performance and minimize fouling of the LGAC. Sampling valves installed in the process plumbing would be located 1) upstream of the primary (lead) LGAC vessel; 2) between the primary (lead) and secondary (lag) LGAC vessels; and 3) downstream of secondary (lag) LGAC vessel. This would enable sampling of the mixture of untreated groundwater from the EWs, and both the primary and secondary LGAC treated groundwater. Decisions regarding LGAC vessel change-out would be based on breakthrough concentrations of trace VOCs detected in groundwater from the primary vessel. The discharge pipeline within the treatment plant compound would be equipped with a flow/totalizer meter. This pipeline would then transition underground to terminate in the bank of the Grand Canal within a structurally-sound headwall structure.

The aboveground P&T process equipment would be installed within a concrete containment area gently sloped to a water-tight sump equipped with a float shut-down switch. If a significant piping failure occurred, released groundwater would drain into the sump and shut off the pumping system. Other shut-down controls would include those related to high or low water pressure and high differential pressure across the bag filter units. In addition, the system would be automated with a telemetry control system that would enable the SRP to shut off the pumping system remotely in the event of an emergency situation on the Grand Canal.

The P&T system would operate on mainly a continuous schedule, except for short periods of routine maintenance. However, it would be necessary to shut off the system for approximately one month annually due to the SRP's canal dry-up period to perform canal maintenance. Water-level monitoring in the vicinity of the EWs would enable determination of sustained plume capture during the approximate one-month shut-down period.

Uncertainty of Duration for Dewatering

The P&T system, operating at constant pumping rates, may slowly dewater the SGWS over time, such that water-level elevations would decline and EWs may go dry. Drought conditions resulting in the lack of groundwater recharge in the Site vicinity could potentially accelerate water-level elevation declines. Depending on the degree of localized dewatering determined from water-level monitoring, strategies for reduced pumping would need to be evaluated. One simple but possibly temporary solution may be to equip the submersible pumps with electrode level controls, so that they would only turn on when a sufficient amount of groundwater recharges into the EW above the pump. Specific submersible pneumatic pumps could also be used that are designed to function in a similar manner. Each pump would then operate to drain the EWs down to near the pump intake, cycling back on after recharge. It is likely that this periodic pumping process would also serve to maintain capture of the groundwater contaminant plume.

Estimated Costs

Estimated costs for installation and O&M of the conceptual P&T system are included in Table 5-6. The costs reveal that at a 30-gpm flow rate, LGAC only treatment would be the most cost-effective alternative compared to air stripping with VGAC. Note that although the Maricopa County Air Quality Division (MCAQD) would not require a permit for emissions from an air stripper, VGAC for off-gas treatment was included in the evaluation because it would be required by ADEQ.[19]

5.6.4 Recommended Alternative for P&T

If a decision to implement a barrier system remedy at the WOC Facility is made, Alternative 3 (P&T) utilizing three EWs with LGAC only treatment is recommended. This remedy is the least costly and most practical alternative. P&T will be immediately effective at containing the groundwater VOC plume, including the significant contribution of contaminant mass migrating into the Site from the NCP. Compared with Alternatives 1 and 2, P&T will be much easier to construct, operate, maintain, and monitor over the course of system operations. Compared with Alternative 2 (enhanced ISB), P&T poses no risk of producing potentially more toxic VOC by-products (i.e., vinyl chloride) or other undesirable aquifer conditions (i.e., biofouling, production of organic acids [lowers pH], redox changes). It is also significantly less costly than Alternative 2. Compared with Alternative 1 (AS/SVE), P&T with LGAC is also much less labor-intensive, will consume significantly less electrical energy, and will not create a potential noise nuisance to residents living at the apartments along Osborn Road.[20]

5.7 REMEDIAL ALTERNATIVES CONSIDERED FOR DOWNGRADIENT PLUME

This section provides a discussion of two remedial alternatives being considered for remediation of the SGWS VOC plume that has migrated downgradient from the WOC facility. Due to the large geographic area in which the occupies, and the fact that this area is densely developed with a combination of residential, commercial, and industrial buildings,

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[19] Based on the 30 gpm flow rate and estimated groundwater influent concentrations, the potential emissions of VOCs from an air stripper without VGAC would still be significantly lower than 3 lbs/day (see Section 5.2.4.4).
[20] The 30 gpm-rated, low-profile air stripper would operate with only a 3-HP, relatively quiet air blower. In contrast, the AS/SVE system, Option 2, would utilize two 60-HP sparge air compressors and a 40-HP SVE blower.

only two remedial alternatives are considered technically feasible and practical in terms of cost to justify consideration. These alternatives are MNA and P&T.

5.7.1 Alternative 1: MNA

5.7.1.1 Application Description

The USEPA Office of Research and Development describes MNA as follows:

> *Natural attenuation is the reduction of contaminants in soil or groundwater through natural physical, chemical, or biological processes. These processes degrade or dissipate contaminants and include aerobic and anerobic biodegradation, dispersion, volatilization, and sorption. MNA is a technique used to monitor or test the progress of the attenuation process. It may be used with other remediation processes as a finishing option or as the only remediation process. Natural processes can then mitigate the remaining amount of pollution, and regular monitoring of the soil or groundwater can track those reductions. MNA is increasingly used in cleanup actions* (EPA, 2007).

Chlorinated solvents and their byproducts are the primary target analytes for monitoring natural attenuation. These analytes are used to determine concentration and distribution of contaminants, and their daughter products, in the aquifer. The degradation process of chlorinated solvents is generally termed dechlorination, and the biotic process of dechlorination is as follows:

PCE → TCE → DCE (typically cis-1,2-DCE) → Vinyl Chloride → Ethene

The contaminates of concern at the Site are VOCs, specifically PCE, TCE, and 1,1-DCE, all of which would be ideal analytes for monitoring degradation at the Site. Other groundwater quality parameters may be collected and analyzed to better understand the degradation processes and rates; and include oxidation-reduction potential, pH, temperature, conductivity, oxygen, nitrates, methane, iron (II), sulfates, alkalinity, and chloride. Site-wide groundwater levels should also be collected to monitor the hydraulic gradient across the Site in order to document the physical aspects of MNA, such as dispersion (EPA, 1998).

5.7.1.2 Implementation at WOC Site

Implementation of MNA at the Site would involve the continuation of groundwater monitoring of the existing network of SGWS wells. Monitoring would include both the gauging of water levels to determine the direction and value of the hydraulic gradient, and water quality sampling to determine the concentrations and composition of VOCs. The data trends for VOC parameters would be tabulated and plotted to evaluate the degree of concentration reduction and sustained attenuation, respectively.

Advantages

Compared to engineered, active remediation technologies, remedies relying on MNA often have the following advantages:

- Significantly less volume generation of remediation-related wastes and reduced potential for cross-media transfer of contaminants that are typically associated with ex-situ treatment processes;

- Reduced risk of exposure to contaminated media;

- The elimination of installing invasive or intrusive infrastructure (i.e., no need for surface structures);

- Potential for application to either all or select portions of the Site;

- Can be used in conjunction with, or as a follow-up to, other active remedial measures; and

- Lower overall remediation costs compared to those associated with active remediation technologies (EPA, 1998).

For purposes of this FS, it is assumed that semi-annual groundwater monitoring of the existing network of 13 SGWS wells would be performed for a period of up to 30 years.

5.7.2 Alternative 2: P&T

The characterized portion of the SGWS plume is approximately 2.25 miles long and 1 mile wide (Figure 3-1). P&T technology has been selected as the only practical active remediation alternative to enable hydraulic containment/remediation of the SGWS plume that has migrated downgradient of the WOC Facility area. Two different groundwater pumping strategies have been considered: 1) the use of three 100 gpm extraction wells to capture the highest concentrations of VOCs from the central core of the plume, and 2) the use of five 100 gpm extraction wells to capture VOCs across the full width of the central portion of the plume. Capture zone modeling was performed to evaluate these two strategies, which is described in Section 5.6.2.1 below. Information in preceding Section 5.4, provides an evaluation of treatment technologies to remove VOCs from groundwater. For the P&T remediation alternative that would addresses the downgradient portion of the plume, a recommendation was made for selecting LGAC only for groundwater treatment (Section 5.5.5).

5.7.2.1 Pumping Modeling and Results

To assist with conceptual design of the screened P&T remedies, simplistic modeling was performed to evaluate plume capture by EWs. The EPA WhAEM code was used to model two-dimensional flow. Use of WhAEM requires situations where the aquifer can be modeled as having constant thickness and is horizontal. Although neither condition may be absolutely true in the SGWS, the assumptions should be acceptable for the purpose of assessing the location and capture zones of pumping wells. Aquifer hydraulic properties used as inputs for modeling were estimated based on: 1) historic aquifer tests performed on SGWS monitoring wells MW-6S and MW-7S at the Site; 2) an aquifer test performed in 2008 on well WCP-227 at the NCP Site; 3) a limited aquifer test performed in 2009 on well MW-206S at the Site; 4) data and other information presented in a draft model of 3-dimensional flow and TCE transport (HSI GeoTrans, 2000); and 5) available ADWR groundwater models. Additional information on the hydrogeologic characteristics and assumptions used for WhAEM modeling are provided in Appendix C.

5.7.2.2 Remedial Pumping with Three EWs

EWs and System Location

Installation of several EWs pumping at 100 gpm each at the central portion of the SGWS plume is expected to effectively contain and gradually remediate the most contaminated zone of the VOC plume. Several conceptual locations of EWs have been selected based on the effectiveness of capture zone modeling (Figure 5-12). Review of aerial photographs indicates that land bounded by West Monte Vista Road on the north, McDowell Road on the south, 39th Avenue on the east, and 43rd Avenue on the west (in the vicinity of MW-206S) is fully developed with residential homes, apartments, a school, and commercial business. A review of vacant land area reveals that portions of Parcels 108-210-002R and 103-210-001E may be technically appropriate for installation of EWs, based on completed capture zone modeling. The low-profile air stripper and LGAC polish treatment plant could potentially be installed in the large parking lot at the southwest end of Parcel 108-210-002R (occupied by Fry's Mercado grocery store, 4320 West McDowell Road). The land development in this area is commercial and industrial, and the plant would be located near two busy roadways (43rd Avenue and McDowell Road). No noise will be generated by the LGAC treatment process.

An east EW could potentially be located in a City alley between West Granada Road and West Coronado Road, between residential Parcels 108-22-045 and 108-22-047. A landscape area at the northeast corner of Parcel 103-210-001E (occupied by the Los Vecinos Apartments, 1950 North 43rd Avenue) could potentially be utilized for installation of a west EW. The locations of these three EWs are identified on Figures 5-10 and 5-11 a,b,c.

Pump Modeling Results

The simulated capture zones with three remedy EWs described above are shown on Figure 5-12. Each of the three EWs would pump at a rate of 100 gpm each. The highest concentrations of VOCs migrating through the core of the SGWS plume would be captured and treated by the system.

5.7.2.3 Remedial Pumping with Five EWs

EWs and System Location

Installation of five EWs pumping at 100 gpm each at the central portion of the SGWS plume is expected to effectively contain and slowly remediate the estimated full width of the plume. Five conceptual locations of EWs for a central P&T system have been selected based on the effectiveness of capture zone modeling. The three central EWs and groundwater treatment plant are located at the same locations as those discussed in Section 5.6.3.2. The additional easternmost and westernmost EWs could potentially be installed in the public ROW of Almeria Road (a residential street), and within Sueno Park, respectively (Figure 5-10).

Pump Modeling Results

Model-simulated capture zones with five pumping wells described are shown on Figure 5-13. Simulations predict that capture of the estimated full width of the plume may be accomplished using five EWs, with a pumping rate of 100 gpm per well. Note that the actual number of required EWs would depend on aquifer characteristics (i.e., hydraulic conductivity, transmissivity, etc.), as determined from pump testing of one or more of the installed EWs.

5.7.2.4 Option for Discharge to Reinjection Wells

P&T System with Three EWs

Conceptual pipeline routes, with potential locations for reinjection wells, are also shown on Figures 5-11a, 5-11b, and 5-11c. The system would utilize two IWs: one for typical full-flow operation and another for use as a backup during periods of IW maintenance. There are multiple locations with sufficient space for installation of the two IWs. Periodically, alternating the full flow between the two IWs is anticipated to be beneficial to optimize infiltration to the subsurface. To minimize costs, and depending on the selected option, the IWs could potentially be installed on the same parcel as the central EW and treatment plant (i.e., Parcel 108-210-002R). Alternatively, IWs could also be located in the public ROW, if necessary. As previously described, treated water would be reinjected via the IWs into the much more transmissive LSGS, which underlies the SGWS. The specific depth of the LSGS for placement of the IW screens would need to be determined from IW boreholes and their associated geophysical logs.

P&T System with Five EWs

Similar to the three-EW alternative, there would be multiple options with sufficient space available for installation of IWs. Due to the supplemental flow from the five-well system (i.e., estimated to be 200 gpm greater than the three-EW system), it is anticipated that an additional IW would be installed to enhance recharge. Ideally, the IWs would be located within reasonably close proximity to the air stripping/LGAC treatment plant, in order to minimize pipeline construction and maintenance costs. Assuming land access from the property owner could be obtained, two of the IW locations could be installed at locations considered for the three EW P&T system, as shown on Figures 5-11a, 5-11b, and 5-11c. The third IW could potentially be sited on the neighboring property with baseball fields to the east, to eliminate the need for crossing either 43rd Avenue or McDowell Road which would greatly complicate permitting and construction efforts.

5.7.2.5 Option for Discharge to COP Storm Sewer

Another option for discharge of the treated water from the central area P&T system may be to connect to the existing 69-inch diameter COP storm sewer installed in 43rd Avenue. A conceptual pipeline route for this discharge pipeline installed between the treatment plant and 43rd Avenue is shown on Figures 5-14 and 5-15. The length of the discharge pipeline would only about 150 linear feet or less. GeoTrans understands that the aforementioned storm sewer outfalls to ADOT's Papago Drainage Ditch, which parallels the north side of Interstate 10, and flows through Glendale, Arizona, to the Agua Fria River (COP, 2007). Based on discussions with the COP, this sewer normally has more than sufficient capacity to convey the additional flow associated with the alternative P&T systems (300 or 500 gpm). However, during periods of intense rainfall, particularly during monsoon season, flooding problems due to extensive runoff exist. Therefore, the P&T system well field/treatment plant would need to be equipped with emergency, remote shut-down capability so that the COP would have the ability to stop the flow of the treated groundwater into its storm sewer system.

5.8 FURTHER EVALUATION OF OPTIONS FOR TREATED WATER DISCHARGE

Assuming that P&T was to be implemented for plume containment/remediation of the SGWS aquifer, significant quantities of water would need to be extracted and treated by the P&T system(s). It is important, particularly in the arid Southwest, to consider the value of the treated water when evaluating discharge options. Viable options may include discharge to:

- The COP municipal water supply system;
- The SRP's Grand Canal for current irrigation and/or future municipal water supply use;
- The COP storm water collection system; and
- The subsurface, via reinjection into the aquifer.

This section further describes the discharge options and those retained for additional analysis.

5.8.1 Discharge to COP Municipal Water System

The ADEQ's Remedial Objectives Report specifically describes that there are ROs to restore, replace, or otherwise provide for the current and future COP groundwater supply. Due to the LSGS groundwater contamination associated with the Site, the municipal water supply fro wells COP-70 and COP-71 was lost when these wells had to be removed from service in 1982. The draft FS for the LSGS (GeoTrans, 2009) includes provisions for installing replacement wells and a wellhead treatment system at the COP-70/71 well site, such that pumped groundwater could be used as part of the municipal water supply, and also serve to remediate groundwater located within the first approximately one-third of the LSGS plume. The treated water would be connected to a COP water main that presumably exists at the well site.

5.8.2 Discharge to SRP's Grand Canal

Discharging treated groundwater from a remedy P&T system(s) into the SRP Grand Canal is another identified option. This would involve installing a conveyance pipeline(s) from groundwater treatment facilities to the SRP's Grand Canal to supplement SRP's needs for irrigation water, particularly during times of drought. The supplemental water could also potentially provide a source for municipal water, assuming a future water treatment plant was built on the Grand Canal at or downstream of the Site area.

Discharge of treated water to the Grand Canal will require obtaining an Individual AZPDES Permit from the ADEQ. The properly monitored GAC treatment facilities would operate such that established limits for agricultural use, and more stringent Federal MCLs and Arizona AWQS for VOCs would be achieved prior to discharge. However, it is anticipated that comprehensive sampling and monitoring activities of the discharge would be required by the AZPDES Permit.

A potential advantage of this option is that the SRP would receive the treated water for its desired use(s). Disadvantages may include: 1) more stringent and costly sampling requirements compared with other discharge options; 2) depending on pumping locations, there could be significantly higher capital costs associated with having to install relatively long conveyance pipelines from treatment facilities to the Grand Canal; and 3) potential loss in the SRP's operational flexibility to control the amount of water in the Grand Canal.

Discharging the treated water into the Grand Canal has been retained as an option for further evaluation.

5.8.3 Discharge to Groundwater Reinjection Wells

As described above in Section 5.7.2.4, another discharge option is to return treated water into the subsurface using IWs. Reinjection would serve to conserve groundwater as a resource. Because space is limited in the residential areas of the Site, and relatively slow water infiltration rates are expected through the heterogeneous vadose zone, the use of infiltration galleries or basins is not considered feasible. However, the use of IWs designed to return the treated water into the transmissive LSGS aquifer is considered viable. The potential advantages of groundwater reinjection include: 1) sampling and reporting requirements for the treated discharge are expected to be less rigorous compared with other options, and 2) reinjection serves to conserve groundwater as a natural resource.

An important disadvantage of the use of IWs is that they typically would require more maintenance than other options due to fouling of the IW screens and adjacent aquifer. Biological or mineral precipitation can periodically clog the IW screens. Clogging of the aquifer could also occur due to entrained air, or from ionic reactions that result in dispersion of clay particles and swelling of colloids in a sand-and-gravel aquifer (EPA, 1999). The degree of IW maintenance would be based on the frequency of fouling/clogging. Typical fouling mitigation techniques would involve mechanical brushing of the IW screens and air-lift well development, as needed to maintain system operations. Discharging the treated water into IWs completed and screened in the LSGS has been retained as an option for further evaluation.

5.8.4 Discharge to COP Storm Sewer

Although it is discouraged by the COP, water from P&T system facilities could potentially be discharged to the COP storm sewer collection system, either on a continuous basis, or solely during the SRP's seasonal dry-up periods for canal maintenance. Water from treatment facilities would be conveyed by storm sewers, which outfall into the Papago Diversion Channel. This channel, owned by the Arizona Department of Transportation (ADOT), is located in the north right-of-way (ROW) of Interstate 10, south of the Site. The channel flows west through Glendale, Arizona, and ultimately into the Agua Fria River, which recharges the UAU via percolation beneath the river.

Based on the anticipated flow rates from operating P&T systems at the central portion of the plume (i.e., modeled rates of 300 gpm and 500 gpm), the adequacy of COP storm sewers sizes to accommodate the additional flow requires evaluation. This information is described in Section 6.2.4.3. Note that an Individual AZPDES Permit would be required by the ADEQ to authorize discharge of the treated groundwater to the COP storm sewer and Papago Drainage Channel systems. Regulation of the discharge by the COP would also be applicable to ensure compliance with its AZPDES Municipal Separate Storm System (MS4) Permit. It is anticipated that relatively frequent sampling of the discharge would be required by the City.

Depending on the location of P&T systems (see Section 5.6.3) a key advantage of this option may be that capital costs can be minimized for construction of the discharge pipeline(s) in the public ROW. For example, a P&T system installed at the central portion of the SGWS plume would require a long pipeline to the Grand Canal rather that a short pipeline to a nearby storm sewer. The ability to install a relatively short discharge pipeline would not only significantly reduce capital costs, but would also minimize the degree of traffic disruption, including potentially for emergency vehicles and for pedestrians in the public ROW. A disadvantage of this option is that, similar to discharging to the Grand Canal, more rigorous sampling and reporting requirements would be required pursuant to an AZPDES and/or COP storm water discharge permit.

6.0 DEVELOPMENT OF REFERENCE REMEDY AND ALTERNATIVE REMEDIES

Using the retained remedial technologies, selection of remedial measures, prescribed remedial strategies, and discharge considerations, a Reference Remedy has been developed along with two alternative remedies for comparison. The Reference Remedy and each alternative remedy consist of a remedial strategy and measures to achieve ROs for the Site. As stated earlier, ROs for the Site were developed following a public involvement process and were reported by the ADEQ in May 2005 (ADEQ, 2005).

The remedial strategies to be developed are discussed below. Note that a strategy may incorporate more than one remediation technology or methodology. As provided in AAC Rl8-16-407(F), remedial strategies for consideration may include:

- Plume remediation to achieve water-quality standards for COCs in waters of the state throughout the Site;
- Physical containment to contain contaminants within definite boundaries;
- Controlled migration to control the direction or rate of migration, but not necessarily to contain migration of contaminants;
- Source control to eliminate or mitigate a continuing source of contamination;
- Monitoring to observe and evaluate the contamination at the Site through the collection of data; and
- No action as a strategy that consists of no action at a Site.

Remedial measures necessary for each alternative remedy have been identified with consideration of the needs of the water providers (COP and SRP) and their customers, including the quantity and quality of water, water rights, other legal constraints, reliability of water suppliers, and any operational implications. Such remedial measures may include, but are not limited to, well replacement, well modification, water treatment, provision of replacement water supplies, and engineering controls. Where remedial measures are necessary to achieve ROs, such remedial measures will remain in effect as long as required to ensure the continued achievement of those objectives.

The combination of the remedial strategy and remedial measures for each alternative remedy are designed to achieve the ROs. The Reference Remedy and each alternative remedy also may include contingent remedial strategies or remedial measures to address reasonable uncertainties regarding the achievement of ROs, or uncertain time frames in which ROs will be achieved. Note that the ROs for the SRP and COP are also addressed in the FS for the LSGS portion of the aquifer (GeoTrans, 2009). The Reference Remedy and the alternative remedies are described below.

6.1 REFERENCE REMEDY – STRATEGY AND MEASURES

6.1.1 Requirements

- The Reference Remedy must allow for the continued definition and monitoring of the contaminated SGWS aquifer under the current network of monitoring wells which have not gone dry;

- The Reference Remedy must provide for the ability of the COP to utilize groundwater at the Site in a timely manner, if and when necessary;

- The Reference Remedy must provide for the ability of the SRP to utilize groundwater at the Site, or provide a provision for replacement water. This action may be needed as soon as is technically feasible;

- The Reference Remedy must provide for remediation of characterized COCs; and

- The Reference Remedy must be capable of achieving the ROs for the Site.

6.1.2 Remedial Strategy and Measures

The remedial strategies and measures for the Reference Remedy are:

1. Installation of an estimated 30-gpm P&T system for hydraulic containment and remediation of contaminated groundwater at the downgradient margin of the WOC Facility. This system, comprised of three EWs, would prevent the migration of VOCs emanating from both the WOC Facility and the NCP. Groundwater treatment would consist of bag filtration followed by LGAC for fine sediment/particulate and VOC removal, respectively. Discharge of the treated groundwater would be to the Grand Canal that borders the north side of the WOC Facility.

2. For the first two years of P&T system operations, monthly water levels and quarterly sampling of the existing SGWS monitoring well network[21] would be performed, along with quarterly reporting for system performance/groundwater monitoring. This is pursuant to the ADEQ's WQARF Program's typical policy.

3. After the second year of P&T system operation, implementation of routine MNA to address the larger portion of the plume which has migrated downgradient (south) of the WOC Facility. MNA would consist of conducting semi-annual groundwater monitoring of the existing SGWS well network at the Site to evaluate the efficacy of natural attenuation over time (i.e., both physical and biodegradation attenuation processes). Groundwater samples would be

[21] Currently, there are 12 SGWS monitoring wells that are typically sampled as shown on Figure 2-2: MW-3SR, WCP-207, MW-102SR, MW-201S, MW-202S, MW-203S, MW-204S, MW-205S, MW-206S, MW-207S, MW-208S and MW-209S.

collected and analyzed semi-annually for VOCs, and annually for pertinent MNA parameters, including nutrients and electron donors and acceptors. Shifts in VOC composition and declining concentrations indicative of natural attenuation processes would be monitored to assess the adequacy of this remedy. Technical reporting of MNA results would be completed on a semi-annual basis.

6.1.3 P&T System at WOC Facility

The conceptual design of a P&T system utilizing three EWs for hydraulic containment/remediation of the WOC plume and NCP is discussed in Section 5.6.3 and shown on Figure 5-8. To assist with conceptual design of the Reference Remedy, simplistic modeling was performed to evaluate plume capture by EWs. The EPA WhAEM code was used to model two-dimensional flow. Use of WhAEM requires situations where the aquifer can be modeled as having constant thickness and is horizontal. Although neither condition may be absolutely true in the SGWS, the assumptions should be acceptable for the purpose of assessing the location and capture zones of pumping wells. Aquifer hydraulic properties used as inputs for modeling were estimated based on: 1) historic aquifer tests performed on SGWS monitoring wells MW-6S and MW-7S at the Site; 2) an aquifer test performed in 2008 on well WCP-227 at the NCP Site; 3) a limited aquifer test performed in 2009 on well MW-206S at the Site; 4) data and other information presented in a draft model of 3-dimensional flow and TCE transport (HSI GeoTrans, 2000); and 5) available ADWR groundwater models. Additional information on the hydrogeologic characteristics and assumptions used for WhAEM modeling are provided in Appendix C.

Results of the WhAEM simulations predict that capture of the estimated full width of the upgradient portion of the SGWS plume may be accomplished using three EWs with a continuous pumping rate of 10 gpm each. These EWs would be located along the southern property boundary of the WOC Facility. The modeled simulated capture zones for the three EWs, each pumping at a rate of 10 gpm, are shown on Figure 5-9.

The most cost-effective and practical option for discharge of the estimated 30-gpm discharge is to the adjacent Grand Canal. This is because the canal is located within very close proximity immediately north of the location for the conceptual treatment, and no fees from SRP to receive treated water flow into the canal are anticipated. However, the P&T system could not discharge to the Grand Canal during the SRP's annual dry-up period for canal maintenance (typically January/early February). To avoid system shut down, the treated discharge could potentially be diverted into the COP storm or sanitary sewer during the annual dry-up period. Alternatively, the treated discharge could also be diverted into existing LSGS well(s) MW-4M and/or MW-3M for reinjection. A discussion of these alternative discharge options is included below.

6.1.4 Alternative Options for Discharge of Treated Water from P&T System

There are multiple options other than discharging the treated groundwater from the P&T system to the Grand Canal. These options could potentially be used to either receive continuous flow from the P&T system, or flow only during the SRP's annual dry-up period for canal maintenance. Several of these options are described below.

6.1.4.1 Discharge to Reinjection Wells

The LSGS aquifer which underlies the SGWS is much more transmissive than the SGWS aquifer, capable of yielding much higher flows of water. Based on information from the RI supported by aquifer tests, the average transmissivity of the LSGS is in the range of 10,700 square feet per day (ft^2/day) to 11,500 ft^2/day. Aquifer testing of select SGWS wells indicated transmissivity in the range of 350 ft^2/day to 7,500 ft^2/day, however, based on borehole lithologic logs, the SGWS estimates are believed to be high for the SGWS in its entirety at the Site (Section 3.2.1). Because of the high LSGS transmissivity, it is reasonable to conclude that it can receive high flows of treated groundwater via use of injection wells. One cost-effective option may be to make retrofit connections to two of the existing LSGS wells at the WOC Facility, converting them into injection wells (IWs). Conceptual pipeline routes from the air stripper treatment compound to wells MW-3M and MW-4M are shown on Figure 6-1. One of these wells could potentially be utilized for typical full-flow operation (estimated 30 gpm), while the other IW would be used as a backup during periods of IW maintenance. Periodically, alternating the full flow between the two IWs is anticipated to be beneficial to optimize infiltration to the subsurface.

The basic construction features of wells MW-3M and MW-4M are:

MW-3M
4-inch diameter PVC
290 feet total depth
Screen placement: 250 to 290 feet bgs

MW-4M
4-inch diameter PVC
285 feet total depth
Screen placement: 245 to 285 feet bgs

Based on the known characteristics of the LSGS as determined from aquifer testing, it is anticipated that a consistent recharge rate of 30 gpm into either MW-3M or MW-4M would be feasible. USEPA WhAEM code modeling, conducted in support of this FS, indicates that re-injection would be possible, without creating groundwater mounding that could potentially spread VOC contamination into the NCP or other unaffected areas of the WOC Site. However, to confirm this belief, infiltration testing could be readily performed on the existing wells. Note that remedy pumping from the COP-70/71 wells site has been recommended in the FS for the LSGS aquifer (GeoTrans, 2009). Modeling indicates that under the influence of this remedy pumping, reinjection at either MW-3M or MW-4M would be definitively controlled.

6.1.4.2 Discharge to COP Storm Sewer

Another option for discharge of the treated water would be to connect to the existing 48-inch diameter COP storm sewer located at the intersection of 35th Avenue and Osborn Road. Assuming the pipeline would be routed from the treatment plant located at the northwest corner of the Middle Parcel, to the south to Osborn Road, and then to the east to 35th Avenue, the approximate connection pipeline distance would be 1350 linear feet. This conceptual pipeline route for connection to the COP storm sewer is shown on Figure 6-2. GeoTrans understands that flows from the aforementioned storm sewer ultimately outfall into ADOT's Papago Drainage Ditch, which parallels the north side of Interstate 10, and flows through Glendale, Arizona, to the Agua Fria River (COP, 2007).

With respect to the frequency of discharge for the treated groundwater, two options are: 1) continuous flow to the storm sewer; or 2) discharge to the storm sewer only during the SRP's annual dry-up period for the Grand Canal. The latter option would be applicable to using the Grand Canal for normal discharge of treated groundwater.

6.1.4.3 Discharge to COP Sanitary Sewer

There is an existing 21-inch sanitary sewer line located within the south ROW of Osborn Road adjacent to the WOC Facility. There also is an existing 6-inch sanitary sewer line that runs beneath the central portion of the West Parcel. It is anticipated that it would be possible to connect the air stripper unit discharge, located at the northwest corner of the Middle Parcel, to either of these COP sanitary sewer lines. Conceptual pipeline routes are shown on Figure 6-3. The pipeline lengths would be approximately 400 or 600 linear feet to connect to the 6-inch or 21-inch line, respectively.

GeoTrans has been authorized by the COP to periodically discharge purged groundwater into the 6-inch sewer line via Manhole No. 404 on the West Parcel. Pursuant to Manhole Entry Permits obtained from the COP for this discharge, the allowable maximum flow rate has consistently been 100 gpm. Because this rate exceeds the conceptual 30 gpm rate of the P&T system at the WOC Facility, presumably it would be acceptable to the COP.

6.1.5 Reference Remedy Permitting

Multiple permits will be necessary to authorize installation and operation of the WOC Facility P&T system, as well as for use of existing or replacement groundwater monitoring wells for use with MNA. Permitting requirements, organized by regulatory agency, are described below.

6.1.5.1 ADWR

Pre-construction notifications (Notice of Intent forms) and post-construction reporting (Driller's Reports) would need to be prepared for each of the three new EWs. They would also need to be prepared for existing wells MW-3M and/or MW-4M if they were to be used as IWs due to their change in purpose. Currently this is ADWR Form 55-44A entitled: *Notice of Intent to Drill, Deepen, or Modify a Monitor/Piezometer/Environmental Well.* In Section 4 of the form, a detailed description of the purpose of the well, including the applicable estimated flow rates will need to be provided.

Well construction and/or modification work must be conducted by an ADWR-licensed driller. New wells must also comply with the ADWR's well construction standards, which are found in ARS §45-594, -595, -596 and -600 of the Groundwater Code. If any replacement monitoring wells are required, most notably due to possible water level declines to a degree whereby existing wells could go dry, the same ADWR requirements for the new wells would apply.

6.1.5.2 COP

- A construction permit from the COP Development Services Department (DSD) – This will require preparation and submittal of design plans and specifications (i.e., civil, plumbing, mechanical, electrical) to the City;

- A Use Permit from the COP Zoning Department in accordance with the COP Zoning Ordinance Section 622056 - To allow installation and operation of environmental remediation facilities (e.g., the WOC Facility P&T system).

- A Revocable Permit (private use agreement) from the COP Street Transportation Department - To allow for continued use of existing monitoring wells, and use of potential new wells, installed within the COP ROW.

- An Industrial Discharge Permit from the COP Pollution Control Division –This permit would authorize discharge of the treated groundwater to the COP sanitary sewer during the SRP's Grand Canal annual dry-up period, assuming this option was chosen.

- A COP Industrial Discharge Permit from the COP Street Transportation Department, Storm Water Management in accordance with the Phoenix City Code Chapter 32C; if the treated discharge from the WOC Facility P&T system was to be discharged to the COP storm sewer.

6.1.5.3 SRP

Based on telephone conversations between GeoTrans and the SRP, we understand that the following would be required by the SRP to authorize discharge of treated water from the WOC Facility P&T system to the Grand Canal.

- An explanation letter describing the requested discharge that would include pertinent information on the proposed location, flow rates, duration of flows, water quality, and environmental permitting of the discharge;

- Submittal of construction drawings for the pipeline and headwall structure routed within the canal ROW; and

- Execution of a formal License Agreement with the SRP to authorize access to the Grand Canal.

The SRP would also likely require that the P&T system be equipped with a remote shut-down control to enable the SRP to shut off the system in the event of an emergency situation on the Grand Canal.

6.1.5.4 Access Agreements with Land Owners

Based upon an understanding of its historic policies, the ADEQ will need to negotiate/obtain access agreements with the current land owner at the WOC Facility to authorize well installation and aquifer testing activities, and the installation, monitoring and O&M of the complete P&T system. As described in Section 5.6.3.2, components of the P&T system would affect portions of the Middle and West Parcels of the WOC Facility.

6.1.6 Source Control

Source control must be considered as an element of the Reference Remedy and all alternative remedies. Initial source control of TCE and 1,1-DCE for the Site has been addressed through the removal of the septic tanks, implementation of the interim SVE system at the Middle Parcel, and abandonment of the WOC irrigation well. Supplemental source control is provided with the inclusion of a P&T remedy designed to contain groundwater contamination emanating from the WOC Facility, as well as the NCP.

6.1.7 Uncertainties and Contingencies

It is anticipated that ADEQ will be responsible for negotiating land access agreements with affected owners of the WOC Facility West and Middle Parcels, to authorize pilot testing, full-scale installation, and long-term O&M of the P&T system. The ability to obtain the access agreements is uncertain. The effects of SGWS pumping on water-table elevations at the Site are unknown. Pumping over time is expected to cause water-table elevations to decline over time. The rate and degree to which water levels decline will be influenced by the remedy pumping rates and regional groundwater recharge rates. It is possible that EWs may gradually go dry, and therefore, altering pumping strategies and/or installing replacement EWs may be necessary. Similarly, existing monitoring wells at the Site could go dry, requiring installation of replacement wells.

In the absence of performing aquifer tests on the proposed EWs, pumping yields and induced capture zones are uncertain. The locations of EWs may need to be adjusted based upon results of aquifer testing as successive EWs are installed.

It is recommended that after the P&T system is operational, converging lines of evidence be used to evaluate the effectiveness of plume capture. Such evidence would include: 1) interpreting water-level measurements; 2) performing flow-rate and capture-zone width calculations; 3) conducting and interpreting capture-zone modeling; and 4) evaluating VOC concentration trends. With this information, the ability to determine actual capture compared to the overall target capture zone can be best assessed.

Based on review of the history of groundwater quality data collected for the SGWS during the previous RI and present FS periods, the efficacy of natural attenuation at the Site is uncertain. VOC concentration declines were observed in the WOC Facility area wells after the Grand Canal was lined, but prior to the NCP migration into the Site. However, these declines probably resulted primarily from 1) declining water levels at the WOC Facility (i.e., physical attenuation processes); and 2) contaminant mass removal by the interim SVE system. Based on review of the historical groundwater quality data for the SGWS, evidence of dechlorination via biodegradation is not apparent. However, the overall remedial strategy is to establish source control via P&T at the WOC Facility, and then assess reduction of VOC concentrations in the larger, downgradient portion of the plume over time. Assuming there continues to be a non-exposure pathway (i.e., the SGWS will not being used for drinking water), this may demonstrate that it is an effective and acceptable remedial alternative. If MNA results indicate that natural attenuation is inadequate and/or occurring too slowly to achieve ROs within a reasonable timeframe, then active P&T for the downgradient portion of the plume may need to be considered. It is recommended that this FS, which presents alternatives for the use of P&T to address the downgradient portion of the plume, be used to support such decisions.

6.1.8 Proposed Remedy to Evaluate

The remedial strategies and measures for the Reference Remedy are presented above. A conceptual design has been developed for the P&T system at the WOC Facility with three EWs installed along the southern margin of the West and Middle Parcels (see Section 5.6.3.2 and Figure 5-8). A description of the general procedures for MNA including technical reporting is presented in Section 6.1.2 above. In Section 7.0, the capital and O&M costs for the Reference Remedy, including costs for MNA associated with the downgradient portion of the SGWS plume, will be compared and evaluated against the alternative remedies.

6.2 MORE AGGRESSIVE ALTERNATIVE REMEDY - STRATEGY AND MEASURES

6.2.1 Requirements

- The More Aggressive Remedy must allow for the continued definition and monitoring of the contaminated SGWS under the current monitoring well network;
- The More Aggressive Remedy must provide for the ability of the COP to utilize groundwater at the Site in a timely manner, if and when necessary;
- The More Aggressive Remedy must provide for remediation of characterized COCs; and
- The More Aggressive Remedy must be capable of achieving the ROs for the Site.

6.2.2 Remedial Strategy and Measures

The remedial strategies and measures for the More Aggressive Remedy are:

1. Installation of an estimated 30-gpm P&T system for hydraulic containment and remediation of contaminated groundwater at the downgradient margin of the WOC Facility. This system, comprised of three EWs, would prevent the migration of VOCs emanating from both the WOC Facility and the NCP. Groundwater treatment would consist of bag filtration followed by LGAC for fine sediment/particulate and VOC removal, respectively. Discharge of the treated groundwater would be to the Grand Canal that borders the north side of the WOC Facility.

2. Installation of three EWs for partial hydraulic containment and remediation of the SGWS aquifer at the central portion of the plume which contains the highest VOC concentrations. The estimated pumping rate of the system would be approximately 300 gpm. Groundwater treatment would consist of bag filtration followed by LGAC for fine sediment/particulate and VOC removal, respectively. The treated groundwater would be discharged via IWs into the LSGS of the aquifer.

3. Use of existing monitoring wells MW-206S and AVB130-01 (see Figure 6-1) to evaluate capture zones of the three EWs. In addition, two supplemental monitoring wells/piezometers, located at strategic locations either between and/or in the vicinity of the EWs, would be installed to evaluate the capture zone and water quality associated with the central area remedy pumping.

4. For the first two years of P&T system operations, monthly water levels and quarterly sampling of the existing SGWS monitoring well network would be performed, along with quarterly reporting for system performance/groundwater monitoring. This is pursuant to the ADEQ's WQARF Program's typical policy.

5. After the second year of P&T system operation, implementation of routine MNA to address the downgradient portions of the plume which would not be actively captured and remediated by the Central Area P&T system (i.e., the outlying areas with less significant contaminant mass). MNA would consist of conducting semi-annual groundwater monitoring of the existing SGWS well network at the Site to evaluate the efficacy of natural attenuation over time (i.e., both physical and biodegradation attenuation processes). Groundwater samples would be collected and analyzed semi-annually for VOCs, and annually for pertinent MNA parameters, including nutrients and electron donors and acceptors. Shifts in VOC composition and declining concentrations indicative of natural attenuation processes would be monitored to assess the adequacy of this remedy. Technical reporting of MNA results would be completed on a semi-annual basis.

6.2.3 Locations of P&T Systems

6.2.3.1 P&T System at WOC Facility

The P&T system at the WOC Facility will be the same as that described in detail for the Reference Remedy in Section 6.1.3 above. The conceptual design for the system layout is shown on Figure 5-8; modeled pumping capture zones are shown on Figure 5-9.

6.2.3.2 Downgradient, Central P&T System

Installation of several EWs pumping at 100 gpm each at the central portion of the SGWS plume is expected to effectively contain and gradually remediate the most contaminated zone of the VOC plume. Several conceptual locations of EWs have been selected based on the effectiveness of capture zone modeling (Figure 6-1). Review of aerial photographs indicates that land bounded by West Monte Vista Road on the north, McDowell Road on the south, 39th Avenue on the east, and 43rd Avenue on the west (in the vicinity of MW-206S) is fully developed with residential homes, apartments, a school, and commercial business. A review of vacant land area reveals that portions of Parcels 108-210-002R and 103-210-001E may be technically appropriate for installation of EWs, based on completed capture zone modeling. The low-profile air stripper and LGAC polish treatment plant could potentially be installed in the large parking lot at the southwest end of Parcel 108-210-002R (occupied by Fry's Mercado grocery store, 4320 West McDowell Road). The land development in this area is commercial and industrial, and the plant would be located near two busy roadways (43rd Avenue and McDowell Road). Thus, noise generated by the air-stripper blower is not expected to be a significant concern.

An east EW could potentially be located in a City alley between West Granada Road and West Coronado Road, between residential Parcels 108-22-045 and 108-22-047. A landscape area at the northeast corner of Parcel 103-210-001E (occupied by the Los Vecinos Apartments, 1950 North 43rd Avenue) could potentially be utilized for installation of a west EW. The locations of these three EWs are identified on Figures 5-10 and 5-11 a,b,c.

6.2.4 Alternative Options for Discharge of Treated Water from P&T Systems

6.2.4.1 Options for Discharge from WOC Facility P&T System

Discharge options for the treated water from the WOC Facility P&T system are the same as those described in the Reference Remedy, Section 6.1.4 above. These options include: 1) discharge to the adjacent SRP Grand Canal; 2) discharge to reinjection wells via existing MW-3M and/or MW-4M; 3) discharge to the COP storm sewer; and 4) discharge to the COP sanitary sewer.

6.2.4.2 Option for Discharge to Reinjection Wells from Downgradient, Central P&T System

Conceptual pipeline routes, with potential locations for reinjection wells, are also shown on Figures 5-11a, 5-11b, and 5-11-7c. The system would utilize two IWs: one for typical full-flow operation, and another for use as a backup during periods of IW maintenance. There are multiple locations with sufficient space for installation of the two IWs. Periodically, alternating the full flow between the two IWs is anticipated to be beneficial to optimize infiltration to the subsurface. To minimize costs, and depending on the selected option, the IWs could potentially be installed on the same parcel as the central EW and treatment plant (i.e., Parcel 108-210-002R). Alternatively, IWs could also be located in the public ROW, if necessary. As previously described, treated water would be reinjected via the IWs into the much more transmissive LSGS, which underlies the SGWS. The specific depth of the LSGS for placement of the IW screens would need to be determined from IW boreholes and their associated geophysical logs.

6.2.4.3 Option for Discharge to COP Storm Sewer from Downgradient, Central P&T System

Another option for discharge of the treated water from the central area P&T system may be to connect to the existing 69-inch diameter COP storm sewer installed in 43rd Avenue. A conceptual pipeline route for the discharge pipeline installed between the treatment plant and 43rd Avenue is shown on Figure 5-14. The length of the discharge pipeline would only be less than 150 linear feet. GeoTrans understands that the aforementioned storm sewer outfalls to ADOT's Papago Drainage Ditch, which parallels the north side of Interstate 10, and flows through Glendale, Arizona, to the Agua Fria River (COP, 2007).

6.2.4.4 Option for Discharge to COP Sanitary Sewer from Downgradient, Central P&T System

There is an existing 21-inch sanitary sewer line located within the south ROW of Osborn Road adjacent to the WOC Facility. There also is an existing 6-inch sanitary sewer line that runs beneath the central portion of the West Parcel. It is anticipated that a connection between the air stripper treatment plant at the northwest corner of the Middle Parcel to either of these COP sanitary sewer lines would be possible. Conceptual pipeline routes are shown on Figure 6-3. The pipeline lengths would be approximately 400 or 600 linear feet to connect to the 6-inch or 21-inch line, respectively.

6.2.5 Permitting and Approvals

Multiple permits will be necessary to authorize installation and operation of the groundwater P&T systems. Permitting requirements, organized by regulatory agency, are described below.

6.2.5.1 ADWR

Pre-construction notifications (Notice of Intent forms) and post-construction reporting (Driller's Reports) would need to be prepared for each of the new EWs and IWs. These requirements are the same as those described for the Reference Remedy in Section 6.1.5.1 above.

6.2.5.2 COP

Several permits from the COP will be required to authorize installation and operation of the P&T groundwater remedy, as noted below:

- Construction permits from the COP DSD – This will require preparation and submittal of design plans and specifications (i.e., civil, plumbing, mechanical, electrical) to the City;

- A Use Permit from the COP Zoning Department in accordance with the COP Zoning Ordinance Section 622056 - To allow installation and operation of environmental remediation facilities (e.g., the P&T facilities);

- An Industrial Discharge Permit from the COP Pollution Control Division – To allow discharge of the treated groundwater to the COP sanitary sewer, assuming this option was chosen; and

- A COP Industrial Discharge Permit from the COP Street Transportation Department, Storm Water Management in accordance with the Phoenix City Code Chapter 32C – This permits will be required if the treated discharge from either or both P&T systems was to be discharged to the COP storm sewer.

6.2.5.3 ADEQ and MCAQD

Obtaining AZPDES permits from the ADEQ Surface Water Section would be required to discharge treated groundwater from the WOC Facility P&T system to the SRP's Grand Canal. The AZPDES permit requirements are pursuant to the Clean Water Act and the AAC R18-9-A902(B). This requirement would also apply to the downgradient, central P&T system, assuming its treated discharge would be diverted to the storm sewer.

6.2.5.4 SRP

The same requirements from SRP would be required as those described in detail above for the Reference Remedy, Section 6.1.5.3.

6.2.5.5 Access Agreements with Land Owners

Based upon an understanding of its historic policies, the ADEQ will need to negotiate/obtain access agreements with the current land owners at the WOC Facility to authorize well installation, aquifer testing, and monitoring and O&M of the P&T system infrastructure on private properties. As described in Section 5.6.3.2, components of the P&T system would affect portions of the Middle and West Parcels of the WOC Facility. Information on the names of the specific current land owners and corresponding Maricopa County Assessor's parcel numbers of the subject properties are included in Table 2-1.

6.2.6 Source Control

Source control must be considered as an element of the More Aggressive Remedy and all alternative remedies. Substantial initial source control of TCE and 1,1-DCE for the Site has been addressed through the removal of the septic tanks, implementation of the interim SVE system at the Middle Parcel source areas, and abandonment of the WOC irrigation well. Supplemental source control is provided with the inclusion of a P&T remedy designed to contain and remediate groundwater contamination emanating from the WOC Facility, as well as the NCP.

6.2.7 Uncertainties and Contingencies

Some of the uncertainties and contingencies for the More Aggressive Remedy are the same as those described in Section 6.1.7 for the Reference Remedy. They are: 1) the ability to obtain land access agreements to authorize pilot testing, full-scale installation, and relatively long-term O&M of the remediation (P&T) system; 2) the duration that the remediation system will need to operate at the WOC Facility; 3) the availability of WQARF Program funding to support long-term operation of the remediation system; and 4) the efficacy of MNA as a remedy for the larger, downgradient portion of the SGWS plume. Contingency provisions for intermittent operation or periodic shut-down of the P&T system at the WOC Facility may need to be considered, if insufficient ADEQ WQARF Program funding for the WOC project exists.

In the absence of performing aquifer tests on proposed EWs, pumping yields and induced capture zones are uncertain. The locations of EWs may need to be adjusted based upon results of aquifer testing after successive EWs and potential necessary piezometer /monitoring wells are installed. Furthermore, the effects of SGWS pumping on water-table elevations at the Site are unknown. Pumping over time is expected to cause water-table elevations to decline over time. The rate and degree to which water levels decline will be influenced by actual pumping rates and regional groundwater recharge rates.

It is possible that EWs may gradually go dry, and therefore, altering pumping strategies and/or installing replacement EWs may be necessary. Similarly, existing piezometer/ monitoring wells could go dry, requiring installation of replacement wells to adequately gauge groundwater conditions to assess remedy pumping performance. If the EWs and monitoring wells do go dry at the WOC Facility, or if sustained pumping rates are inadequate to achieve plume capture, it may be appropriate to select new locations for and/or install supplemental EWs and monitoring wells. Decisions to replace EWs would be based on actual observed pumping rates, VOC capture zones, and groundwater monitoring while the pumping system is operational.

The ADEQ conducts 5-year reviews of implemented groundwater remediation remedies at WQARF Sites. In this case, the effectiveness of the More Aggressive Remedy strategies and measures (i.e., P&T and MNA) would be assessed at least every five years. For the P&T system, it is recommended that converging lines of evidence be used to evaluate the effectiveness of plume capture. Such evidence would include: 1) interpreting water-level measurements; 2) performing flow-rate and capture-zone width calculations; 3) conducting and interpreting capture-zone modeling; and 4) evaluating VOC concentration trends. With this information, the ability to determine actual capture zones compared to the overall design/target capture can best be assessed.

6.2.8 Proposed Remedy to Evaluate

The remedial strategies and measures for the More Aggressive Remedy are presented above. Pumping rates from proposed EWs to achieve effective capture zones for the SGWS plume have been evaluated by WhAEM model simulations (Sections 6.2.3.1 and 6.2.3.2). In Section 7.0, the capital and O&M costs for the Reference Remedy will be compared and evaluated against the alternative remedies.

6.3 LESS AGGRESSIVE ALTERNATIVE REMEDY - STRATEGY AND MEASURES

6.3.1 Requirements

- The Less Aggressive Remedy must allow for the continued definition and monitoring of the SGWS under the current monitoring well network;
- The Less Aggressive Remedy must provide for the ability of the COP to utilize groundwater at the Site in a timely manner, if and when necessary;
- The Less Aggressive Remedy must address remediation of characterized COCs; and
- The Less Aggressive Remedy must be capable of achieving the ROs for the Site.

6.3.2 Remedial Strategy

The remedial strategy and measures for the Less Aggressive Remedy involve solely MNA for SGWS groundwater that has been characterized with elevated VOCs at the WOC Site. This FS assumes that the entire network of existing, active SGWS wells (i.e., all SGWS wells which have not gone dry) would be included in the MNA program. This network currently consists of 13 SGWS monitoring wells (Figure 3-1). Consistent with MNA described for the Reference Remedy, groundwater level measurements and samples would be collected on a semi-annual basis. Sample analysis for VOCs and MNA parameters would occur on a semi-annual and annual basis, respectively. Technical reporting to evaluate the direction and value of the hydraulic gradient, and to assess MNA performance, would also occur on a semi-annual basis.

6.3.3 Permitting and Approvals

The only permitting and approvals anticipated to be necessary for the Less Aggressive Remedy would be associated with drilling/installing potential new or replacement groundwater monitoring wells. New wells could be necessary to support MNA strategy for more fully characterizing the extent of the dynamic VOC plume. In addition, replacement wells could be necessary if declining water levels cause one or more of the existing wells to go dry, or if potential damage to a well(s) occurred preventing the ability to effectively monitor the well(s).

The permitting and approvals associated with installing new and/or replacing groundwater monitoring wells is described below.

6.3.3.1 ADWR

Pre-construction notifications (Notice of Intent forms) and post-construction reporting (Driller's Reports) would need to be prepared and submitted to the ADWR for each new or replacement monitoring well. Well construction and/or modification work would need to be conducted by an ADWR-licensed driller. Any new wells must also comply with the ADWR's well construction standards, which are found in ARS §45-594, -595, -596 and -600 of the Groundwater Code.

6.3.3.2 COP

If any of the new or replacement wells would be located within the COP right-of-way (ROW), the COP DSD would require obtaining a ROW Building Permit. This will require preparation/submittal of an application form, the well design plans and specifications, and applicable permitting fees to the City.

A Revocable Permit (RP-97020) currently exists between UIC (owned by Textron) and the COP, which authorizes use of the public ROW for monitoring the investigation groundwater wells. However, this permit is not transferrable. Based on recent discussions with the COP, GeoTrans understands that a new permit will need to be established between ADEQ and COP.

6.3.3.3 Access Agreements with Land Owners

GeoTrans understands that ADEQ would negotiate/obtain access agreements with the current land owners at the WOC Facility to authorize groundwater monitoring and potential well installation activities. Information on the names of the specific current land owners and corresponding Maricopa County Assessor's parcel numbers for the subject properties are included in Table 2-1.

6.3.4 Source Control

Source control must be considered as an element of the Less Aggressive Remedy and all alternative remedies. Source control of TCE and 1,1-DCE at the Site has been initially achieved through the removal of septic tanks, implementation of the ERA SVE, and abandonment of the Pincus (irrigation) well at the WOC Facility.

6.3.5 Uncertainties and Contingencies

Since there are no active remediation technologies proposed for the Less Aggressive Remedy, the uncertainties and contingencies are specific solely to MNA. These uncertainties are essentially the same as those described for the strategy component of MNA in the Reference Remedy (Section 6.1.7).

6.3.6 Proposed Remedy to Evaluate

The remedial strategy and measures for the Less Aggressive Remedy are presented above. A description of the general procedures for MNA, including technical reporting is presented in Section 6.1.2 above. In Section 7.0, the costs for Site-wide MNA of the SGWS will be evaluated.

7.0 DETAILED COMPARISON OF REFERENCE REMEDY AND ALTERNATIVE REMEDIES, AND IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES

7.1 COMPARISON CRITERIA: PRACTICABILITY, COST, RISK, AND BENEFIT

In accordance with the Remedy Selection Rule (R18-16-407, Feasibility Study), this FS has been completed to identify a Reference Remedy and alternative remedies that appear to be capable of achieving ROs, and to evaluate the remedies based on the comparison criteria to select a remedy that complies with ARS §49-282.06. The Remedy Selection Rule specifies that practicability, costs, risks, and. benefits are the primary basis for which to evaluate remedies.

7.2 DETAILED EVALUATION OF REMEDIES

7.2.1 Reference Remedy

7.2.1.1 Practicability

The P&T system at the WOC Facility southern boundary proposed in the Reference Remedy is considered practical. Upon start-up, the P&T system will promptly establish hydraulic containment (i.e., source control) of any remaining VOCs emanating from the WOC Facility, as well as the significant contribution of VOCs emanating from the adjacent NCP. Once source control is established, long-term MNA to assess reduction of VOCs in the downgradient portion of the plume will be performed. Because MNA involves no capital or O&M expenses as are associated with active remediation systems, it is the most practical and cost-effective option.

Figures 5-9 and 6-3 provide the model-simulated capture zones and conceptual design for the Reference Remedy source area P&T system, respectively. Due to its proximity at the north side of the WOC Facility, discharging treated groundwater from the P&T system to SRP's Grand Canal is considered the most practical option. During the SRP's winter dry-up period for canal maintenance, it is assumed that the treated water would be discharged to the COP sanitary sewer via a line connection at the West Parcel (Figure 6-3).

MNA, consisting of semi-annual groundwater monitoring of the SGWS monitoring well network, would provide detailed information on the fate and transport of VOC mass in the SGWS as remediation progresses.

7.2.1.2 Cost

Table 7-1 includes summarized estimated costs for the Reference Remedy. These costs are considered practical given the limited current and foreseeable funding available by the ADEQ WQARF program, which will be responsible for implementing the remedy.

P&T System at WOC Facility (30 gpm)

Section 5.6.3.2 and Table 5-6 provide a discussion of the conceptual design and a summary of estimated capital and O&M costs for the 30-gpm P&T system operating with three EWs installed along the southern property boundary of the WOC Facility. Normal discharge of the treated groundwater from the air stripper system would be to the SRP's Grand Canal. During the winter dry-up period for canal maintenance, it is assumed that discharge of the treated water would be to the nearby COP sanitary sewer (see Figure 6-3). The projected capital costs are approximately $588,000 (K), and the annual O&M costs are estimated to be approximately $52K.

<u>Long-Term MNA and Reporting</u>

Section 5.6.1 provides a discussion of MNA as applicable to the downgradient portion of the VOC plume. Table 7-1 includes the estimated combined annual costs for MNA and reporting, plus P&T system performance. This amount is approximately $112K, assuming a semi-annual frequency for monitoring and reporting.

<u>Total Estimated Costs – Reference Remedy</u>

Total estimated costs for the Reference Remedy are presented in Table 7-1. The total estimated cost is approximately $4.1M over a 30-year project life. The NPV of costs, using a 30-year LC and 7% discount rate, is estimated to be approximately $2.1M.

7.2.1.3 Risk

Hydraulic containment of the source area of the plume by the Reference Remedy, which includes containment of impacts migrating into the WOC Site from the NCP, will help to minimize risk to potential future downgradient receptors. As source control is established through P&T at the WOC Facility, VOC concentration reduction in the larger, downgradient portion of the plume will be monitored over time. This will provide a means to implement contingency measures, as necessary, if potential future receptors are threatened by the contaminant plume.

7.2.1.4 Benefits

The Reference Remedy provides prompt hydraulic containment of the estimated full width of the VOC plume emanating from the WOC Facility and NCP. This will prevent the continued migration of contaminant mass into the Site and beyond the WOC Facility boundary to reduce the time to complete remediation. The 30-gpm discharge from the P&T system at the WOC Facility will provide beneficial use of water for irrigation, if needed, by the SRP. The source of VOCs originating from the WOC Facility has been removed. Continued monitoring of the groundwater system during source area P&T operations and via MNA will provide a means for evaluating the effectiveness of remediation.

7.2.2 More Aggressive Remedy

7.2.2.1 Practicability

P&T is a well-established technology considered to be the only technically appropriate and practical solution for active remediation of groundwater throughout the WOC Site. The More Aggressive Remedy provides for hydraulic containment/remediation of the large-scale and relatively deep TCE SGWS plume. This has been determined from the results of the technology screening described in Section 5.0.

Both P&T systems proposed in the More Aggressive Remedy are considered practical. Upon start-up, the P&T system installed at the southern boundary of the WOC Facility will promptly establish hydraulic containment (i.e., source control) of any remaining VOCs emanating from the WOC Facility, as well as the significant contribution of VOCs emanating from the adjacent NCP. The P&T system at the central area of the Site will serve to contain and remediate the greatest contaminant mass moving through the core of the plume, thus minimizing potential impact to downgradient receptors.

The P&T system at the WOC Facility would be the same as that described for the Reference Remedy in Section 7.2.1.1 above. For the central area P&T system, conceptual pipeline routes for options to either discharge treated groundwater to IWs, or to the COP storm sewer are depicted on Figures 5-11a, 5-11b, 5-11c and 5-14. Connection to the COP storm sewer via constructing an approximately 120-foot long pipeline is considered to be the most cost-effective and practical option. This is because drilling, installation, and maintenance of IWs could be avoided. However, discharge to the storm sewer would not conserve the water; therefore, the use of IWs has been recommended for inclusion in the More Aggressive Remedy. Note that construction of the central P&T system involves installing significant lengths of pipelines in the City ROW. Conflicts involving existing City and other public utilities will need to be resolved during the design, permitting, and construction phases of the work.

The More Aggressive Remedy includes continued semi-annual groundwater monitoring of the SGWS well network, which parallels MNA in the Reference Remedy. The purpose of the monitoring would be to evaluate the effectiveness of the two P&T system remedies over time. Model-simulated capture zones for the central area extraction wells are shown on Figure 5-12. Since the central area P&T system focuses on capturing and remediating the central core of the plume (it is not predicted to capture the full width of the downgradient plume), MNA is also part of the More Aggressive Remedy.

Based upon the limited current and foreseeable funding available for the ADEQ WQARF Program, the More Aggressive Remedy is considerably less practical in terms of cost than the Reference and Less Aggressive Remedies. The practicability must be weighed against the benefits which could potentially be realized by the additional remedy pumping (see below).

7.2.2.2 Cost

Estimated costs for the More Aggressive Remedy, assuming the discharge of treated groundwater would be to injection wells, are presented in Table 7-1. The cost for capital items is approximately $2.6M. The collective annual O&M, MNA, and reporting costs are estimated to be approximately $251K per year after the first two years, when ADEQ would require more frequent and expensive groundwater monitoring.

Total Estimated Costs – More Aggressive Remedy

The total cost over an assumed 30-year project life is estimated to be approximately $10.4M, assuming that injection wells would be used for the discharge of treated water from the central area P&T system. This cost also assumes that two replacement monitoring wells, and one replacement injection well, would be installed in life cycle years 10 and 20. The calculated NPV of costs is approximately $5.9M.

7.2.2.3 Risk

Compared with the Reference Remedy, the More Aggressive Remedy reduces risk because of the supplemental active central area P&T system that would capture/remediate a large portion of the downgradient, central core of the plume (Figure 5-12). The more Aggressive Remedy is more robust; therefore, it will more fully protect for the future use of groundwater by the COP and SRP by providing additional active remediation of VOCs in the SGWS plume at the Site. The MNA associated with this remedy will also enhance risk prevention, by providing information on the fate and transport of the downgradient plume during the active remediation.

7.2.2.4 Benefit

In addition to the benefits described above for the Reference Remedy (Section 7.2.1), the More Aggressive Remedy conserves the groundwater resource via re-injection of the 300 GPM P&T flow from the central area. It reduces risk as described in Section 7.2.2.3. The central system provides for containment and remediation of the highest concentrations of VOCs moving downgradient through the core of the VOC plume.

7.2.3 Less Aggressive Remedy

7.2.3.1 Practicability

The Less Aggressive Remedy, consisting of solely MNA, is by far the most cost-effective and strategy. It is extremely practical because the existing SGWS monitoring well infrastructure is already installed, and no new extraction wells, treatment facilities, or re-injection wells would need to be designed, permitted, or installed.

7.2.3.2 Cost

The Less Aggressive Remedy is estimated to be approximately $2.7M for 30 years of assumed semi-annual MNA and reporting. Compared with the approximate 30-year estimated costs for the Reference Remedy ($4.1M) and More Aggressive Remedy ($10.4M), the Less Aggressive Remedy is approximately $1.4M and $7.7M lower in cost, respectively. The calculated NPV of costs for the Less Aggressive Remedy is approximately $1.15M. This information is presented in Table 7-1.

7.2.3.3 Risk

The Less Aggressive Remedy has an increased risk relative to the two other remedies, simply because no active remediation involving source control or containment of VOCs from P&T technology exists. Instead, the Less Aggressive Remedy relies solely on passive remediation via MNA. Consequently, the absence of active remediation represents a greater risk to potential future downgradient receptors.

7.2.3.4 Benefit

The benefit identified for the Less Aggressive Remedy is significantly lower costs. Furthermore, all construction-related disruptions associated with installing extraction wells, conveyance pipelines, treatment plants, and/or injection wells could be avoided.

7.3 COMPARISON OF REMEDIES

Comparison of the remedies with one another is required under the Remedy Selection Rule, R18-16-407, Feasibility Study. A comparison of the remedies is provided below:

7.3.1 Practicability

Each of the selected remedies is considered to be technically and operationally practicable.

7.3.2 Cost

The estimated costs for the three evaluated remedies are presented in Table 7-1. The NPV is the best measure to compare costs among multiple alternatives. The least costly alternative is the Less Aggressive Remedy, which relies solely on MNA (NPV approximately $1.1M; total estimate approximately $2.7M). The Reference Remedy has the median cost (NPV estimate approximately $2.1M; total estimate approximately $4.1M). The More Aggressive Remedy has the highest cost (NPV approximately $5.9M; total estimate approximately $10.4M).

7.3.3 Risk

The More Aggressive Remedy provides the least risk as described in Section 7.2.2.3. The Less Aggressive Remedy represents the most potential risk as described in Section 7.2.3.3. The Reference Remedy is considered to provide a balance or risk between the two aforementioned remedies (Section 7.2.1.3). It should be noted that currently, the risk posed by the existing SGWS groundwater contamination is low because of the absence of groundwater pumping for potable uses within the area. The risk posed by future use of groundwater by the COP is addressed through the operation of the P&T systems for both the LSGS and SGWS at the Site, assuming either the Reference Remedy or More Aggressive

Remedy which include active pumping are selected for the SGWS. The FS for the WOC Site LSGS provides an evaluation of remedies for the LSGS groundwater (GeoTrans, 2009).

7.3.4 Benefit

The three remedies each benefit the environment through remediation of the SGWS groundwater plume over time. Although it is clearly the lowest cost, the Less Aggressive Remedy does not contain/remediate groundwater at the source or downgradient areas, and thus, provides less benefit that would presumably result in a longer time period to achieve plume remediation. The Reference Remedy provides for source control P&T with downgradient MNA at costs considered practical between the Less and More Aggressive Remedies. The More Aggressive Remedy includes both source area containment/remediation, and P&T containment/remediation downgradient to addresses the central core of the plume. Contamination which is not captured by this P&T system would be addressed by MNA. Therefore, the More Aggressive Remedy provides the greatest benefit for completeness of remediation and protection of potential downgradient receptors.

8.0 PROPOSED REMEDY

8.1 PROCESS AND REASON FOR SELECTION

The Reference Remedy is recommended as the proposed remedy. This recommendation is based on what is considered to be the best combination of remedial effectiveness, practicability, cost, and benefit for restoration and use of the SGWS resource.

8.2 ACHIEVEMENT OF REMEDIAL OBJECTIVES

In combination with the conclusions of the FS for the LSGS (GeoTrans, 2009), the Reference Remedy for the SGWS achieves the ROs for the Site, as described in Section 3.5. As presented in the FS for the LSGS, pumping and treating LSGS groundwater at the COP-70/71 well site will restore lost pumping capacity and protects for use of the groundwater resource by the COP.

As described in this FS for the SGWS, discharging an estimated 30 GPM of treated water from the WOC Facility P&T system into the adjacent Grand Canal is part of the proposed Reference Remedy. During the SRP's canal dry-up period for maintenance of the Grand Canal, the treated water would be diverted to the COP sanitary sewer. The flow into the Grand Canal would augment the SRP's existing irrigation water supply. The FS for the LSGS also includes contingency provisions for purchasing additional replacement water to fulfill SRP's possible future needs for more water, due to lost capacity at production wells 8.5E-7.5N and/or 9.5E-7.7N at the Site (GeoTrans, 2009). This would be instituted as necessary, and deemed to be financially feasible, rather than by pumping the aforementioned wells.

8.3 ACHIEVEMENT OF REMEDIAL ACTION CRITERIA PURSUANT TO ARS §49-282.06

It is recommended that the Reference Remedy be selected as the Final Remedy for the SGWS at the Site. Based on a comparison with the More Aggressive and Less Aggressive Remedies, the Reference Remedy appears to:

- Provide for adequate protection of public health and welfare and the environment;
- Provides a thorough and timely means for continued monitoring of the existing groundwater contamination, including assessment of plume capture by remedy EWs, and evaluation of the progress of remediation over time;
- To the extent practicable, provides for the control, management, and cleanup of the COCs in the SGWS groundwater;

- Provides for the beneficial use of the groundwater resource by the COP and SRP, when combined with the recommended remedial strategies and measures for the LSGS; and

- Is reasonable, cost-effective, and technically feasible.

8.4 CONSISTENCY WITH WATER MANAGEMENT PLANS

GeoTrans has reviewed the COP's latest Water Resources Plan, 2005 Update, to determine if the proposed remedial actions are generally consistent with the COP's written plans. Although the COP currently uses groundwater for less than 3% of its total demands, wells are reportedly important for providing water supply and infrastructure redundancy. Many of the COP's groundwater wells have been removed from service due to age, reduced efficiency, and/or groundwater contamination. The disconnection and/or abandonment of the wells due to water-quality concerns and aging equipment has left the COP capable of only meeting 10 to 15% of its peak demand with groundwater. In addition to VOCs in groundwater that have impacted COP wells located within WQARF sites, nitrate, arsenic, heavy metals, and hydrocarbons have also affected wells located outside and within WQARF sites. GeoTrans understands that wellhead treatment facilities for arsenic and nitrate removal have been installed and currently operate as part of the COP's network for municipal water sources.

The COP has identified a need to substantially rebuild its well capacity for drought redundancy, operating flexibility, and system emergencies. Groundwater needs for operating flexibility, including peaking, and system emergencies, are reportedly more compelling in the short term than needs to offset drought impacts (COP, 2006). In correspondence and discussions with the ADEQ and EPA, the COP has emphasized that the Central Phoenix Aquifer is an important future water supply that the COP will need to be able to access.

The Water Resources Plan, 2005 Update, indicates that the COP will work closely with ADEQ and EPA on cleanup strategies for the Central Phoenix contamination issues. Based on our review, the COP document has not been updated since 2005. In Chapter 5, Strategic Concepts, the COP considers environmental benefits and costs in the analysis of water supply and demand management efforts. This section states that *"strategic location and operation of wells may also bring benefits with regard to plume containment and cleanup efforts. As potential well sites are evaluated, ongoing or planned plume remediation efforts would be considered to determine if the locations would support such efforts without compromising the quality of the water supply."*

The proposed Reference Remedy for the SGWS, in combination with recommended remedial strategies and measures for the LSGS (GeoTrans, 2009), are believed to be consistent with the COP's 2005 update to its published water management plan. These remedies, strategies, and measures also appear to be consistent with the Site ROs (ADEQ, 2005), and provide an opportunity for a solution that will serve a dual purpose: 1) restoration of COP-70/71 as part of rebuilding COP's well capacity (particularly in the Central Phoenix area), and 2) the environmental benefits associated with remedy pumping. Furthermore, there appears to be sufficient space to accommodate the proposed COP-70/71 treatment infrastructure at the

COP's existing well site, and land acquisition costs specific well site can presumably be avoided.

According to discussions with the COP, a functional Groundwater and Reclaimed Water Management Plan is being developed. Phase 1 of this plan, which will provide a broad overview of the Phoenix-area needs, was scheduled for completion in July 2008. Phase 2 of this plan will provide more detailed information on the needs/plans for specific areas, including Central Phoenix. Phase 2 was scheduled for completion by or near the end of December 2008. However, based on our review, this information is not available on the COP website.

8.5 CONSISTENCY WITH GENERAL LAND USE PLANNING

As discussed in the RO Report (ADEQ, 2005), the zoning pattern in the Site area has long been established, and there are no foreseeable changes for the future. Installation of P&T systems at the conceptual locations identified in this FS will require negotiations of land access with private land owners (WOC Facility property and central area P&T systems) and potentially the COP, if restoring pumping at the COP-68 well site is desired. Although formal discussions have not taken place, the presence of available land suggests that the installation of P&T systems is feasible.

8.6 CONTINGENCIES

Monitoring existing groundwater wells to evaluate plume capture for the P&T system at the WOC Facility has been recommended. This would be performed periodically, while the 30-gpm containment P&T system is operating. Should monitoring results indicate inadequate plume capture of the VOC plume, contingency actions could be implemented. These actions may include: 1) increasing the pumping rate from one or more EWs to expand plume capture; 2) installing additional EWs and connecting them to the P&T systems to enhance plume capture; and 3) installing supplemental monitoring wells or piezometer wells, as necessary, for use with evaluating the adequacy of plume capture. Although simple modeling indicates that pumping rates of 10 gpm per well will achieve capture of the estimated full width of the plume, the system appurtenances should be designed to convey and treat flows exceeding these rates to allow for system expansion, if necessary.

If EWs go dry in response to lack of recharge in the Site vicinity, drought, and/or gradual SGWS dewatering from remedy pumping, strategies for periodic pumping could potentially be employed to maintain plume capture and remediation. In addition, deeper replacement EWs could be installed to address significant water-level elevation declines at the Site.

9.0 REFERENCES

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TABLES

Table 2-1
Monitoring Well Construction Details
West Osborn Complex WQARF Site, Phoenix, Arizona

Well ID	ADWR 55 - Number	Surveyed Measuring Point (feet amsl)	Diameter (inches)	Total Depth of Borehole (feet bgs)	Screened Interval (feet bgs)
SGWS (Shallow) Monitor Wells					
MW-1S	532636	1109.45	4	130	90 - 130
MW-2S	532372	1107.83	4	120	90 - 120
MW-3S	532373	1109.34	4	100	55 - 95
MW-3SR	907557	1110.62	4	190	132 - 182
MW-4S	534122	1107.64	4	125	85 - 125
MW-5S	534123	1108.05	4	135	95 - 135
MW-6S	558699	1098.35	4	125	80 - 120
MW-7S	558664	1105.22	4	108	63 - 103
MW-100S	562004	1106.62	5	146	87 - 137
MW-101S	563318	1107.34	5	151.5	90 - 140
MW-102S	564733	1106.02	4	135	95 - 135
MW-102SR	907556	1105.71	4	175	130 - 175
MW-103S	564982	1100.81	4	130	90 - 130
MW-104S	564984	1100.36	4	135	65 - 135
MW-201S	571594	1095.26	4	139	98 - 138
MW-202S	902161	1100.76	4	170	130 - 165
MW-203S	902164	1094.45	4	168	123 - 163
MW-204S	902165	1092.35	4	170	130 - 165
MW-205S	902166	1097.20	4	170	130 - 165
MW-206S	904092	1082.55	4	227	132 - 202
MW-207S	904093	1088.79	4	181	131 - 171
MW-208S	907555	1076.40	4	210	137 - 177
MW-209S	907554	1075.82	4	175	130 - 175
ARCO-MW2	536034	1097.75	4	145	99 - 139
WCP-204	589528	1097.47	4	151	110 - 150
WCP-207	901266	1106.33	NR	166	120 - 165
LSGS (Middle) Monitor Wells					
MW-2M	558431	1106.48	8	370	330 - 370
MW-3M	558432	1111.34	8	290	250 - 290
MW-4M	558433	1107.28	8	285	245 - 285
MW-6M	558697	1098.16	4.5	365	325 - 365
MW-7M	558665	1107.86	8	305	260 - 300
MW-102M	564732	1108.14	4	450	340 - 380
MW-105M	564985	1101.39	4	360	320 - 360
MW-106M	564731	1109.25	4	325	280 - 320
MW-107M	585080	1095.95	4	345	305 - 340
MW-108M	590468	1089.13	4	420	300 - 340
MW-109M	594742	1086.79	4	365	320 - 365
MW-110M	594741	1099.01	4	340	295 - 340
MW-203M	902167	1094.64	4	410	360 - 400
MAU (Lower) Monitor Wells					
MW-4L	558430	1110.34	8	810	770 - 810
MW-6L	558698	1100.85	4.5	820	740 - 780
MW-7L	558666	1107.92	8	820	755 - 795

Notes:
ADWR = Arizona Department of Water Resources
amsl = above mean sea level
bgs = below ground surface
NR = Not reported
SGWS = Shallow Groundwater System
LSGS = Lower Sand and Gravel Subunit
MAU = Middle Alluvial Unit

Table 2-2
WOC Facility Ownership
West Osborn Complex WQARF Site, Phoenix, Arizona

Period	Owner	Operator	Type of Operation	Comments
Prior to 1957				Agricultural land
8/57 to 5/59	Andrew P. and Mary J. Tell			
5/59 to 7/59	U.S. Electronics Development Corporation (U.S. EDCOR) of California	U.S. EDCOR of Arizona	Production of film capacitors, diodes	Filed bankruptcy
7/59 to 7/60	United Industrial Corporation (UIC)	U.S. Semiconductor Products Division of UIC	Production of tantalum capacitors, diodes	Topp Industries purchased assets and property in mid-1959; merged as UIC in 12/59
7/60 to 5/62	U.S. Semiconductor Products, Inc.	U.S. Semiconductor Products, Inc. (Arizona, new) as a subsidiary of UIC	Production of tantalum capacitors, diodes	U.S. Semiconductor Products was a wholly-owned subsidiary of UIC until 9/60, when UIC reduced its ownership to 10.62%
5/62 to 4/62	Nucor Corporation	U.S. Semcor, a subsidiary of Nucor Corporation (formerly Nuclear Corporation of America)	Production of tantalum capacitors, diodes, and rare earth metal crystals	Nucor purchased in May 1961 89.38% of total outstanding shares of U.S. Semiconductor Products common stock from UIC
4/62 to 10/65		U.S. Semcor, a Division of Nucor Corporation	Production of tantalum capacitors, diodes, and rare earth metal crystals	In April 1962, Nucor acquired the remaining shares of U.S. Semiconductor Products common stock
10/65 to 6/71	Components, Inc. (old)	Semcor Division of Components, Inc. (old)	Production of tantalum capacitors, diodes and transistors	Components, Inc. (old) purchased the property from Nucor Corporation
6/71 to 10/76	Corning Glass Works	Components, Inc. (new)	Apparently, production of tantalum capacitors, diodes and silicon wafers	Corning Glass Works purchased the property from Components, Inc. (old) through a pooling-of-interest Components (new) was a wholly-owned subsidiary of Corning Glass Works

Table 2-2
WOC Facility Ownership
West Osborn Complex WQARF Site, Phoenix, Arizona

Period	Owner	Operator	Type of Operation	Comments
1976 to 1978	Corning Glass Works sold the property in three separate parcels:			
Middle Parcel (Parcel 107-33-31Q)				
10/76 to 2/79	Marbar Corporation	Lansdale Transistor & Electronics, Inc. (Nevada)	Production of transistors and semiconductors	Lansdale Transistor & Electronics, Inc. (Nevada) leased the property and facilities; this company was controlled by the Pincus family
2/79 to 1/83	Marbar Corporation	Lansdale Transistor & Electronics, Inc. (Delaware)	Production of transistors and semiconductors	Walter Kidde & Company leased the property and facilities under the name of Lansdale Transistor & Electronics, Inc. (Delaware)
1/83 to 12/86	Marbar Corporation	Lansdale Transistor & Electronics, a Division of Electronic Technologies, Inc. (12/86 to 2/87)	Production of transistors and semiconductors	Walter Kidde & Company was acquired by Hanson Industries in 1987 and sold operating assets to Electronics Technologies, Inc. (Delaware)
12/86 to 12/88	Lenore U. Pincus, Trustee of the Pincus Family Trust			
12/88 to 12/92	Lenore U. Pincus, Trustee of the Lenore U. Pincus Family Trust	Lansdale Semiconductor, Inc. (2/87 to 12/92)	Production of transistors and semiconductors	Operations acquired by Lansdale Semiconductors, Inc. (Delaware), a corporation 100% owned by R. D. Lillard
12/92 to Present	Charles Delaney	Capital Liquidators (12/92 to 12/99)	Furniture liquidation	
		Capital Sleep & Sofa (2003 to 2006)	Mattress refurbishing and sales	
		Furniture Sales and Auction (2006 to Present)	Auctioning and sales of used furniture	
East Parcel (Parcel 107-33-31R)				
11/76 to 9/02	Eugene R. Perri and Laura L. Perri	Western Dynex, Inc.	Disc-drive assembler for minicomputers	Eugene Perri was president for Western Dynex, Inc.
9/02 to Present	The Seven Angels, LLC	Industrial Chassis, Inc.	Hot Rods / Custom Car Fabrication and Repair	

Table 2-2
WOC Facility Ownership
West Osborn Complex WQARF Site, Phoenix, Arizona

Period	Owner	Operator	Type of Operation	Comments
West Parcel (Parcels 107-33-31, U through Z, 107-33-394, and 107-33-134)				
6/78 to 2/00	Charles G. May	May Industries, Inc., Metal Joining, Arizona Textile, Arizona Mail Orders, Tumbleweeds, Aztec Chemical, Jazzercise	May Industries, Inc. was a precision machine shop for aerospace industry	Five multiple-tenant office buildings and two industrial buildings Parcel 107-33-31X was owned by Charles G. and Estrella L. May Northeast parcel was owned by Gloria Chestnut
2/00 to Present	Elm Properties, LLC	Intrepid Tool Industries (APN 107-33-031U) Choice Printing, Inc. (APN 107-33-031 V and W) Ellison Surface Technologies (APN 107-33-394; former APN 107-33-031X and Y) BT Molding (APN 107-33-031Z) Pfeifer Manufacturing (APN 107-33-134)	Intrepid Tool Industries – Carbide Tool Design and Manufacturing Choice Printing, Inc. – Printing and Binding Services Ellison Surface Technologies – Thermal Spray Coatings BT Molding – Molding Fabrication Pfeifer Manufacturing – Sheet Metal Fabrication and Cutting;	Five multiple-tenant office buildings and two industrial buildings Northeast parcel was owned by Gloria Chestnut until April 2000, when it was sold to Elm Properties, LLC Parcels 107-33-031X and Y no longer valid APNs.

Sources: ADEQ, 1989b
BCC, 1992
All Lands Title, 1996
GeoTrans, 2004
Maricopa County Assessor's Website, 2011

Table 3-1
Summary of Historical VOC Analytical Data for SGWS and LSGS Monitoring Wells
West Osborn Complex WQARF Site, Phoenix, Arizona

		Analytical Results for Selected Volatile Organic Compounds						
Well ID	**Date Sampled**	**PCE (µg/L)**	**TCE (µg/L)**	**cis-1,2-DCE (µg/L)**	**trans-1,2-DCE (µg/L)**	**1,1-DCE (µg/L)**	**Vinyl Chloride (µg/L)**	**Chloroethane (µg/L)**
Aquifer Water Quality Standard (µg/L)		**5**	**5**	**70**	**100**	**7**	**2**	**NE**
MW-1S	11/18/96	<0.50	**19**	<0.50	<0.50	<0.50	<0.50	<0.50
	02/10/97	<0.50	**17**	<0.50	<0.50	<0.50	<0.50	<0.50
	05/05/97	<0.50	**27**	<0.50	<0.50	<0.50	<0.50	<0.50
	08/05/97	0.7	**73**	<0.50	<0.50	1.3	<0.50	<0.50
	11/18/97	<1.3	**58**	<1.3	<1.3	<1.3	<1.3	<1.3
	02/17/98	<1.25	**65**	<1.25	<1.25	1.6	<1.25	<1.25
	05/26/98	<1.25	**37**	<1.25	<1.25	<1.25	<1.25	<1.25
	08/25/98	<0.5	**45**	<0.5	<0.5	1.20	<0.5	<0.5
	11/09/98	<1.0	**46**	<1.0	<1.0	<1.0	<1.0	<1.0
	02/16/99	0.58	**39**	<5.0	<5.0	0.95	<5.0	<5.0
MW-2S	11/19/96	<0.50	1.6	<0.50	<0.50	<0.50	<0.50	<0.50
	02/11/97	<0.50	3.5	<0.50	<0.50	<0.50	<0.50	<0.50
	05/07/97	<0.50	1.7	<0.50	<0.50	<0.50	<0.50	<0.50
	08/04/97	<0.50	2.0	<0.50	<0.50	<0.50	<0.50	<0.50
	11/18/97	<0.50	2.9	<0.50	<0.50	<0.50	<0.50	<0.50
	02/13/98	<0.50	1.8	<0.50	<0.50	<0.50	<0.50	<0.50
	05/21/98	<0.50	**9.90**	<0.50	<0.50	<0.50	<0.50	<0.50
	08/27/98	<0.50	0.92	<0.50	<0.50	<0.50	<0.50	<0.50
	11/10/98	<0.50	0.99	<0.50	<0.50	<0.50	<0.50	<0.50
	02/16/99	<0.50	2.40	<0.50	<0.50	<0.50	<0.50	<0.50
MW-3S	11/19/96	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	02/11/97	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	05/07/97	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	08/05/97	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	11/18/97	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	02/13/98	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
MW-3SR	10/29/07	**12**	**250**	3.1	<0.50	**41**	<0.50	<5.0
	12/19/07	**12**	**380**	3.3	<1.0	**54**	<1.0	<10
	05/01/08	**8.1**	**230**	<2.0	<1.0	**20**	<1.0	<10
	09/03/08	**5.9**	**170**	<2.0	<1.0	**21**	<1.0	<10
	12/18/08	**7.2**	**220**	<4.0	<2.0	**31**	<2.0	<20
	03/09/09	3.7	**170**	1.7	<0.50	**27**	<0.50	<5.0
	09/10/09	4.9	**120**	1.9	<0.50	**14**	<0.50	<5.0
	09/16/10	<1.0	**160**	<2.0	<1.0	**28**	<1.0	<10
	09/16/11	**10**	**180**	<2.0	<1.0	**22**	<1.0	<10
MW-4S	11/18/96	<25	**340**	<25	<25	<25	<25	<25
	02/05/97	4.5	**130**	<2.5	<2.5	3.7	<2.5	<2.5
	05/06/97	<25	**600**	<25	<25	<25	<25	<25
	08/04/97	**18**	**480**	<10.0	<10.0	**11**	<10.0	<10.0
	11/17/97	**5.5**	**170**	<5.0	<5.0	<5.0	<5.0	<5.0
	02/11/98	<1.0	**25**	<1.0	<1.0	<1.0	<1.0	<1.0
	05/26/98	<0.50	**7.2**	<0.50	<0.50	<0.50	<0.50	<0.50
	08/28/98	<0.50	**15**	<0.50	<0.50	<0.50	<0.50	<0.50
	11/11/98	<0.50	4.9	<0.50	<0.50	<0.50	<0.50	<0.50
	02/18/98	0.79	**14**	<0.50	<0.50	<0.50	<0.50	<0.50
MW-5S	11/18/96	<25	**480**	<25	<25	**86**	<25	<25
	02/07/97	**7.5**	**230**	<5.0	<5.0	**41**	<5.0	<5.0
	05/05/97	<10	**230**	<0.50	<0.50	**33**	<0.50	<0.50
	08/04/97	**6.0**	**140**	1.4	<0.50	**29**	<0.50	<0.50

Table 3-1
Summary of Historical VOC Analytical Data for SGWS and LSGS Monitoring Wells
West Osborn Complex WQARF Site, Phoenix, Arizona

Analytical Results for Selected Volatile Organic Compounds								
Well ID	**Date Sampled**	**PCE (µg/L)**	**TCE (µg/L)**	**cis-1,2-DCE (µg/L)**	**trans-1,2-DCE (µg/L)**	**1,1-DCE (µg/L)**	**Vinyl Chloride (µg/L)**	**Chloroethane (µg/L)**
Aquifer Water Quality Standard (µg/L)		**5**	**5**	**70**	**100**	**7**	**2**	**NE**
MW-5S (cont)	11/13/97	3.4	**97**	<2.5	<2.5	**14**	<2.5	<2.5
	02/17/98	3.6	**96**	<2.5	<2.5	**18**	<2.5	<2.5
	05/21/98	1.40	**39**	<2.5	<2.5	6.4	<2.5	<2.5
	08/28/98	<2.5	**110**	<2.5	<2.5	**10**	<2.5	<2.5
	11/09/98	3.30	**110**	<2.5	<2.5	**8.7**	<2.5	<2.5
	02/19/99	4.50	**91**	<2.5	<2.5	**16**	<2.5	<2.5
	06/08/01	2	**100**	7	<0.2	5	<0.2	<0.2
	03/07/02	2.1	**75**	2.2	<0.50	3.4	<0.50	<0.50
MW-6S	11/20/96	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	02/07/98	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	05/05/97	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	08/05/97	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	11/17/97	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	02/11/98	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	05/19/98	<0.50	1.00	<0.50	<0.50	NA	<0.50	<0.50
	08/21/98	<0.50	<0.50	<0.50	<0.50	NA	<0.50	<0.50
	11/05/98	<0.50	<0.50	<0.50	<0.50	NA	<0.50	<0.50
	02/09/99	<0.50	<0.50	<0.50	<0.50	NA	<0.50	<0.50
MW-7S	11/19/96	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	02/10/97	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	05/07/97	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	08/04/97	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	11/13/97	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	02/23/98	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	05/26/98	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
MW-100S	06/18/03	2.3	**70**	2.1	<1.0	**7.7**	<1.0	<1.0
	09/19/03	1.6	**34**	<1.0	<1.0	3.1	<1.0	<1.0
	01/16/04	2.0	**47**	1.6	<1.0	4.4	<1.0	<1.0
MW-102S	02/18/98	1.6	**60**	<1.3	<1.3	4.4	<1.3	<1.3
	05/20/98	3.70	**98**	<0.50	<0.50	**7.50**	<0.50	<0.50
	08/25/98	1.40	**49**	<0.50	<0.50	4.70	<0.50	<0.50
	11/10/98	<1.0	**41**	<0.50	<0.50	3.40	<0.50	<0.50
	02/11/99	1.80	**40**	<0.50	<0.50	3.60	<0.50	<0.50
	06/11/01	1	**59**	<0.2	<0.2	**7**	<0.2	<0.2
	03/07/02	1.7	**110**	0.58	<0.50	6.4	<0.50	<0.50
	06/17/03	2.7	**120**	<1.0	< 1.0	**12**	<1.0	<1.0
MW-102SR	10/29/07	2.6	**120**	1.3	<0.50	6.7	<0.50	<5.0
	12/19/07	1.9	**130**	<1.0	<0.5	**8.6**	<0.5	<5.0
	04/30/08	1.2	**110**	<1.0	<0.5	3.4	<0.5	<5.0
	09/03/08	1.2	**100**	<1.0	<0.5	4.9	<0.5	<5.0
	12/17/08	1.3	**110**	<1.0	<0.5	4.7	<0.5	<5.0
	03/06/09	<0.50	**65**	<1.0	<0.50	3.6	<0.50	<5.0
	09/09/09	0.99	**69**	<1.0	<0.50	1.7	<0.50	<5.0
	09/16/10	1.2	**83**	<1.0	<0.50	4.7	<0.50	<5.0
	09/15/11	1.8	**91**	<1.0	<0.50	5.5	<0.50	<5.0
MW-103S	02/09/98	<1.3	**59**	<1.3	<1.3	2.0	<1.3	<1.3
	05/18/98	<1.0	**29**	<1.0	<1.0	<1.0	<1.0	<1.0
	08/20/98	<0.50	**28**	<0.50	<0.50	0.78	<0.50	<0.50
	11/06/98	<0.50	**29**	<0.50	<0.50	<0.50	<0.50	<0.50

Table 3-1
Summary of Historical VOC Analytical Data for SGWS and LSGS Monitoring Wells
West Osborn Complex WQARF Site, Phoenix, Arizona

		Analytical Results for Selected Volatile Organic Compounds						
Well ID	Date Sampled	PCE (µg/L)	TCE (µg/L)	cis-1,2-DCE (µg/L)	trans-1,2-DCE (µg/L)	1,1-DCE (µg/L)	Vinyl Chloride (µg/L)	Chloroethane (µg/L)
Aquifer Water Quality Standard (µg/L)		5	5	70	100	7	2	NE
MW-103S (cont)	02/08/99	0.60	**40**	<0.50	<0.50	1.20	<0.50	<0.50
	11/23/99	<0.50	**34**	<0.50	<0.50	0.89	<0.50	<0.50
	06/07/01	0.4	**30**	<0.2	<0.2	1	<0.2	<0.2
	03/07/02	0.57	**40**	<0.50	<0.50	1.4	<0.50	<0.50
MW-104S	02/09/98	<1.0	**32**	<1.0	<1.0	**9.9**	<1.0	<1.0
	05/19/98	<1.0	**25**	<1.0	<1.0	**11**	<1.0	<1.0
	08/20/98	<0.50	**67**	<0.50	<0.50	**17**	<0.50	<0.50
	11/06/98	<2.5	**110**	<2.5	<2.5	**13**	<2.5	<2.5
	02/08/99	<2.5	**83**	<2.5	<2.5	**11**	<2.5	<2.5
	06/29/99	<2.0	**44**	<2.0	<2.0	**8**	<2.0	<2.0
	11/20/99	1.60	**81**	<0.50	<0.50	**8.6**	<0.50	<0.50
	06/11/01	3	**130**	1.0	<0.2	**19**	<0.2	<0.2
	03/07/02	4.2	**200**	2.9	<0.50	**27**	<0.50	<0.50
	06/17/03	4.4	**190**	2.2	<1.0	**10**	<1.0	<1.0
	09/19/03	3.4	**180**	2.0	<1.0	**24**	<1.0	<1.0
MW-201S	02/08/99	0.61	**21**	<0.50	<0.50	<0.50	<0.50	<0.50
	06/29/99	<0.50	2.1	<0.50	<0.50	<0.50	<0.50	<0.50
	11/20/99	<0.50	1.6	<0.50	<0.50	<0.50	<0.50	<0.50
	06/07/01	0.8	**72**	<0.2	<0.2	4.0	<0.2	<0.2
	03/07/02	0.9	**57**	<0.50	<0.50	2.6	<0.50	<0.50
	06/18/03	<1.0	**39**	<1.0	<1.0	2.9	<1.0	<1.0
	09/18/03	<1.0	**38**	<1.0	<1.0	2.5	<1.0	<1.0
	01/16/04	<1.0	**27**	<1.0	<1.0	1.5	<1.0	<1.0
	05/21/04	<1.0	4.2	<1.0	<1.0	<1.0	<1.0	<1.0
	06/28/05	<0.50	1.6	<0.50	<0.50	<0.50	<0.50	<5.0
	09/14/06	<1.0	**23**	<1.0	<1.0	2.0	<1.0	<1.0
	06/11/07	0.6	**27**	<0.50	<0.50	2.2	<0.50	<0.50
	12/19/07	0.5	**24**	<1.0	<0.5	1.9	<0.5	<5.0
	04/29/08	0.5	**23**	<1.0	<0.5	<1.0	<0.5	<5.0
	09/04/08	<0.5	**17**	<1.0	<0.5	1.3	<0.5	<5.0
	12/16/08	0.53	**32**	<1.0	<0.5	2.3	<0.5	<5.0
	3/9/2009	<0.50	**10**	<1.0	<0.50	<1.0	<0.50	<5.0
	9/11/2009	<0.50	**11**	<1.0	<0.50	<1.0	<0.50	<5.0
	9/22/2010	<0.50	**14**	<1.0	<0.50	<1.0	<0.50	<5.0
	9/21/2011	<0.50	**7.2**	<1.0	<0.50	<1.0	<0.50	<5.0
MW-202S	06/13/05	<0.50	**27**	<0.50	<0.50	0.62	<0.50	<5.0
	06/28/05	0.62	**26**	<0.50	<0.50	0.60	<0.50	<5.0
	09/20/06	<1.0	**22**	<1.0	<1.0	<1.0	<1.0	<1.0
	06/12/07	<0.50	**22**	<0.50	<0.50	0.52	<0.50	<0.50
	12/18/07	<0.5	**21**	<1.0	<0.5	<1.0	<0.5	<5.0
	04/29/08	<0.5	**16**	<1.0	<0.5	<1.0	<0.5	<5.0
	09/02/08	<0.5	**12**	<1.0	<0.5	<1.0	<0.5	<5.0
	12/16/08	<0.5	**21**	<1.0	<0.5	<1.0	<0.5	<5.0
	03/05/09	<0.5	**10**	<1.0	<0.5	<1.0	<0.5	<5.0
	09/09/09	<0.5	**13**	<1.0	<0.5	<1.0	<0.50	<5.0
	09/15/10	<0.50	**12**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/15/11	<0.50	**11**	<1.0	<0.50	<1.0	<0.50	<5.0
MW-203S	06/28/05	**5.3**	**140**	2.9	<0.50	**36**	<0.50	<5.0
	09/15/06	2.9	**160**	1.9	<1.0	**15**	<1.0	<1.0

Table 3-1
Summary of Historical VOC Analytical Data for SGWS and LSGS Monitoring Wells
West Osborn Complex WQARF Site, Phoenix, Arizona

		Analytical Results for Selected Volatile Organic Compounds						
Well ID	**Date Sampled**	**PCE (µg/L)**	**TCE (µg/L)**	**cis-1,2-DCE (µg/L)**	**trans-1,2-DCE (µg/L)**	**1,1-DCE (µg/L)**	**Vinyl Chloride (µg/L)**	**Chloroethane (µg/L)**
Aquifer Water Quality Standard (µg/L)		**5**	**5**	**70**	**100**	**7**	**2**	**NE**
MW-203S (cont)	06/12/07	2.5	**90**	1.7	<0.5	**16**	<0.50	<0.50
	12/19/07	1.9	**110**	1.3	<0.5	**16**	<0.5	<5.0
	04/29/08	1.3	**76**	<1.0	<0.5	**6.9**	<0.5	<5.0
	09/04/08	1.5	**93**	<1.0	<0.5	**14**	<0.5	<5.0
	12/16/08	1.4	**96**	<1.0	<0.5	**15**	<0.5	<5.0
	03/03/09	<0.50	**40**	<1.0	<0.5	**8.8**	<0.50	<5.0
	09/09/09	1.1	**65**	<1.0	<0.50	6.6	<0.50	<5.0
	09/15/10	1.8	**75**	1.0	<0.50	**12**	<0.50	<5.0
	09/15/11	2.1	**95**	<1.0	<0.50	**10**	<0.50	<5.0
MW-204S	06/13/05	3.5	**150**	1.1	<0.50	**12**	<0.50	<5.0
	07/01/05	3.9	**160**	1.2	<0.50	**17**	<0.50	<5.0
	09/20/06	3.9	**190**	<1.0	<1.0	**13**	<1.0	<1.0
	06/12/07	3.3	**150**	1.4	<0.50	**15**	<0.50	<0.50
	12/19/07	4.0	**260**	<2.0	<1.0	**26**	<1.0	<10
	04/30/08	3.7	**230**	<2.0	<1.0	**17**	<1.0	<10
	09/03/08	3.1	**210**	<2.0	<1.0	**20**	<1.0	<10
	12/18/08	3.3	**270**	<4.0	<2.0	**32**	<2.0	<20
	03/05/09	1.4	**150**	<1.0	<0.50	**17**	<0.50	<5.0
	09/10/09	2.4	**150**	<1.0	<0.50	**8.9**	<0.50	<5.0
	09/16/10	<5.0	**140**	<10	<5.0	**7.0**	<5.0	<50
	09/16/11	3.0	**180**	<2.0	<1.0	**16**	<1.0	<10
MW-205S	06/15/05	2.5	**77**	<0.50	<0.50	**7.3**	<0.50	<5.0
	06/28/05	2.3	**97**	<0.50	<0.50	6.0	<0.50	<5.0
	09/20/06	2.2	**75**	<1.0	<1.0	4.2	<1.0	<1.0
	06/12/07	1.7	**83**	<0.50	<0.50	5.5	<0.50	<0.50
	12/18/07	1.3	**100**	<1.0	<0.5	3.8	<0.5	<5.0
	04/29/08	1.2	**110**	<1.0	<0.5	2.2	<0.5	<5.0
	09/02/08	1.2	**110**	<1.0	<0.5	4.5	<0.5	<5.0
	12/17/08	1.4	**150**	<1.0	<0.5	6.2	<0.5	<5.0
	03/06/09	<0.50	**83**	<1.0	<0.50	3.0	<0.50	<5.0
	09/09/09	0.91	**79**	<1.0	<0.50	1.7	<0.50	<5.0
	09/15/10	0.85	**67**	<1.0	<0.50	3.4	<0.50	<5.0
	09/15/11	1.1	**82**	<1.0	<0.50	2.7	<0.50	<5.0
MW-206S	09/19/06	2.0	**55**	<1.0	<1.0	2.5	<1.0	<1.0
	06/12/07	3.0	**140**	1.8	<0.50	**16.0**	<0.50	<0.50
	12/18/07	2.5	**180**	1.6	<0.5	**16**	<0.5	<5.0
	04/30/08	2.2	**160**	<1.0	<0.5	**11**	<0.5	<5.0
	09/02/08	2.3	**150**	<2.0	<1.0	**16**	<1.0	<10.0
	12/18/08	2.3	**160**	1.1	<1.0	**18**	<0.5	<5.0
	03/05/09	0.73	**74**	<1.0	<0.50	**8.8**	<0.50	<5.0
	09/10/09	1.50	**86**	<1.0	<0.50	**8.7**	<0.50	<5.0
	09/16/10	1.6	**98**	1.1	<0.50	**14**	<0.50	<5.0
	09/16/11	2.2	**130**	<2.0	<1.0	**14**	<1.0	<10
MW-207S	09/19/06	3.9	**67**	<1.0	<1.0	6.0	<1.0	<1.0
	06/12/07	**5.0**	**51**	0.60	<0.50	**9.0**	<0.50	<0.50
	12/18/07	2.1	**70**	<1.0	<0.5	6.6	<0.5	<5.0
	04/29/08	4.1	**56**	<1.0	<0.5	2.7	<0.5	<5.0
	09/02/08	2.3	**66**	<1.0	<0.5	3.6	<0.5	<5.0
	12/17/08	3.2	**100**	<1.0	<0.5	**13**	<0.5	<5.0

Table 3-1
Summary of Historical VOC Analytical Data for SGWS and LSGS Monitoring Wells
West Osborn Complex WQARF Site, Phoenix, Arizona

Analytical Results for Selected Volatile Organic Compounds								
Well ID	**Date Sampled**	**PCE (µg/L)**	**TCE (µg/L)**	**cis-1,2-DCE (µg/L)**	**trans-1,2-DCE (µg/L)**	**1,1-DCE (µg/L)**	**Vinyl Chloride (µg/L)**	**Chloroethane (µg/L)**
Aquifer Water Quality Standard (µg/L)		**5**	**5**	**70**	**100**	**7**	**2**	**NE**
MW-207S (cont)	03/06/09	2.7	**39**	<0.50	<0.50	6.5	<0.50	<5.0
	09/10/09	2.0	**37**	<1.0	<0.50	2.5	<0.50	<5.0
	09/15/10	**7.2**	**55**	0.54	<0.50	6.6	<0.50	<5.0
	09/15/11	**5.6**	**50**	<1.0	<0.50	3.3	<0.50	<5.0
MW-208S	10/30/07	0.95	**49**	1.3	<0.50	<1.0	<0.50	<5.0
	12/18/07	0.98	**72**	<1.0	<0.5	6.3	<0.5	<5.0
	04/29/08	0.57	**47**	<1.0	<0.5	2.4	<0.5	<5.0
	09/02/08	0.55	**39**	<1.0	<0.5	2.9	<0.5	<5.0
	12/16/08	0.85	**69**	<1.0	<0.5	**7.2**	<0.5	<5.0
	03/05/09	<0.50	**12**	<0.50	<0.50	1.8	<0.50	<5.0
	09/09/09	<0.50	**28**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/15/10	<0.50	**22**	<1.0	<0.50	2.0	<0.50	<5.0
	09/15/11	0.53	**32**	<1.0	<0.50	2.8	<0.50	<5.0
MW-209S	10/30/07	**10**	1.4	0.58	<0.50	<0.50	<0.50	<5.0
	12/18/07	**8.9**	1.2	<1.0	<0.5	<1.0	<0.5	<5.0
	04/29/08	**8.9**	0.92	<1.0	<0.5	<1.0	<0.5	<5.0
	09/02/08	**6.3**	0.90	<1.0	<0.5	<1.0	<0.5	<5.0
	12/16/08	**7.0**	1.0	<1.0	<0.5	<1.0	<0.5	<5.0
	03/03/09	1.7	<0.50	<1.0	<0.5	<1.0	<0.5	<5.0
	09/09/09	**7.9**	0.95	<1.0	<0.50	<1.0	<0.50	<5.0
	09/15/10	4.0	<0.50	<1.0	<0.50	<1.0	<0.50	<5.0
	09/15/11	**7.7**	0.85	<1.0	<0.50	<1.0	<0.50	<5.0
ARCO MW-2	06/18/03	<1.0	<1.0	32	<1.0	<1.0	<1.0	<1.0
	09/19/03	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	01/16/04	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	05/21/04	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	06/27/05	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<5.0
	09/14/06	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	09/21/10	<0.50	0.51	<1.0	<0.50	<1.0	<0.50	<5.0
WCP-204	06/28/05	<0.50	0.66	<0.50	<0.50	<0.50	<0.50	<5.0
	09/19/06	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
WCP-207	09/19/06	3.1	**95**	1.5	<1.0	4.5	<1.0	<1.0
	12/18/08	**7.7**	**88**	<1.0	<0.50	6.0	<0.50	<5.0
	03/06/09	2.6	**48**	<1.0	<0.50	2.9	<0.50	<5.0
	09/23/10	**9.4**	**83**	<1.0	<0.50	5.5	<0.50	<5.0
	09/15/11	**11**	**85**	1.2	<0.50	3.3	<0.50	<5.0
MW-2M	12/05/96	<5.0	**75**	<5.0	<5.0	<5.0	<5.0	<5.0
	02/04/97	< 2.5	**80**	<2.5	<2.5	<2.5	<2.5	<2.5
	05/07/97	<2.5	**72**	<2.5	<2.5	<2.5	<2.5	<2.5
	08/08/97	<2.5	**61**	<2.5	<2.5	<2.5	<2.5	<2.5
	11/18/97	<2.5	**120**	<2.5	<2.5	<2.5	<2.5	<2.5
	02/13/98	<2.5	**110**	<2.5	<2.5	<2.5	<2.5	<2.5
	05/21/98	<2.5	**64**	<2.5	<2.5	<2.5	<2.5	<2.5
	08/27/98	<2.5	**67**	<2.5	<2.5	<2.5	<2.5	<2.5
	11/10/98	<2.5	**65**	<2.5	<2.5	<2.5	<2.5	<2.5
	02/12/99	0.68	**40**	<0.50	<0.50	<0.50	<0.50	<0.50
	11/19/99	0.83	**46**	<0.50	<0.50	<0.50	<0.50	<0.50
	06/14/01	**5**	**70**	<0.2	<0.2	<0.2	<0.2	<0.2
	06/13/03	**11**	**43**	<1.0	<1.0	<1.0	<1.0	<1.0

Table 3-1
Summary of Historical VOC Analytical Data for SGWS and LSGS Monitoring Wells
West Osborn Complex WQARF Site, Phoenix, Arizona

		Analytical Results for Selected Volatile Organic Compounds						
Well ID	Date Sampled	PCE (µg/L)	TCE (µg/L)	cis-1,2-DCE (µg/L)	trans-1,2-DCE (µg/L)	1,1-DCE (µg/L)	Vinyl Chloride (µg/L)	Chloroethane (µg/L)
Aquifer Water Quality Standard (µg/L)		5	5	70	100	7	2	NE
MW-2M (cont)	01/16/04	**11**	**45**	<1.0	<1.0	<1.0	<1.0	<1.0
	07/01/05	**11**	**59**	<0.50	<0.50	0.67	<0.50	<5.0
	09/13/06	**12**	**56**	<1.0	<1.0	<1.0	<1.0	<1.0
	09/19/07	**12**	**46**	<0.50	<0.50	0.56	<0.50	<5.0
	05/02/08	**7.8**	**35**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/04/08	**9.4**	**39**	<1.0	<0.50	<1.0	<0.50	<5.0
	03/11/09	**5.5**	**29**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/16/09	**6.9**	**22**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/21/10	**13**	**29**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/20/11	**13**	**29**	<1.0	<0.50	<1.0	<0.50	<5.0
MW-3M	12/03/96	<0.50	**7.3**	<0.50	<0.50	<0.50	<0.50	<0.50
	02/04/97	<0.50	1.6	<0.50	<0.50	<0.50	<0.50	<0.50
	05/07/97	<0.50	**83**	<2.50	<2.50	<2.50	<2.50	<2.50
	08/09/97	<0.50	3.1	<0.50	<0.50	<0.50	<0.50	<0.50
	11/18/97	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	02/13/98	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	05/21/98	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	08/27/98	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	11/10/98	<0.50	**7.7**	<0.50	<0.50	<0.50	<0.50	<0.50
	02/12/99	0.57	**23**	<0.50	<0.50	<0.50	<0.50	<0.50
	11/19/99	1.8	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	06/16/03	**7.6**	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	01/12/04	**9.6**	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
MW-4M	12/02/96	<0.50	**6.3**	<0.50	<0.50	<0.50	<0.50	<0.50
	02/03/97	<0.50	**5**	<0.50	<0.50	<0.50	<0.50	<0.50
	05/08/97	<0.50	**12**	<0.50	<0.50	<0.50	<0.50	<0.50
	08/06/97	<0.50	3.2	<0.50	<0.50	<0.50	<0.50	<0.50
	11/17/97	<0.50	**8.3**	<0.50	<0.50	<0.50	<0.50	<0.50
	02/11/98	<0.50	**8.4**	<0.50	<0.50	<0.50	<0.50	<0.50
	05/26/98	<0.50	**5.9**	<0.50	<0.50	<0.50	<0.50	<0.50
	08/28/98	<0.50	**7.5**	<0.50	<0.50	<0.50	<0.50	<0.50
	11/11/98	<0.50	3.1	<0.50	<0.50	<0.50	<0.50	<0.50
	02/17/99	<0.50	1.4	<0.50	<0.50	<0.50	<0.50	<0.50
	11/19/99	2	**7.5**	<0.50	<0.50	<0.50	<0.50	<0.50
	06/14/01	**19**	**14**	<0.2	<0.2	<0.2	<0.2	<0.2
	06/16/03	**34**	**18**	<1.0	<1.0	1	<1.0	<1.0
	01/15/04	**27**	**14**	<1.0	<1.0	<1.0	<1.0	<1.0
	07/01/05	**31**	**15**	<0.50	<0.50	1	<0.50	<5.0
	09/13/06	**21**	**13**	<1.0	<1.0	1.3	<1.0	<1.0
	09/19/07	**15**	**14**	<0.50	<0.50	1.4	<0.50	<5.0
	05/02/08	**10**	**8.0**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/03/08	**11**	**9.6**	<1.0	<0.50	<1.0	<0.50	<5.0
	03/11/09	4.6	4.7	<1.0	<0.50	<1.0	<0.50	<5.0
	09/15/09	**5.3**	**5.7**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/21/10	**9.5**	**8.5**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/19/11	**6.8**	**9.4**	<1.0	<0.50	<1.0	<0.50	<5.0
MW-6M	12/06/96	<0.50	**6.2**	<0.50	<0.50	<0.50	<0.50	<0.50
	02/04/97	<0.50	**6.2**	<0.50	<0.50	<0.50	<0.50	<0.50
	05/06/97	<0.50	**8.4**	<0.50	<0.50	<0.50	<0.50	<0.50

Table 3-1
Summary of Historical VOC Analytical Data for SGWS and LSGS Monitoring Wells
West Osborn Complex WQARF Site, Phoenix, Arizona

Analytical Results for Selected Volatile Organic Compounds								
Well ID	Date Sampled	PCE (µg/L)	TCE (µg/L)	cis-1,2-DCE (µg/L)	trans-1,2-DCE (µg/L)	1,1-DCE (µg/L)	Vinyl Chloride (µg/L)	Chloroethane (µg/L)
Aquifer Water Quality Standard (µg/L)		5	5	70	100	7	2	NE
MW-6M (cont)	08/08/97	<0.50	**8.3**	<0.50	<0.50	<0.50	<0.50	<0.50
	11/18/97	<0.50	**8.3**	<0.50	<0.50	<0.50	<0.50	<0.50
	02/11/98	<0.50	**8.6**	<0.50	<0.50	<0.50	<0.50	<0.50
	05/19/98	<0.50	3.1	<0.50	<0.50	<0.50	<0.50	<0.50
	08/21/98	<0.50	4.6	<0.50	<0.50	<0.50	<0.50	<0.50
	11/05/98	<0.50	**6**	<0.50	<0.50	<0.50	<0.50	<0.50
	02/09/99	<0.50	**5.8**	<0.50	<0.50	<0.50	<0.50	<0.50
	11/18/99	<0.50	**25**	<0.50	<0.50	0.52	<0.50	<0.50
	06/14/01	<0.2	**5**	<0.2	<0.2	<0.2	<0.2	<0.2
	06/13/03	<1.0	**12**	<1.0	<1.0	<1.0	<1.0	<1.0
	01/14/04	<1.0	**19**	<1.0	<1.0	<1.0	<1.0	<1.0
	07/01/05	0.72	**14**	<0.50	<0.50	<0.50	<0.50	<5.0
	09/12/06	<1.0	**56**	<1.0	<1.0	<1.0	<1.0	<1.0
	09/18/07	<0.50	**45**	0.91	<0.50	<0.50	<0.50	<5.0
	05/02/08	<0.50	**9.7**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/05/08	<0.50	**20**	<1.0	<0.50	<1.0	<0.50	<5.0
	03/11/09	<0.50	**8.2**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/15/09	<0.50	**8**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/17/10	<0.50	**5.3**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/19/11	<0.50	**9.0**	<1.0	<0.50	<1.0	<0.50	<5.0
MW-7M	12/05/96	<0.50	**9.7**	<0.50	<0.50	<0.50	<0.50	<0.50
	02/04/97	<0.50	**9.7**	<0.50	<0.50	<0.50	<0.50	<0.50
	05/08/97	<0.50	**13**	<0.50	<0.50	<0.50	<0.50	<0.50
	08/06/97	<0.50	**21**	<0.50	<0.50	1.1	<0.50	<0.50
	11/19/97	<0.50	**6.8**	<0.50	<0.50	0.52	<0.50	<0.50
	02/12/98	<0.50	**8.9**	<0.50	<0.50	<0.50	<0.50	<0.50
	05/20/98	<0.50	**5.9**	<0.50	<0.50	<0.50	<0.50	<0.50
	08/27/98	<0.50	2.3	<0.50	<0.50	<0.50	<0.50	<0.50
	11/12/98	<0.50	1.9	<0.50	<0.50	<0.50	<0.50	<0.50
	02/15/99	<0.50	3.2	<0.50	<0.50	<0.50	<0.50	<0.50
	11/29/99	<0.50	4.4	<0.50	<0.50	<0.50	<0.50	<0.50
	06/17/03	**20**	**20**	<1.0	<1.0	1.8	<1.0	<1.0
	01/14/04	**20**	**22**	<1.0	<1.0	1.9	<1.0	<1.0
MW-102M	02/18/98	<0.50	**11**	<0.50	<0.50	<0.50	<0.50	<0.50
	05/20/98	<0.50	**15**	<0.50	<0.50	<0.50	<0.50	<0.50
	08/25/98	<0.50	**13**	<0.50	<0.50	<0.50	<0.50	<0.50
	11/10/98	<0.50	**13**	<0.50	<0.50	<0.50	<0.50	<0.50
	02/11/99	<0.50	**8.7**	<0.50	<0.50	<0.50	<0.50	<0.50
	11/19/99	<0.50	**8.2**	<0.50	<0.50	<0.50	<0.50	<0.50
	06/13/03	<1.0	1.4	<1.0	<1.0	<1.0	<1.0	<1.0
	01/15/04	<1.0	1.1	<1.0	<1.0	<1.0	<1.0	<1.0
MW-105M	02/18/98	<1.0	**52**	<1.0	<1.0	<1.0	<1.0	<1.0
	05/26/98	<1.25	**41**	<1.25	<1.25	<1.25	<1.25	<1.25
	08/25/98	<0.50	**32**	<0.50	<0.50	0.73	<0.50	<0.50
	11/06/98	<0.50	**36**	<0.50	<0.50	<0.50	<0.50	<0.50
	02/09/99	0.56	**37**	<0.50	<0.50	0.83	<0.50	<0.50
	11/29/99	0.66	**40**	<0.50	<0.50	<0.50	<0.50	<0.50
	06/04/01	2	**53**	<0.2	<0.2	0.8	<0.2	<0.2
	06/12/03	**7.5**	**41**	<1.0	<1.0	<1.0	<1.0	<1.0

Table 3-1
Summary of Historical VOC Analytical Data for SGWS and LSGS Monitoring Wells
West Osborn Complex WQARF Site, Phoenix, Arizona

Analytical Results for Selected Volatile Organic Compounds								
Well ID	Date Sampled	PCE (µg/L)	TCE (µg/L)	cis-1,2-DCE (µg/L)	trans-1,2-DCE (µg/L)	1,1-DCE (µg/L)	Vinyl Chloride (µg/L)	Chloroethane (µg/L)
Aquifer Water Quality Standard (µg/L)		5	5	70	100	7	2	NE
MW-105M (cont)	01/15/04	**8.9**	**36**	<1.0	<1.0	<1.0	<1.0	<1.0
	06/30/05	**13**	**47**	<0.50	<0.50	0.66	<0.50	<5.0
	09/18/06	**13**	**60**	<1.0	<1.0	1.9	<1.0	<1.0
	09/19/07	**12**	**46**	<0.50	<0.50	1.4	<0.50	<5.0
	05/03/08	**11**	**46**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/05/08	**13**	**60**	<1.0	<0.50	2.6	<0.50	<5.0
	03/10/09	4.9	**35**	<1.0	<0.50	1.7	<0.50	<5.0
	09/16/09	**6.6**	**32**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/22/10	**12**	**36**	<1.0	<0.50	1.3	<0.50	<5.0
	09/20/11	**11**	**41**	<1.0	<0.50	1.4	<0.50	<5.0
MW-106M	02/18/98	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	05/26/98	2.8	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	08/27/98	2.6	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	11/10/98	3.5	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	02/17/99	2.6	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	11/19/99	4.1	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	06/13/03	3.2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	01/14/04	3	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
MW-107M	04/05/01	<1.0	**56**	1.3	<1.0	<1.0	<1.0	<1.0
	05/07/01	<1.0	**51**	1.1	<1.0	<1.0	<1.0	<1.0
	06/04/01	0.6	**56**	<1.0	<0.2	0.4	<0.2	<0.2
	06/13/03	<1.0	**51**	<1.0	<1.0	<1.0	<1.0	<1.0
	09/19/03	<1.0	**41**	1.2	<1.0	<1.0	<1.0	<1.0
	01/14/04	<1.0	**54**	1.5	<1.0	<1.0	<1.0	<1.0
	07/07/05	0.81	**45**	1.6	<0.50	<0.50	<0.50	<0.50
	09/27/06	<1.0	**52**	1.4	<1.0	<1.0	<1.0	<1.0
	09/20/07	0.77	**55**	1.4	<0.50	<0.50	<0.50	<5.0
	05/03/08	<0.50	**9.4**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/05/08	2.1	2.7	<1.0	<0.50	<1.0	<0.50	<5.0
	03/04/09	<0.50	**12**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/14/09	<0.50	**12**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/23/10	<0.50	**9.3**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/22/11	0.52	**35**	<1.0	<0.50	<1.0	<0.50	<5.0
MW-108M	04/03/02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	06/13/03	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	09/22/03	<1.0	1.1	<1.0	<1.0	<1.0	<1.0	<1.0
	01/19/04	<1.0	1.6	<1.0	<1.0	<1.0	<1.0	<1.0
	05/20/04	<1.0	2.5	<1.0	<1.0	<1.0	<1.0	<1.0
	06/27/05	<0.50	**5**	<0.50	<0.50	<0.50	<0.50	<5.0
	09/15/06	<1.0	**6.1**	<1.0	<1.0	<1.0	<1.0	<1.0
	09/20/07	<0.50	**11**	<0.50	<0.50	<0.50	<0.50	<5.0
	05/02/08	<0.50	3.9	<1.0	<0.50	<1.0	<0.50	<1.0
	09/04/08	2.2	1.4	<1.0	<0.50	<1.0	<0.50	<5.0
	03/05/09	<0.50	**5.3**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/14/09	<0.50	**4.0**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/23/10	<0.50	**1.6**	<1.0	<0.50	<1.0	<0.50	<5.0
	09/22/11	0.55	**9.2**	<1.0	<0.50	<1.0	<0.50	<5.0
MW-109M	05/13/03	<1.0	1.8	<1.0	<1.0	<1.0	<1.0	<1.0
	06/16/03	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

Table 3-1
Summary of Historical VOC Analytical Data for SGWS and LSGS Monitoring Wells
West Osborn Complex WQARF Site, Phoenix, Arizona

Analytical Results for Selected Volatile Organic Compounds								
Well ID	**Date Sampled**	**PCE (µg/L)**	**TCE (µg/L)**	**cis-1,2-DCE (µg/L)**	**trans-1,2-DCE (µg/L)**	**1,1-DCE (µg/L)**	**Vinyl Chloride (µg/L)**	**Chloroethane (µg/L)**
Aquifer Water Quality Standard (µg/L)		**5**	**5**	**70**	**100**	**7**	**2**	**NE**
MW-109M	09/22/03	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
(cont)	01/13/04	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	05/20/04	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	06/27/05	<0.50	0.87	<0.50	<0.50	<0.50	<0.50	<5.0
	09/12/06	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	09/18/07	<0.50	1.3	<0.50	<0.50	<0.50	<0.50	<5.0
	05/01/08	<0.50	1.1	<1.0	<0.50	<1.0	<0.50	<5.0
	09/03/08	<0.50	1.2	<1.0	<0.50	<1.0	<0.50	<5.0
	03/09/09	<0.50	1.0	<1.0	<0.50	<1.0	<0.50	<5.0
	09/15/09	<0.50	1.1	<1.0	<0.50	<1.0	<0.50	<5.0
	09/20/10	<0.50	3.2	<1.0	<0.50	<1.0	<0.50	<5.0
	09/19/11	<0.50	3.2	<1.0	<0.50	<1.0	<0.50	<5.0
MW-110M	05/13/03	<1.0	1.9	<1.0	<1.0	<1.0	<1.0	<1.0
	06/17/03	<1.0	1.5	<1.0	<1.0	<1.0	<1.0	<1.0
	09/22/03	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	01/13/04	<1.0	1.1	<1.0	<1.0	<1.0	<1.0	<1.0
	05/21/04	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	06/27/05	<0.50	1.5	<0.50	<0.50	<0.50	<0.50	<5.0
	09/27/06	<1.0	2	<1.0	<1.0	<1.0	<1.0	<1.0
	09/19/07	0.73	2.1	<0.50	<0.50	<0.50	<0.50	<5.0
	04/29/08	0.56	1.6	<1.0	<0.50	<1.0	<0.50	<5.0
	09/20/10	1.2	3	<1.0	<0.50	<1.0	<0.50	<5.0
	09/03/08	0.73	2.0	<1.0	<0.50	<1.0	<0.50	<5.0
	03/10/09	<0.50	1.3	<1.0	<0.50	<1.0	<0.50	<5.0
	09/15/09	<0.50	1.3	<1.0	<0.50	<1.0	<0.50	<5.0
	09/20/10	1.2	3.0	<1.0	<0.50	<1.0	<0.50	<5.0
	09/16/11	1.1	2.8	<1.0	<0.50	<1.0	<0.50	<5.0
MW-203M	06/15/05	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<5.0
	07/07/05	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<5.0
	09/15/06	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	09/20/07	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<5.0
	05/01/08	<0.50	0.53	<1.0	<0.50	<1.0	<0.50	<5.0
	09/02/08	<0.50	<0.50	<1.0	<0.50	<1.0	<0.50	<5.0
	03/05/09	<0.50	<0.50	<1.0	<0.50	<1.0	<0.50	<5.0
	09/11/09	<0.50	<0.50	<1.0	<0.50	<1.0	<0.50	<5.0
	09/17/10	<0.50	<0.50	<1.0	<0.50	<1.0	<0.50	<5.0
	09/22/11	<0.50	<0.50	<1.0	<0.50	<1.0	<0.50	<5.0

Notes:
SGWS = shallow groundwater system
LSGS = lower sand and gravel subunit
VOC = Volatile Organic Compound
NE = Not Established
µg/L = micrograms per liter
<1.0 = Analyte not detected above the listed detection limit
PCE = Tetrachloroethylene
TCE = Trichloroethylene
cis-1,2-DCE = cis-1,2-Dichloroethylene
trans-1,2-DCE = trans-1,2-Dichloroethylene
1,1-DCE = 1,1-Dichloroethylene
Bolded results indicate exceedances of Aquifer Water Quality Standards

Table 3-2
Summary of Inorganic Parameters
in Wells MW-206S, MW-208S, and MW-102SR
West Osborn Complex WQARF Site, Phoenix, Arizona

Parameter	AWQS	Groundwater Monitoring Wells		
		MW-206S	MW-208S	MW-102SR
INORGANIC PARAMETERS (mg/L)				
Alkalinity (Total)	NE	**340**	**480**	**260**
Bicarbonate	NE	**340**	**480**	**260**
Carbonate	NE	<10	<10	<10
Chloride	NE	**410**	**410**	**150**
Ferric Iron	NE	<0.1	**38**	**3.2**
Ferrous Iron	NE	<0.1	**0.36**	**0.21**
Hardness (Total)	NE	**310**	**350**	**100**
Hydroxide	NE	<10	<10	<10
Nitrate	10	**10**	**8.5**	**2.1**
Nitrate + Nitrite	10	**11**	**8.5**	**2.1**
Nitrite	1	<0.1	<0.1	<0.1
Sulfate	NE	**150**	**160**	**97**
Total Organic Carbon (TOC)	NE	**5.2**	**8.5**	**4.9**
Total Carbon Dioxide	NE	**380**	**500**	**250**
ADDITIONAL INORGANIC PARAMETERS				
Conductivity (µmhos/cm)	NE	**2,200**	**2,200**	**1,100**
pH	NE	**6.9**	**7.1**	**7.3**
TOTAL METALS (mg/L)				
Aluminum	NE	**0.074**	**24**	**2.2**
Arsenic	0.05*	**0.0037**	**0.016**	**0.0065**
Calcium	NE	**69**	**78**	**19**
Chromium	0.1*	**0.015**	**0.14**	**0.016**
Copper	NE	**0.0**	**0.0**	**0.0059**
Iron	NE	<200	**38**	**3.4**
Magnesium	NE	**34**	**37**	**13**
Potassium	NE	**4**	**6.3**	**2.3**
Sodium	NE	**330**	**420**	**210**
Zinc	NE	<20	**110**	**14**
DISSOLVED METALS (mg/L)				
Aluminum	NE	<20	**0.13**	<10
Arsenic	0.05*	**0.0042**	**0.0043**	**0.008**
Calcium	NE	**67**	**51**	**17**
Chromium	0.1*	**0.023**	**0.025**	**0.017**
Copper	NE	**0.0059**	**0.0069**	**0.0033**
Iron	NE	<0.20	<0.20	<0.10
Magnesium	NE	**33**	**29**	**13**
Potassium	NE	**4**	**3.3**	**1.8**
Sodium	NE	**330**	**350**	**210**
Zinc	NE	<0.020	<0.020	<0.010
SILICAS (mg/L)				
Total Silica	NE	**30**	**190**	**57**
Dissolved Silica	NE	**29**	**27**	**22**

Notes:
AWQS = Aquifer Water Quality Standard
mg/L = milligrams per liter
NE = not established
µmhos/cm = micromhos per centimeter
* = AWQS is for total metals
Bold = Results are above laboratory method detection limits
Highlighted = Results are above AWQS

Table 3-3
Concentrations of Selected VOCs Detected in October 2008 Soil Vapor Samples and Historical Groundwater Samples
West Osborn Complex WQARF Site, Phoenix, Arizona

Sample Location	Screen Interval (feet bgs)	Well Dry Since	Vapor Concentrations								Highest Detected Historic Groundwater TCE Concentration (µg/L)	Date of Highest Detected Historic Groundwater TCE Concentration	Henry's Law TCE Vapor Concentration† (µg/m³)	Approximate TCE Soil Concentration in Sand (mg/kg)††	Approximate TCE Soil Concentration in Loam (mg/kg)††	Approximate TCE Soil Concentration in Silt (mg/kg)††	Approximate TCE Soil Concentration in Clay (mg/kg)††
			TCE		PCE		1,1-DCE		cis-1,2-DCE								
			ppbv	µg/m³	ppbv	µg/m³	ppbv	µg/m³	ppbv	µg/m³							
MW-4S	85 - 125	Aug. 2001	**2,800**	**15,000**	**130**	**880**	**140**	**560**	<10	<39.6	**600**	5/6/1997	252,600	0.030	0.035	0.037	0.040
MW-5S	95 - 135	May 2003	**4,900**	**26,000**	**110**	**750**	**810**	**3,200**	**580**	**2,300**	**480**	11/18/1996	202,100	0.050	0.060	0.065	0.065
MW-100S	87 - 137	May 2004*	**15,000**	**81,000**	**400**	**2,700**	**2,600**	**10,000**	**660**	**2,600**	**70**	6/18/2003	29,600	0.160	0.180	0.195	0.205
MW-101S	90 - 140	May 2004*	**970**	**5,200**	<50	<339	**300**	**1,200**	<50	<198	--	--		0.010	0.011	0.013	0.013
SVE-1	65 - 110	NA	**25**	**130**	**2.2**	**15**	**2.2**	**8.7**	<0.50	<1.98	NA	NA	--	<0.001	<0.001	<0.001	<0.001
SVE-2	65 - 110	NA	**250**	**1,300**	<10	<67.8	**32**	**130**	<10	<39.6	NA	NA	--	0.003	0.003	0.004	0.004
SVE-3	65 - 110	NA	**280**	**1,500**	**12**	**81**	**30**	**120**	<5.0	<19.8	NA	NA	--	0.003	0.004	0.004	0.004

Notes:

VOCs = Volatile Organic Compounds
TCE = Trichloroethene
PCE = Tetrachloroethene
1,1-DCE = 1,1 Dichloroethene
cis-1,2-DCE = cis-1,2-Dichloroethene
VOCs detected in soil vapor were analyzed using EPA Method TO-15.
VOCs detected in groundwater were analyzed using EPA Method 8260B.
* = Estimated date
-- = Historic groundwater data for well MW-101S could not be found in database.

bgs = below ground surface
ppbv = parts per billion volumetric
µg/m³ = micrograms per cubic meter
µg/L = microgram per liter
mg/kg = milligrams per kilogram
NA = not applicable
Concentrations shown in **bold** were detected at or above the laboratory reporting limit.

† = Henry's Law Vapor Concentration is calculated assuming 1 atm barometric pressure and 25 °C.
†† = Soil concentrations were based on intercalculation within the SL Screen of the Johnson & Ettinger Model (2002). Concentrations were approximated based on actual vapor concentrations in the table above. ADEQ established regulatory criteria for TCE includes:
Groundwater Protection Limit = 0.61 mg/kg
Residential Soil Remediation Level = 3.0 mg/kg
Non-Residential Soil Remediation Level = 65 mg/kg

Table 4-1
SVE Operation Data Including Estimated Mass Removal of VOCs
West Osborn Complex WQARF Site, Phoenix, Arizona

Operation Period	SVE Operation Hours	SVE Operation Days	Average SVE Flow Rate[1] (scfm)	Average Total VOC Concentration[2] (mg/m^3)	Treated Discharge VOC Concentration (mg/m^3)	VOC Mass Removal Rate (lbs/day)	VOC Mass Discharge Rate (lbs/day)	Mass VOCs Removed/Treated[3] (lbs)
1999								
08/04-08/12	9.00	0.38	48	325	0	1.40	0.00	0.53
08/12-08/30	54.30	2.26	119	325	0	3.48	---	7.88
08/30-09/20	57.92	2.41	136	325	0	3.98	---	9.60
09/20-10/21	311.13	12.96	136	325	0	3.98	0.00	51.57
10/21-12/21	963.78	40.16	152	167	0	2.28	0.00	91.74
2000								
12/21-02/09	876.99	36.54	152	167	0	2.28	0.00	83.48
02/09-02/21	287.15	11.96	115	167	0	1.73	0.00	20.68
02/21-02/28	170.54	7.11	122	80	0	0.88	0.00	6.24
02/28-04/18	1100.47	45.85	132	80	0	0.95	0.00	43.58
04/18-05/23	793.54	33.06	132	50	0	0.59	0.00	19.64
05/23-06/23	718.44	29.94	94	40	0	0.34	0.00	10.13
06/23-07/10	397.60	16.57	94	40	0	0.34	0.00	5.61
07/10-10/11	859.03	35.79	98	36	0	0.32	0.00	11.36
10/11-12/14	1100.93	45.87	122	36	0	0.40	0.00	18.13
12/14-12/31	422.00	17.58	122	24	0	0.26	0.00	4.63
2001								
01/01-01/25	588.00	24.50	135	24	0	0.29	0.00	7.14
01/25-02/14	482.87	20.12	136	24	0	0.29	0.00	5.91
02/14-05/17	673.64	28.07	131	22	0	0.26	0.00	7.28
05/17-08/23	529.29	22.05	126	22	0	0.25	0.00	5.50
08/23-10/17	1023.37	42.64	142	16	0	0.20	0.00	8.72
10/17-12/31	1149.89	47.91	163	11	0	0.16	0.00	7.73
2002								
01/01-02/07	530.33	22.10	165	11.0	0	0.16	0.00	3.61
02/07-05/03	1923.45	80.14	167	8.5	0	0.13	0.00	10.24
05/03-09/12	1737.93	72.41	142	6.9	0	0.09	0.00	6.39
09/12-10/21	771.98	32.17	145	5.3	0	0.07	0.00	2.22
TOTALS	**17,533.57**	**730.57**						**449.55**

Notes:

SVE = soil vapor extraction
VOCs = volatile organic compounds
scfm = standard cubic feet per minute, using 70 °F and 14.7 psi absolute for standard air
mg/m^3 = milligrams per cubic meter (total detected contaminant mass per unit volume)
lbs = pounds
psi = pounds per square inch
ID = inside diameter
1 = The SVE rate was determined by converting a direct field measurement of air velocity measured from the system plumbing (3-in. ID). Temperature and pressure readings were also collected to allow conversion from actual to scfm, based on standard air (70 °F and 14.7 psi absolute).
2 = Average concentrations of untreated extraction vapor based on available analytical data.
3 = Represents total estimated mass of VOCs extracted from soil and treated to remove VOCs prior to discharge into the atmosphere.

Table 5-1
Cost Analysis for Air Stripping Only Treatment Option
West Osborn Complex WQARF Site, Phoenix, Arizona

Estimated Capital Costs for Air Stripping Only Treatment Option--300 GPM System		
Category	**Estimated Cost**	
Furnish and Install Air Stripper	$95,000	Carbonair STAT 400
Electrical Power, Distribution, and Controls	$45,000	
Concrete Foundation, Canopy, Block Fenced Compound, Collection Sump, Yard Piping	$150,000	
Engineering, Permitting, H&S, CM, Start-up, Contingency (25%)	$72,500	
Total Capital Costs	**$362,500**	

Estimated Annual O&M for Air Stripping Only Treatment Option--300 GPM System		
Category	**Estimated Units & Unit Costs**	**Estimated Cost**
Labor		
-- O&M Operator	24 hrs/mo @ $70/hr	$20,160
-- O&M Mgmt./Engineering	4 hr/mo @ $130/hr	$6,240
Electric Power, EW Pumps (10 HP x 3 = 30 HP) and Air Stripper Blower (25 HP) @ 95% Run Time	341,452 kw-hrs @ $0.14/kw-hr	$47,803
Anti-Scalent Chemicals for Air Stripper (Flow-Proportional Feed Pump Additions)	65 gals/mo @ $8.75/gal	$6,825
Performance Sampling (Lab Analysis) for Each EW, AS Influent, Treated Effluent	5 samples/mo @ $120/sample	$7,200
Maintenance	Varies	$3,000
Total Annual O&M Costs		**$91,228**

Estimated Life-Cycle Costs for Air Stripping Only Treatment Option--300 GPM System		
Capital Costs	$362,500	
Annual O&M Costs (30 years)	$2,736,847	
Future Cost: Replace Worn-out Air Stripper in Year 20	$95,000	
30-Year Life-Cycle Costs	**$3,194,347**	
Net Present Value of 30 Year Life-Cycle Costs, Discounted at 7%	**$1,519,099**	

GPM = gallons per minute
O&M = operation and maintenance
kw-hr = kilowatt-hours
EW = extraction well
HP = horsepower
CM = construction management
H&S = health & safety
AS = air stripping

Table format adopted from Cost Effective Design of Pump and Treat Systems, EPA, 2005.

*Capital costs exclude EW and submersible pump installations, and electrical service & distribution for well pumps.

These costs are the same for each of the other four 300 GPM P&T alternatives.

Table 5-2
Cost Analysis for AS with VGAC Treatment Option
West Osborn Complex WQARF Site, Phoenix, Arizona

Estimated Capital Costs for Air Stripping with VGAC Treatment--300 GPM System		
Category	**Estimated Cost**	
Furnish and Install Air Stripper	$95,000	Carbonair STAT 400
VGAC Units for Off-Gas Treatment	$25,000	(2) 3,000 lb units
		(Siemens FB-3000)
Electrical Power, Distribution, and Controls	$50,000	
Concrete Foundation, Canopy, Block Fenced Compound, Yard Piping	$165,000	
Engineering, H&S, CM, Start-up, Contingency (25%)	$83,750	
Total Capital Costs	**$418,750**	
Estimated Annual O&M for Air Stripping with VGAC Treatment--300 GPM System		
Category	**Estimated Units & Unit Costs**	**Estimated Cost**
Labor		
-- O&M Operator	28 hrs/mo @ $70/hr	$23,520
-- O&M Mgmt./Engineering	5 hr/mo @ $130/hr	$7,800
Electric Power, EW Pumps (10 HP x 3 = 30 HP) and Air Stripper Blower (25 HP) @ 95% Run Time	341,452 kw-hrs @ $0.14/kw-hr	$47,803
VGAC Usage (Ave Siemens & Prominent Isotherms)	33 lbs/day @ $0.95/lb	$11,443
Anti-Scalent Chemicals for Air Stripper (Flow-Proportional Feed Pump Additions)	65 gals/mo @ $8.75/gal	$6,825
Perform. Sampling (Lab Analysis) for Each EW, Water Influent, Vapor from Lag VGAC Unit, and Treated Water Effluent	6 samples/mo @ $120/sample	$8,640
Maintenance	Varies	$4,000
Total Annual O&M Costs		**$110,031**
Estimated Life-Cycle Costs for Air Stripping with VGAC Treatment--300 GPM System		
Capital Costs	$418,750	
Annual O&M Costs (30 years)	$3,300,929	
30 Year Life-Cycle Costs	**$3,719,679**	
Future Cost: Replace Worn-out Air Stripper in Year 20	$95,000	
Net Present Value of 30 Year Life-Cycle Costs, Discounted at 7%	**$1,808,672**	

AS = air stripping
LGAC = liquid-phase granular activated carbon
GPM - gallons per minute
O&M = operation and maintenance
kw-hr = kilowatt-hours
EW = extraction well
HP = horsepower
CM = construction management
H&S = health & safety
U.G. = underground

Table format adopted from Cost Effective Design of Pump and Treat Systems, EPA, 2005.

*Capital costs exclude EW and submersible pump installations, and electrical service & distribution for well pumps.

These costs are the same for each of the other four 300 GPM P&T alternatives.

Table 5-3
Cost Analysis for AS with LGAC Treatment Option
West Osborn Complex WQARF Site, Phoenix, Arizona

Estimated Capital Costs for Air Stripping with LGAC Treatment--300 GPM System		
Category	Estimated Cost	
Furnish and Install Air Stripper	$95,000	Carbonair STAT 400
(1) Liquid GAC Polishing Unit and (2) Bag Filters	$120,000	(1)10,000 lb unit
		(Siemens HP-810)
Electrical Power, Distribution, and Controls	$45,000	
Concrete Foundation, U.G. Backwash Tank, Canopy, Block Fenced Compound, Yard Piping	$175,000	
Engineering, H&S, CM, Start-up, Contingency (25%)	$108,750	
Total Capital Costs	**$543,750**	

Estimated Annual O&M for Air Stripping with LGAC Treatment--300 GPM System		
Category	Estimated Units & Unit Costs	Estimated Cost
Labor		
-- O&M Operator	28 hrs/mo @ $70/hr	$23,520
-- O&M Mgmt./Engineering	5 hr/mo @ $130/hr	$7,800
Electric Power, EW Pumps (10 HP x 3 = 30 HP) and Air Stripper Blower (25 HP) @ 95% Run Time	341,452 kw-hrs @ $0.14/kw-hr	$47,803
LGAC Usage (Ave Siemens & Prominent Isotherms)	62 lbs/day @ $0.95/lb	$21,499
Anti-Scalent Chemicals for Air Stripper (Flow-Proportional Feed Pump Additions)	65 gals/mo @ $8.75/gal	$6,825
Perform. Sampling (Lab Analysis) for Each EW, Influent to AS and LGAC Unit, Treated Effluent	6 samples/mo @ $120/sample	$8,640
Maintenance	Varies	$4,000
Total Annual O&M Costs		**$120,087**

Estimated Life-Cycle Costs for Air Stripping with LGAC Treatment--300 GPM System		
Capital Costs	$543,750	
Annual O&M Costs (30 years)	$3,602,602	
30 Year Life-Cycle Costs	**$4,146,352**	
Future Cost: Replace Worn-out Air Stripper in Year 20	$95,000	
Net Present Value of 30 Year Life-Cycle Costs, Discounted at 7%	**$2,058,454**	

AS = air stripping
LGAC = liquid-phase granular activated carbon
GPM - gallons per minute
O&M = operation and maintenance
kw-hr = kilowatt-hours
EW = extraction well
HP = horsepower
CM = construction management
H&S = health & safety
U.G. = underground

Table format adopted from Cost Effective Design of Pump and Treat Systems, EPA, 2005.

These costs are the same for each of the other four 300 GPM P&T alternatives.

Table 5-4
Cost Analysis for AS with VGAC and LGAC Treatment Option
West Osborn Complex WQARF Site, Phoenix, Arizona

Estimated Capital Costs for Air Stripping with VGAC and LGAC Treatment--300 GPM System		
Category	Estimated Cost	
Furnish and Install Air Stripper	$95,000	Carbonair STAT 400
(1) Liquid GAC Polishing Unit and (2) Bag Filters	$120,000	(1)10,000 lb unit
		(Siemens HP-810)
VGAC Units for Off-Gas Treatment	$25,000	(2) 3,000 lb units
		(Siemens FB-3000)
Electrical Power, Distribution, and Controls	$45,000	
Concrete Foundation, U.G. Backwash Tank, Canopy, Block Fenced Compound, Yard Piping	$180,000	
Engineering, H&S, CM, Start-up, Contingency (25%)	$116,250	
Total Capital Costs	**$581,250**	
Estimated Annual O&M for Air Stripping with VGAC and LGAC Treatment--300 GPM System		
Category	**Estimated Units & Unit Costs**	**Estimated Cost**
Labor		
-- O&M Operator	32 hrs/mo @ $70/hr	$26,880
-- O&M Mgmt./Engineering	6 hr/mo @ $130/hr	$9,360
Electric Power, EW Pumps (10 HP x 3 = 30 HP) and Air Stripper Blower (25 HP) @ 95% Run Time	341,452 kw-hrs @ $0.14/kw-hr	$47,803
VGAC Usage (Ave Siemens & Prominent Isotherms)	33 lbs/day @ $0.95/lb	$11,443
LGAC Usage (Siemens Isotherm)	7 lbs/day @ $0.95/lb	$2,427
Anti-Scalent Chemicals for Air Stripper (Flow-Proportional Feed Pump Additions)	65 gals/mo @ $8.75/gal	$6,825
Perform. Sampling (Lab Analysis) for Each EW, Influent Water to AS and LGAC Unit, Vapor Discharge and Treated Water Effluent	7 samples/mo @ $120/sample	$10,080
Maintenance	Varies	$5,000
Total Annual O&M Costs		**$119,818**
Estimated Life-Cycle Costs for Air Stripping w/VGAC and LGAC Treatment--300 GPM System		
Capital Costs	$581,250	
Annual O&M Costs (30 years)	$3,594,547	
30 Year Life-Cycle Costs	**$4,175,797**	
Future Cost: Replace Worn-out Air Stripper in Year 20	$95,000	
Net Present Value of 30 Year Life-Cycle Costs, Discounted at 7%	**$2,092,622**	

AS = air stripping
LGAC = liquid-phase granular activated carbon
GPM - gallons per minute
O&M = operation and maintenance
kw-hr = kilowatt-hours
EW = extraction well
HP = horsepower
CM = construction management
H&S = health & safety
U.G. = underground

Table format adopted from Cost Effective Design of Pump and Treat Systems, EPA, 2005.

*Capital costs exclude EW and submersible pump installations, and electrical service & distribution for well pumps.
These costs are the same for each of the other four 300 GPM P&T alternatives.

Table 5-5
Cost Analysis for LGAC Only Treatment Option
West Osborn Complex WQARF Site, Phoenix, Arizona

Estimated Capital Costs for LGAC Only Treatment Option--300 GPM System		
Category	**Estimated Cost**	
(2) LGAC Units, Manifold, and (2) Bag Filters	$200,000	Siemens HP-810
		(2) Eaton MBE HE
Electrical Power, Distribution, and Controls	$40,000	
Concrete Foundation, U.G. Backwash Tank, Canopy, Block Fenced Compound, Yard Piping	$175,000	
Engineering, Permitting, H&S, CM, Start-up, Contingency (25%)	$103,750	
Total Capital Costs	**$518,750**	
Estimated Annual O&M for LGAC Only Treatment Option--300 GPM System		
Category	**Estimated Units & Unit Costs**	**Estimated Cost**
Labor		
-- O&M Operator	20 hrs/mo @ $70/hr	$16,800
-- O&M Mgmt./Engineering	3 hr/mo @ $130/hr	$4,680
Electric Power, EW Pumps (10 HP x 3 = 30 HP) @ 95% Run Time	186,246 kw-hrs @ $0.14/kw-hr	$26,074
LGAC Usage (Ave. of Isotherms: Siemens WT, Prominent, & Carbonair) @ 95% Run Time	62 lbs/day @ $0.95/lb	$20,424
LGAC Change-out Service	2 events @ 1,500 ea	$3,000
Performance Sampling (Lab Analysis) for Each EW, Influent to Each LGAC Unit, Treated Effluent	6 samples/mo @ $120/sample	$8,640
Maintenance (Equip. or Controls, Supplies, etc.)	Varies	$3,500
Total Annual O&M Costs		**$83,118**
Estimated Life-Cycle Costs for LGAC Only Treatment Option--300 GPM System		
Capital Costs	$518,750	
Annual O&M Costs (30 years)	$2,493,542	
30-Year Life-Cycle Costs	**$3,012,292**	
Net Present Value of 30-Year Life-Cycle Costs, Discounted at 7%	**$1,550,162**	

GPM - gallons per minute
LGAC = liquid-phase granular activated carbon
O&M = operation and maintenance
kw-hr = kilowatt-hours
EW = extraction well
HP = horsepower
CM = construction management
H&S = health & safety
U.G. = underground
AS = air stripping

Table format adopted from Cost Effective Design of Pump and Treat Systems, EPA, 2005.

*Capital costs exclude EW and submersible pump installations, and electrical service & distribution for well pumps.

These costs are the same for each of the other four 300 GPM P&T alternatives.

Table 5-6
Cost Estimates for Remedial Alternatives Considered for WOC Facility
West Osborn Complex WQARF Site, Phoenix, Arizona

	ALTERNATIVE					
CAPITAL	**1a**	**1b**	**2a**	**2b**	**3**	**4**
Drill and Install Remediation Wells and Performance MWs, Well Development, and IDW Management	$188,000	$491,000	$320,000	$775,000	$110,000	$110,000
Conduct Treatability Study, Pilot-Scale Feasibility Tests, or Aquifer Tests Including Work Plan and Results Reporting	$20,000	$20,000	$75,000	$75,000	$40,000	$40,000
Furnish and Install Wellhead Vaults, Wellhead Instrumentation, and All Process Piping and Connections	$54,000	$139,000	$15,000	$21,000	$80,000	$80,000
Furnish and Install Wellhead Pumps and Flow Meters	$0	$0	$0	$0	$25,000	$25,000
Furnish and Install All Mechanical and Treatment Equipment	$90,000	$156,000	$10,000	$15,000	$65,000	$80,000
Install New Electric Power Service, Electrical Distribution, and System Controls	$30,000	$35,000	$0	$0	$40,000	$50,000
Install Treatment Plant Compound (Slab, Containment, Sump, CMU Block Enclosure, Security Gates, U.G. Backwash Tank for LGAC, Housekeeping Pads, Canopy, etc..)	$35,000	$35,000	$10,000	$10,000	$70,000	$60,000
Land Access for Treatment Compound (Assumed)	$30,000	$40,000	$20,000	$30,000	$40,000	$40,000
Subtotal Capital	$447,000	$916,000	$450,000	$926,000	$470,000	$485,000
Engineering, H&S, Permitting, & CM (25%)	$111,750	$229,000	$112,500	$231,500	$117,500	$121,250
Total Capital	$558,750	$1,145,000	$562,500	$1,157,500	$587,500	$606,250
ANNUAL O&M						
Labor	$30,000	$35,000	$10,000	$20,000	$21,000	$21,000
Electric Power	$38,200	$94,100	$0	$0	$3,500	$5,000
LGAC and/or VGAC Use	$2,100	$4,300	$0	$0	$3,000	$3,500
Substrate Injections for ISB or Antiscalent Additions for Air Stripper (Average Annual)*	$0	$0	$24,000	$65,500	$0	$4,200
Misc. System Repairs, Routine Sampling (Includes Field Equip. & Lab Analysis Costs)	$11,500	$13,500	$10,000	$27,000	$6,500	$7,500
System Performance/Status Reporting	$13,000	$13,000	$6,500	$8,500	$15,000	$17,500
Total O&M	$94,800	$159,900	$50,500	$121,000	$49,000	$58,700
Install Replacement Pumps, Years 10 and 20	$0	$0	$0	$0	$20,000	$20,000
TOTALS AND NPV						
Total Cost (Capital + O&M for Life-Cycle Period of Operation)	$3,402,750	$5,942,000	$2,077,500	$4,787,500	$2,057,500	$2,367,250
Life-Cycle NPV**	$1,735,000	$3,129,000	$1,189,000	$2,659,000	$1,211,000	$1,350,000

ALTERNATIVE DESCRIPTIONS:

Alternative 1a: Barrier AS/SVE System on Middle Parcel w/ VGAC Treatment; 15-Year Life Cycle
Alternative 1b: Barrier AS/SVE System on Middle and West Parcels w/ VGAC Treatment; 15-Year Life Cycle
Alternative 2a: Barrier Enhanced ISB System on Middle Parcel w/ EVO Substrate Additions; 15-Year Life Cycle
Alternative 2b: Barrier Enhanced ISB System on Middle and West Parcels w/ EVO Substrate Additions; 15-Year Life Cycle
Alternative 3: Full Containment P&T System, 3 EWs @ 10 GPM Each, LGAC Only Treatment; 30-Year Life Cycle
Alternative 4: Full Containment P&T System, 3 EWs @ 10 GPM Each, Air Stripper and VGAC Treatment; 30-Year Life Cycle

AS/SVE = air sparge/soil vapor extraction
CM = construction management
CMU = cement masonry unit
EVO = emulsified vegetable oil
EW = extraction well
ISB = in situ bioremediation
H&S = health and safety
IDW = investigation-derived waste
LGAC = liquid-phase granular activated carbon
MWs = monitoring wells
NPV = net present value
O&M = operation and maintenance
P&T = pump-and-treat
VGAC = vapor-phase granular activated carbon

* Actual substrate injections for enhanced ISB would occur every 2 years. However, an average annual cost has been used.
** Net Present Value, 30 years O&M, 7% discount factor, plus capital cost rounded to $1,000.

Table 7-1
Cost Estimates for Reference, More Aggressive, and Less Aggressive Remedy Alternatives
West Osborn Complex WQARF Site, Phoenix, Arizona

Capital Items	Reference	More Aggressive	Less Aggressive
Drill/ Install Extraction Wells, Piezometers/ Monitoring Wells, Well Development, and IDW Management	$110,000	$405,103	$0
Conduct Aquifer (Pump) Tests Including Field Equipment and IDW Management	$40,000	$110,000	$0
Drill/ Install Injection Wells, Well Development, and IDW Management	$0	$285,000	$0
Furnish/ Install Wellhead Vaults & Instrumentation, Construct All Wellhead Connections	$40,000	$75,000	$0
Furnish/ Install Well Pumps and Flow Meters	$25,000	$55,000	$0
Furnish/ Install Flow Equalization Tanks, Bag Filters, Transfer Pumps, and/or LGAC Treatment Equipment	$65,000	$350,000	$0
Furnish/ Install all Conveyance Pipelines Between Extraction Wells, Treatment Equipment, and Discharge Locations	$40,000	$550,000	$0
Install New or Upgraded Electric Power Supplies, Power Distribution, and System Controls	$40,000	$150,000	$0
Install Treatment Plant Compounds (Slabs, Containment, U.G. Backwash Storage, CMU Block Enclosures, Canopies, Security Gates, etc.)	$70,000	$160,000	$0
Land Access for Treatment Compounds (Assumed)	$40,000	$60,000	$0
Subtotal Capital	$470,000	$2,200,103	$0
Engineering, Permitting, H&S, and CM (25% Reference, 20% More Aggressive)	$117,500	$440,021	$0
Total Capital	$587,500	$2,640,124	$0
O&M, MNA and REPORTING			
Annual Labor for O&M	$21,000	$46,920	$0
Annual Electric Power for Pumps and Plant Operation[1]	$3,500	$32,100	$0
Annual LGAC Usage	$4,000	$28,000	$0
Annual P&T System Performance and Discharge Sampling Analysis	$8,500	$12,000	$0
Annual Misc. Maintenance of Pipelines & Equipment	$2,500	$8,500	$0
Annual Maintenance of Injection Wells	$0	$3,500	$0
MNA and Reporting: Years 1 - 2 of SGWS Groundwater Monitoring and Reporting, Plus P&T System Performance Reporting (as applicable)[2]	$112,900	$165,000	$125,000
MNA and Reporting: Years 3 - 30 of SGWS Groundwater Monitoring and Reporting, Plus P&T System Performance Reporting (as applicable)[3]	$72,900	$120,000	$85,000
Total Annual O&M, MNA, and Reporting, Years 1 - 2	$152,400	$296,020	$125,000
Total Annual O&M, MNA, and Reporting, Years 3 - 30	$112,400	$251,020	$85,000
Supplemental Costs Specific to Replacing SGWS Monitoring Wells and/or Injection Wells [4]	$60,000	$155,000	$60,000
Total O&M, MNA, and Reporting (30 Years)	$3,512,000	$7,775,600	$2,690,000
Total Costs, Capital Plus 30 Years O&M, MNA, and Reporting	$4,099,500	$10,415,724	$2,690,000
Present Value, Capital, 30 Years O&M, MNA, and Reporting[5]	$2,078,000	$5,896,000	$1,150,000

Reference Remedy: 30 GPM P&T at WOC Facility w/LGAC only treatment and discharge to Grand Canal; Long-Term MNA for downgradient plume

More Aggressive Remedy: 30 GPM P&T at WOC Facility w/ LGAC only treatment and discharge to Grand Canal; 300 GPM P&T at Central Area w/LGAC only treatment; discharge of Central Area treated water to injection wells.

Less Aggressive Remedy: Long-Term MNA for entire WOC Site

[1]Assumes operation rates of 95% for P&T systems at WOC Facility and Central Area, as applicable.

[2]Assumes monthly gauging of water levels and quarterly groundwater sampling and reporting for all SGWS monitoring wells. Also includes quarterly P&T system(s) performance reporting.

[3]Assumes semi-annual gauging of water levels and groundwater sampling and reporting for all SGWS monitoring wells. Also includes semi-annual P&T system(s) performance reporting.

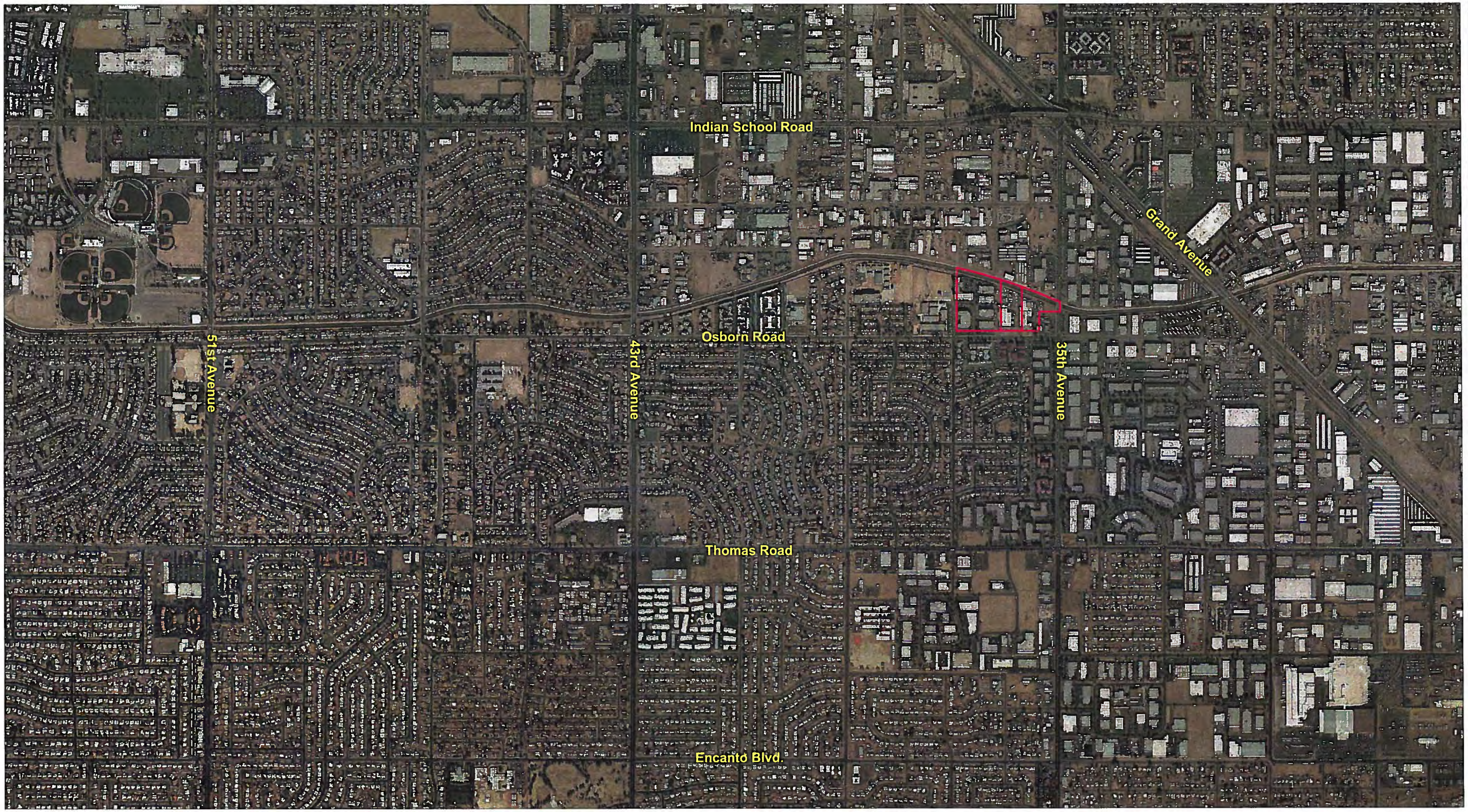
[4]Assumes two monitoring wells will need to be replaced in each of years 10 and 20. For the More Aggressive Remedy, also assumes one injection well will need to be replaced in years 10 and 20.

[5]Capital plus 30 years O&M, MNA, and reporting for P&T at WOC Facility. For the More Aggressive Remedy, also includes 30 years O&M and reporting for P&T system at Central Area. A 7% discount factor with rounding to 1000 is used in the present value calculations.

AS = air stripping
CM = construction management
LGAC = liquid granular activated carbon
H&S = health and safety
IDW = investigation-derived waste
MNA = monitored natural attenuation
O&M = operation and maintenance
P&T = pump and treat
SGWS = shallow groundwater system
U.G. = underground

FIGURES

P:\ACAD\dwg-library\2209.002 UIC\RI figs\FIG 1-1 Vicinity Map.dwg



Site Boundary

0 1000 2000
APPROXIMATE SCALE IN FEET

TITLE:	VICINITY MAP
LOCATION:	WEST OSBORN COMPLEX WQARF SITE PHOENIX, ARIZONA

GeoTrans, Inc. A TETRA TECH COMPANY

CHECKED	SB	FIGURE
DRAFTED	JLB	1-1
PROJECT	2209.002	
DATE	01/23/04	

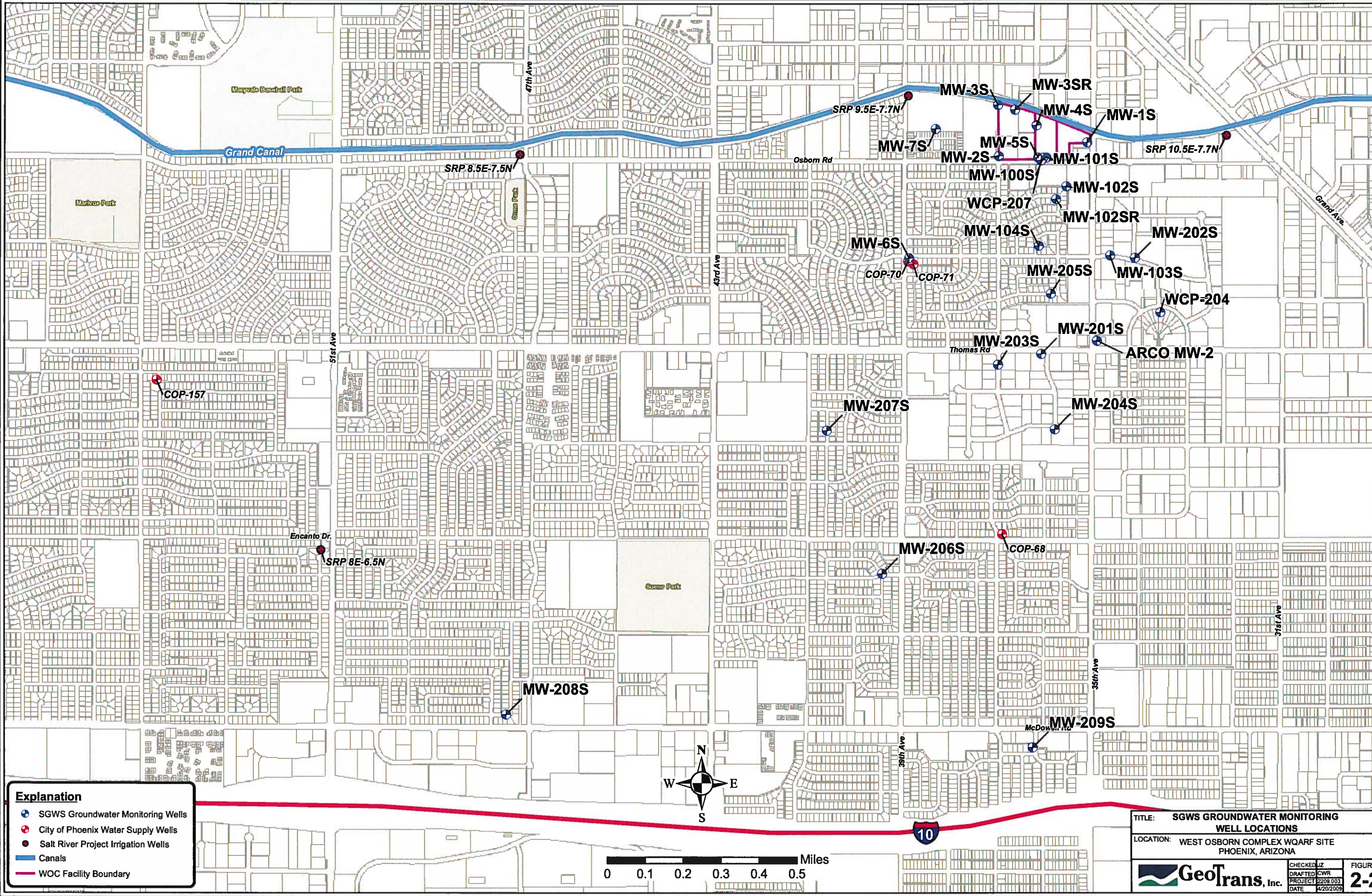
TITLE: **WEST OSBORN COMPLEX FACILITY MAP**

LOCATION: WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA

GeoTrans, Inc.

CHECKED	JZ
DRAFTED	CWR
PROJECT	2209.003
DATE	5/29/08

FIGURE **2-1**



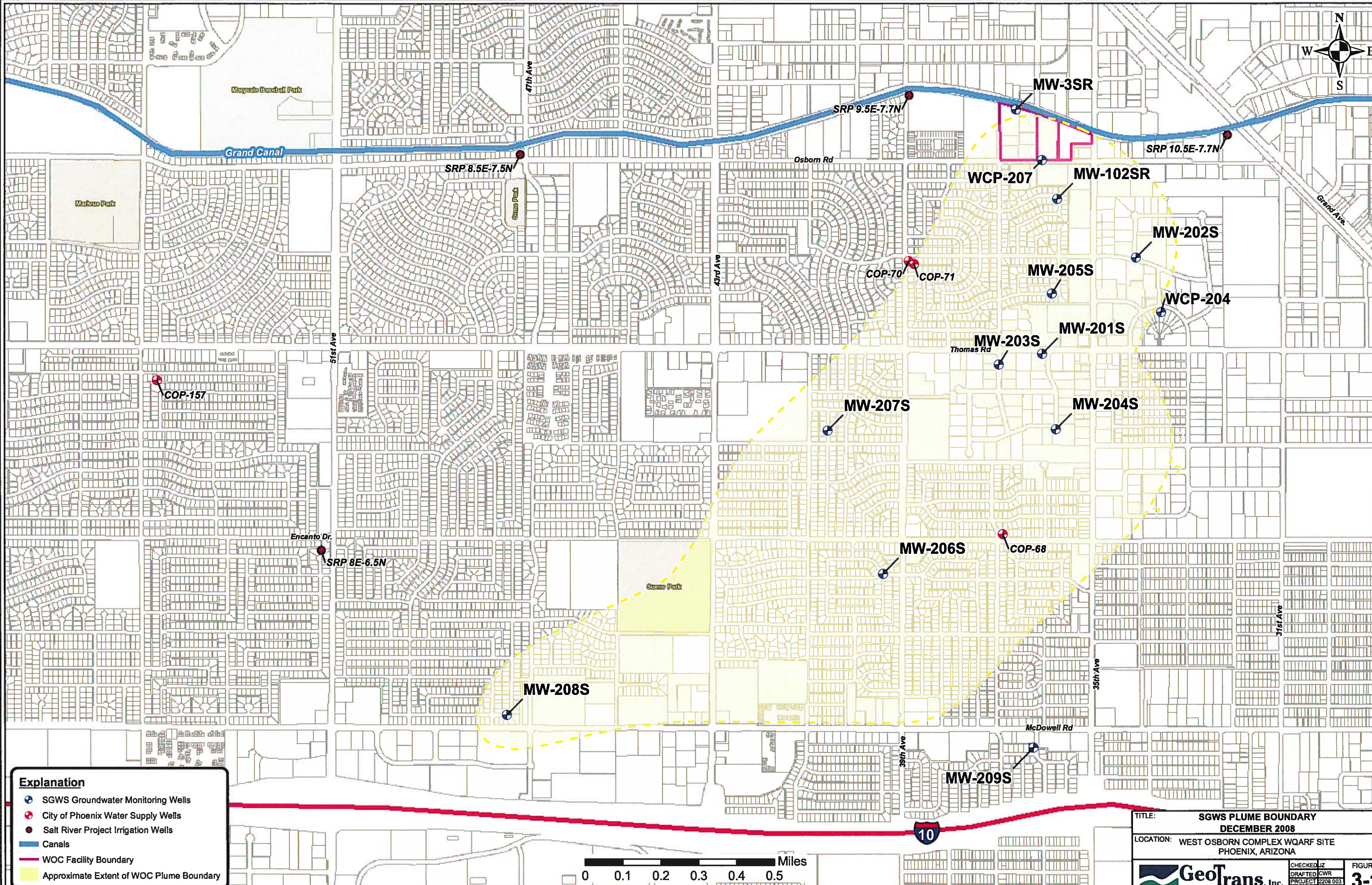
TITLE: SGWS GROUNDWATER MONITORING WELL LOCATIONS

LOCATION: WEST OSBORN COMPLEX WQARF SITE PHOENIX, ARIZONA

GeoTrans, Inc.

CHECKED	JZ
DRAFTED	CWR
PROJECT	2209.003
DATE	4/20/2009

FIGURE 2-2



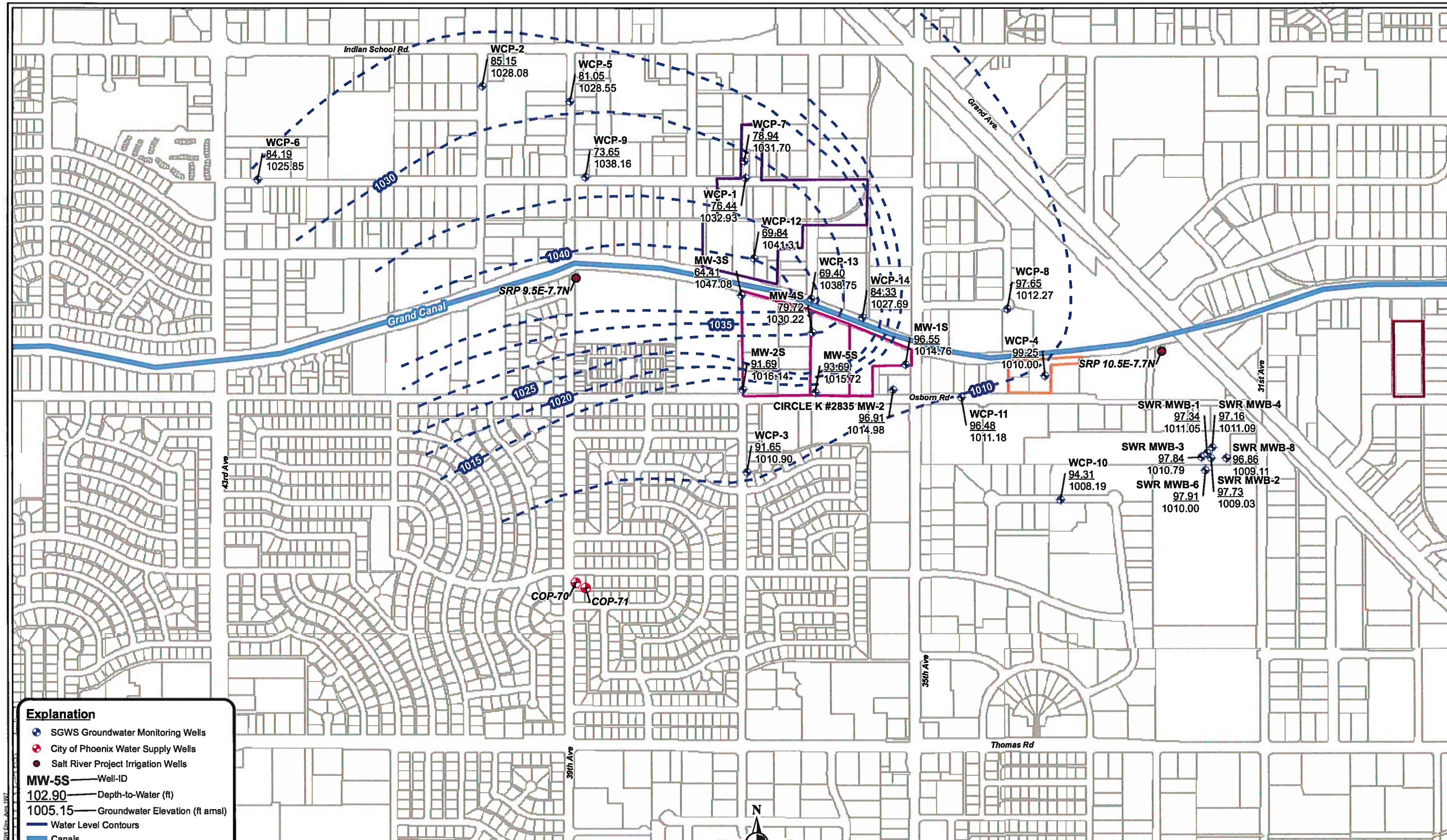
TITLE: SGWS PLUME BOUNDARY
DECEMBER 2008

LOCATION: WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA

GeoTrans, Inc.

CHECKED	JZ
DRAFTED	CWR
PROJECT	2209.003
DATE	4/20/2009

FIGURE 3-1

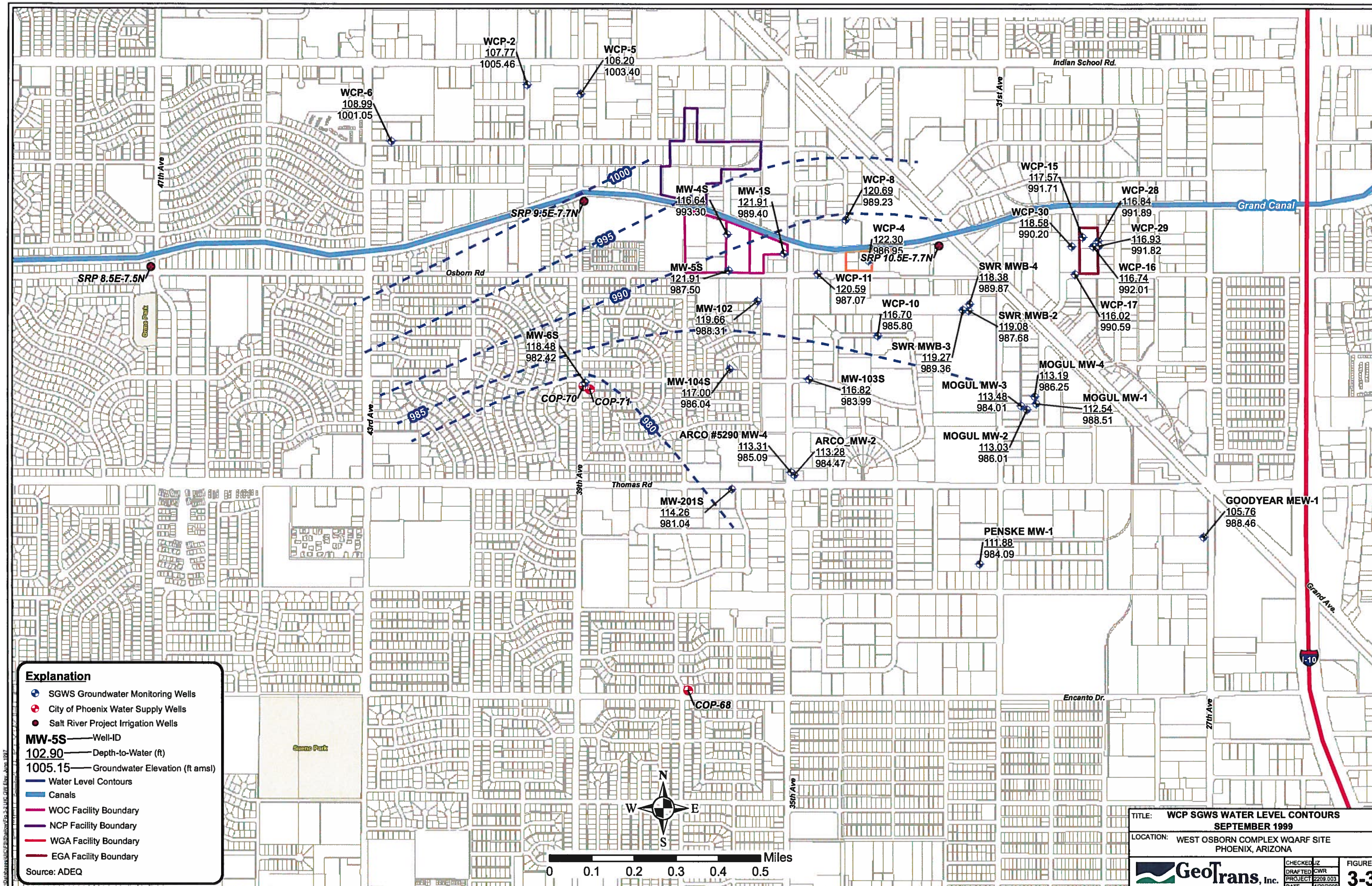


TITLE:	WCP SGWS WATER LEVEL CONTOURS FEBRUARY 1996
LOCATION:	WEST OSBORN COMPLEX WQARF SITE PHOENIX, ARIZONA

GeoTrans, Inc.

CHECKED	LZ
DRAFTED	CWR
PROJECT	2209.003
DATE	4/20/2009

FIGURE 3-2



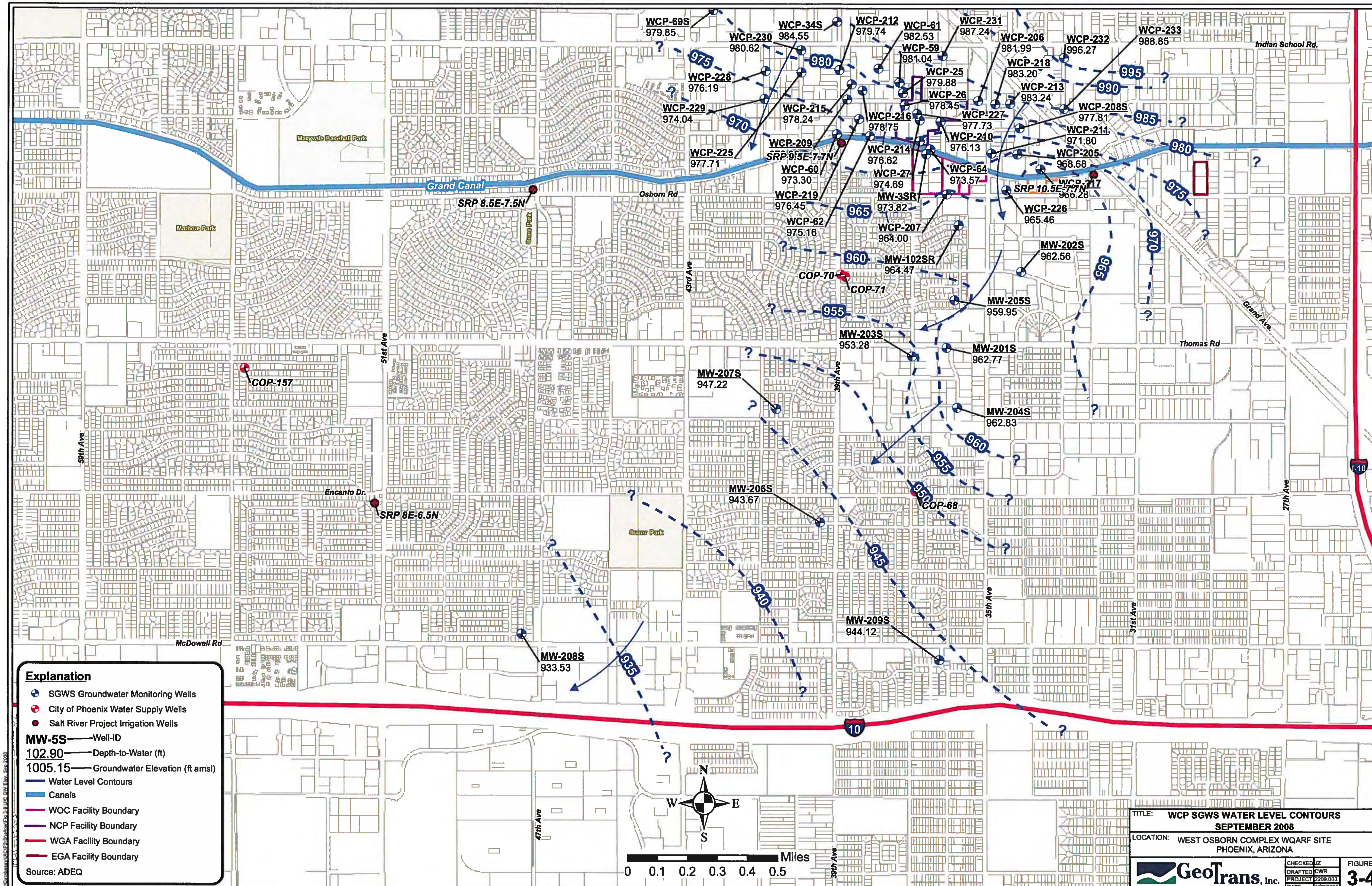
TITLE: WCP SGWS WATER LEVEL CONTOURS SEPTEMBER 1999

LOCATION: WEST OSBORN COMPLEX WQARF SITE PHOENIX, ARIZONA

GeoTrans, Inc.

CHECKED	JZ
DRAFTED	CWR
PROJECT	2209.003
DATE	4/20/2009

FIGURE 3-3

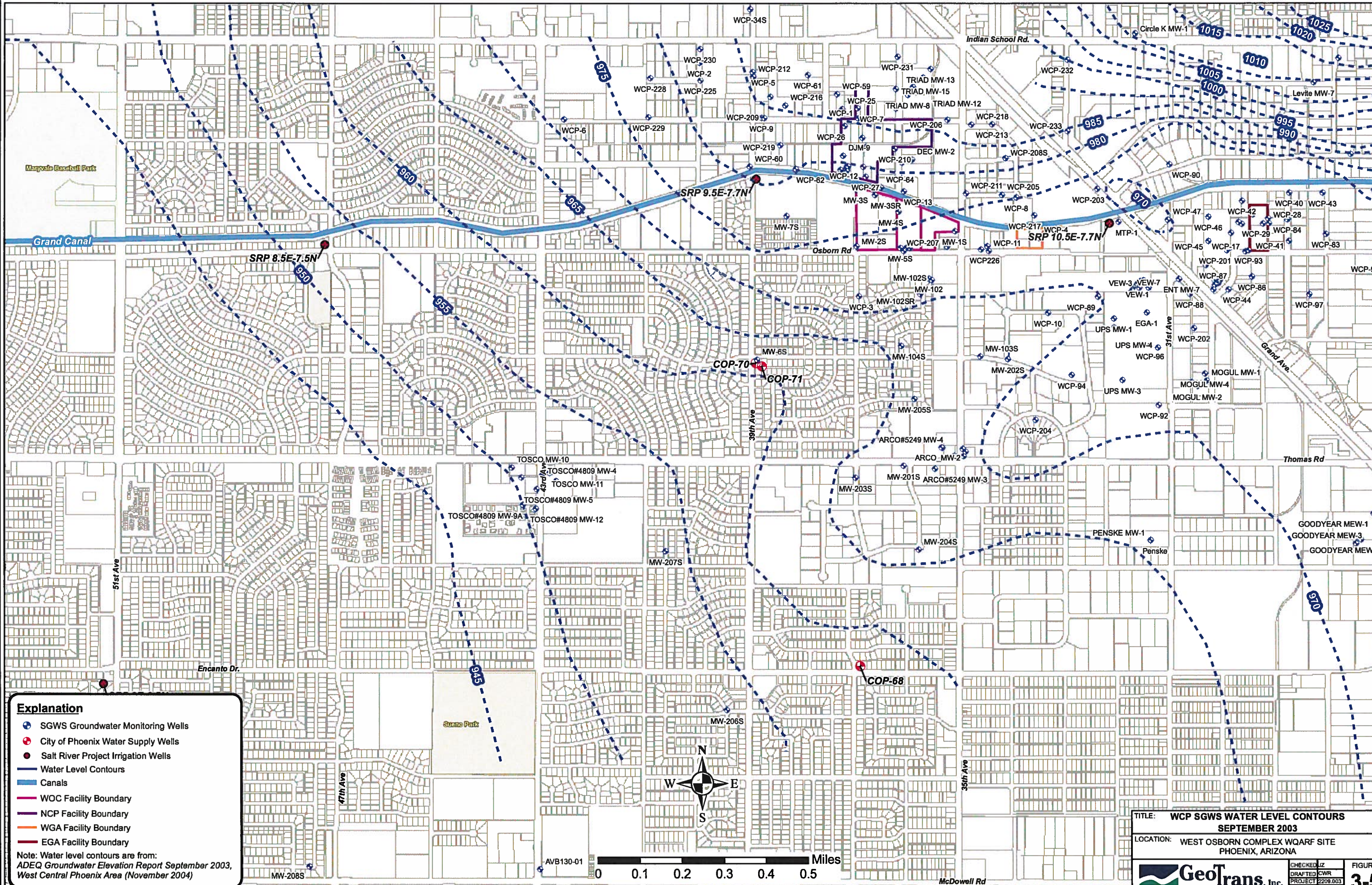


TITLE:	WCP SGWS WATER LEVEL CONTOURS SEPTEMBER 2008
LOCATION:	WEST OSBORN COMPLEX WQARF SITE PHOENIX, ARIZONA

GeoTrans, Inc.

CHECKED	JZ
DRAFTED	CWR
PROJECT	2209.003
DATE	4/20/2009

FIGURE 3-4



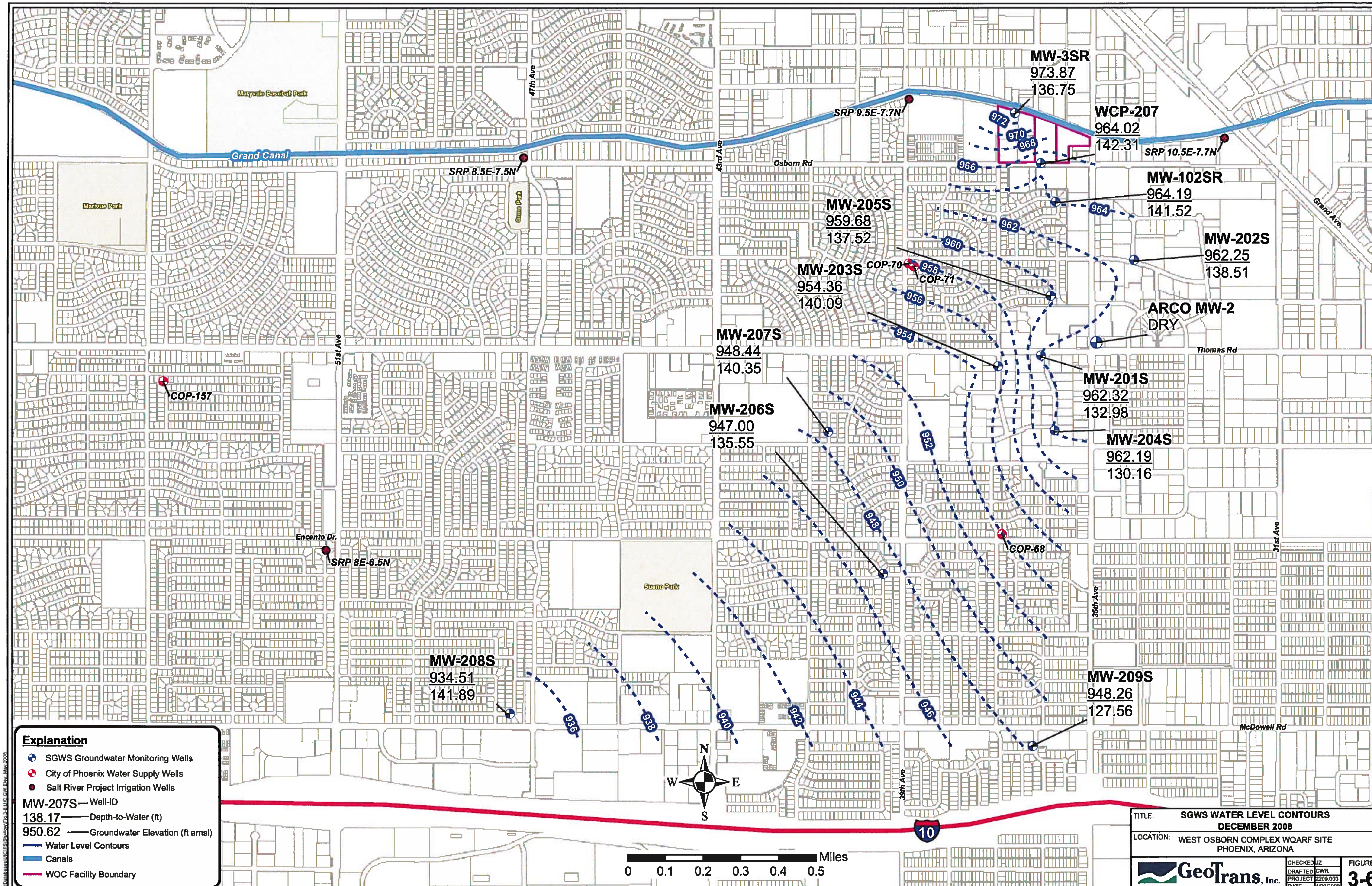
TITLE: WCP SGWS WATER LEVEL CONTOURS SEPTEMBER 2003

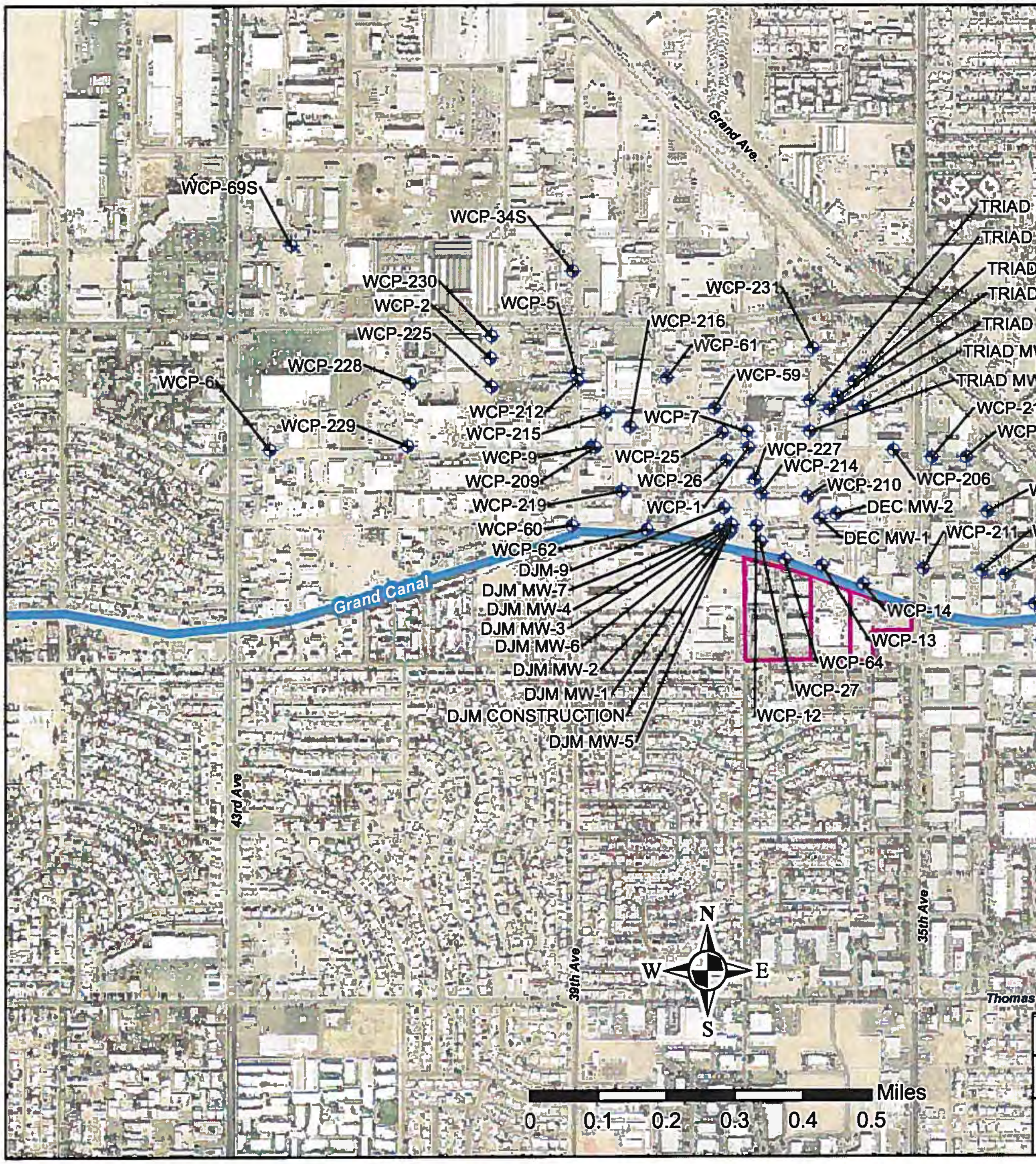
LOCATION: WEST OSBORN COMPLEX WQARF SITE PHOENIX, ARIZONA

GeoTrans, Inc.

CHECKED	LIZ
DRAFTED	CWR
PROJECT	2209.003
DATE	5/18/2009

FIGURE 3-5


MW-3SR
973.87
136.75
WCP-207
964.02
142.31
MW-102SR
964.19
141.52
MW-205S
959.68
137.52
MW-202S
962.25
138.51
MW-203S
954.36
140.09
ARCO MW-2
DRY
MW-207S
948.44
140.35
MW-201S
962.32
132.98
MW-206S
947.00
135.55
MW-204S
962.19
130.16
MW-208S
934.51
141.89
MW-209S
948.26
127.56
SRP 9.5E-7.7N
SRP 8.5E-7.5N
SRP 10.5E-7.7N
SRP 8E-6.5N
COP-70
COP-71
COP-157
COP-68
Grand Canal
Osborn Rd
Thomas Rd
McDowell Rd
Encanto Dr.
Grand Ave.
47th Ave
43rd Ave
51st Ave
39th Ave
35th Ave
31st Ave
Maryvale Baseball Park
Marivue Park
Sueno Park
10
Explanation
SGWS Groundwater Monitoring Wells
City of Phoenix Water Supply Wells
Salt River Project Irrigation Wells
MW-207S—Well-ID
138.17—Depth-to-Water (ft)
950.62—Groundwater Elevation (ft amsl)
Water Level Contours
Canals
WOC Facility Boundary
0 0.1 0.2 0.3 0.4 0.5 Miles
N
S
E
W
TITLE: SGWS WATER LEVEL CONTOURS
DECEMBER 2008
LOCATION: WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA
GeoTrans, Inc.
CHECKED JZ
DRAFTED CWR
PROJECT 2209.003
DATE 4/20/2009
FIGURE
3-6

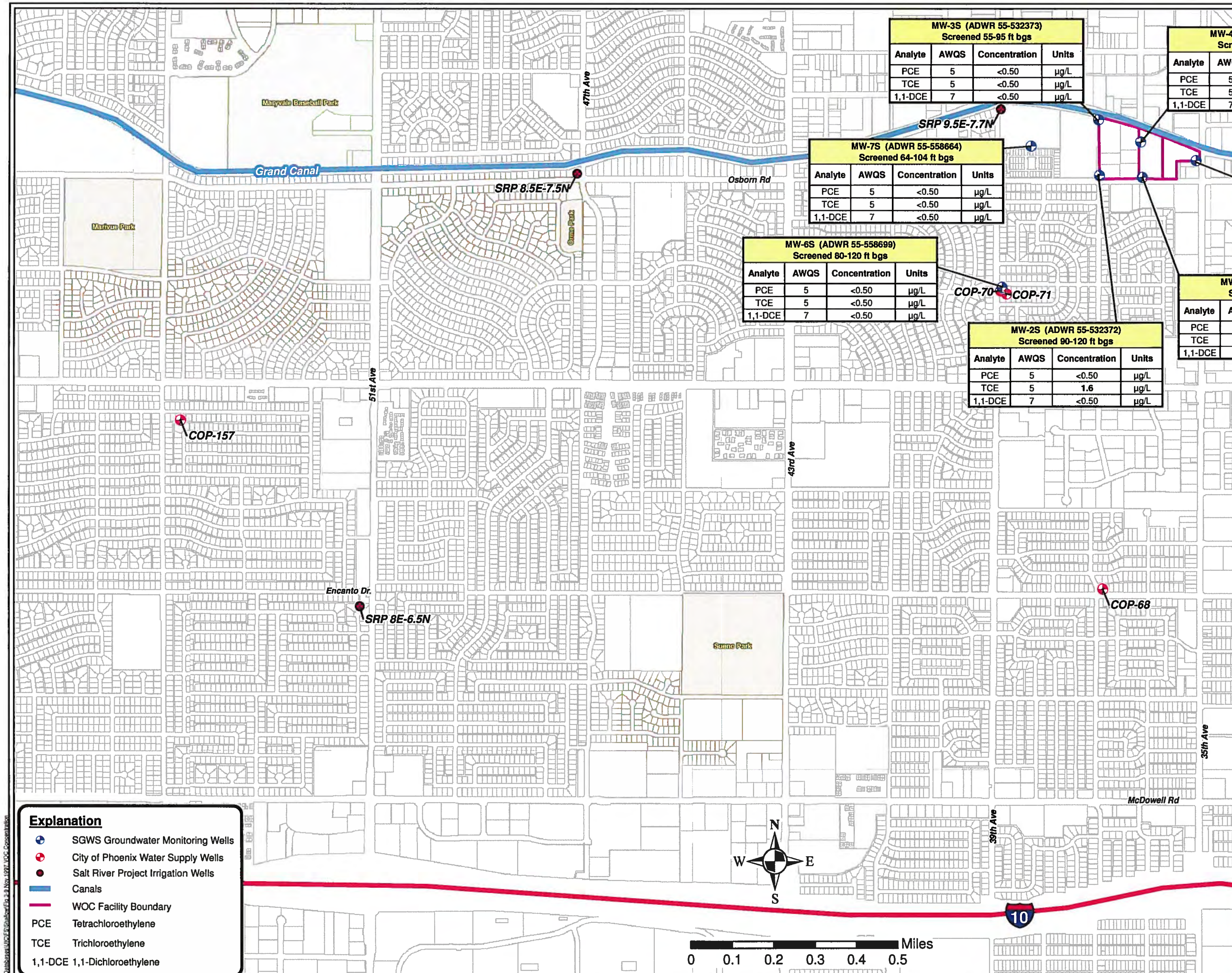


TITLE: **NORTH CANAL PLUME WELL LOCATIONS**

LOCATION: WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA

GeoTrans, Inc.

CHECKED	JZ	FIGURE
DRAFTED	CWR	3-7
PROJECT	2209.003	
DATE	5/13/2009	



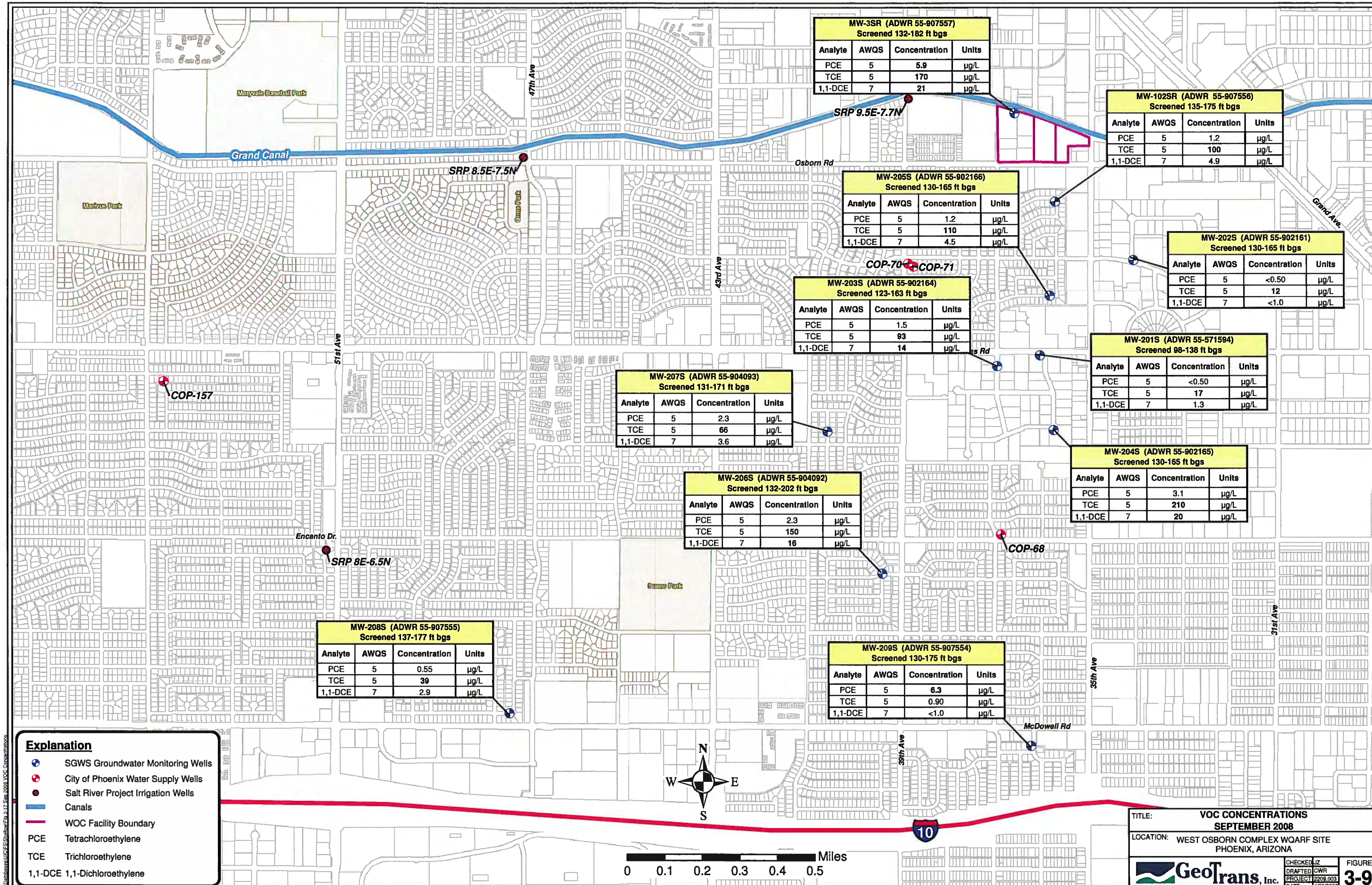
TITLE: VOC CONCENTRATIONS NOVEMBER 1996

LOCATION: WEST OSBORN COMPLEX WQARF SITE PHOENIX, ARIZONA

GeoTrans, Inc.

CHECKED	JZ
DRAFTED	CWR
PROJECT	2209.003
DATE	4/21/2009

FIGURE 3-8



MW-3SR (ADWR 55-907557) Screened 132-182 ft bgs

Analyte	AWQS	Concentration	Units
PCE	5	**5.9**	µg/L
TCE	5	**170**	µg/L
1,1-DCE	7	**21**	µg/L

MW-102SR (ADWR 55-907556) Screened 135-175 ft bgs

Analyte	AWQS	Concentration	Units
PCE	5	1.2	µg/L
TCE	5	**100**	µg/L
1,1-DCE	7	4.9	µg/L

MW-205S (ADWR 55-902166) Screened 130-165 ft bgs

Analyte	AWQS	Concentration	Units
PCE	5	1.2	µg/L
TCE	5	**110**	µg/L
1,1-DCE	7	4.5	µg/L

MW-202S (ADWR 55-902161) Screened 130-165 ft bgs

Analyte	AWQS	Concentration	Units
PCE	5	<0.50	µg/L
TCE	5	**12**	µg/L
1,1-DCE	7	<1.0	µg/L

MW-203S (ADWR 55-902164) Screened 123-163 ft bgs

Analyte	AWQS	Concentration	Units
PCE	5	1.5	µg/L
TCE	5	**93**	µg/L
1,1-DCE	7	**14**	µg/L

MW-201S (ADWR 55-571594) Screened 98-138 ft bgs

Analyte	AWQS	Concentration	Units
PCE	5	<0.50	µg/L
TCE	5	**17**	µg/L
1,1-DCE	7	1.3	µg/L

MW-207S (ADWR 55-904093) Screened 131-171 ft bgs

Analyte	AWQS	Concentration	Units
PCE	5	2.3	µg/L
TCE	5	**66**	µg/L
1,1-DCE	7	3.6	µg/L

MW-204S (ADWR 55-902165) Screened 130-165 ft bgs

Analyte	AWQS	Concentration	Units
PCE	5	3.1	µg/L
TCE	5	**210**	µg/L
1,1-DCE	7	**20**	µg/L

MW-206S (ADWR 55-904092) Screened 132-202 ft bgs

Analyte	AWQS	Concentration	Units
PCE	5	2.3	µg/L
TCE	5	**150**	µg/L
1,1-DCE	7	**16**	µg/L

MW-208S (ADWR 55-907555) Screened 137-177 ft bgs

Analyte	AWQS	Concentration	Units
PCE	5	0.55	µg/L
TCE	5	**39**	µg/L
1,1-DCE	7	2.9	µg/L

MW-209S (ADWR 55-907554) Screened 130-175 ft bgs

Analyte	AWQS	Concentration	Units
PCE	5	**6.3**	µg/L
TCE	5	0.90	µg/L
1,1-DCE	7	<1.0	µg/L

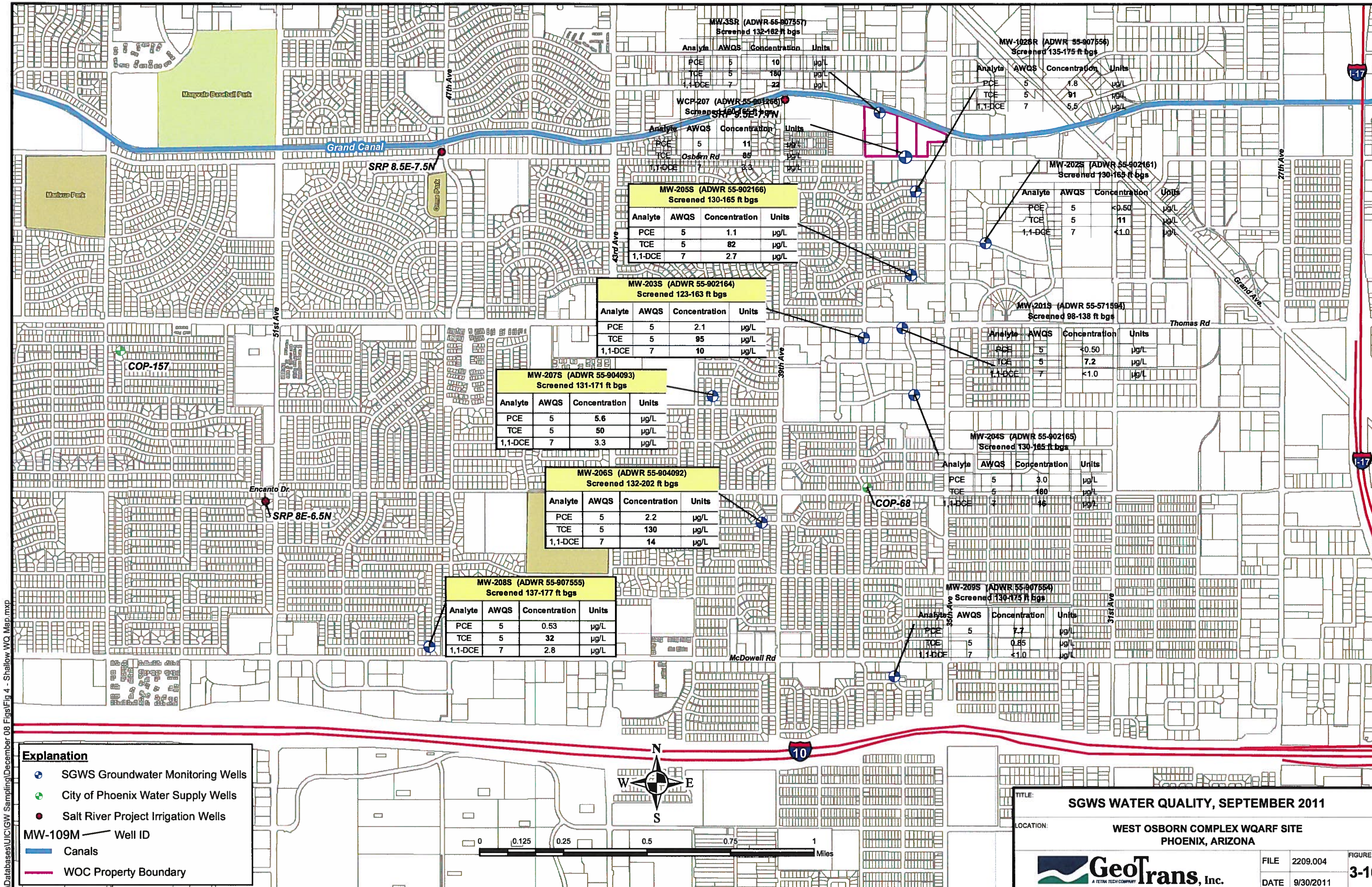
TITLE: VOC CONCENTRATIONS SEPTEMBER 2008

LOCATION: WEST OSBORN COMPLEX WQARF SITE PHOENIX, ARIZONA

GeoTrans, Inc.

CHECKED	JZ
DRAFTED	CWR
PROJECT	2209.003
DATE	4/20/2009

FIGURE 3-9



P:\Databases\UIC\GW Sampling\December 08 Figs\Fig 4 - Shallow WQ Map.mxp

TITLE: **SGWS WATER QUALITY, SEPTEMBER 2011**

LOCATION: **WEST OSBORN COMPLEX WQARF SITE**
PHOENIX, ARIZONA

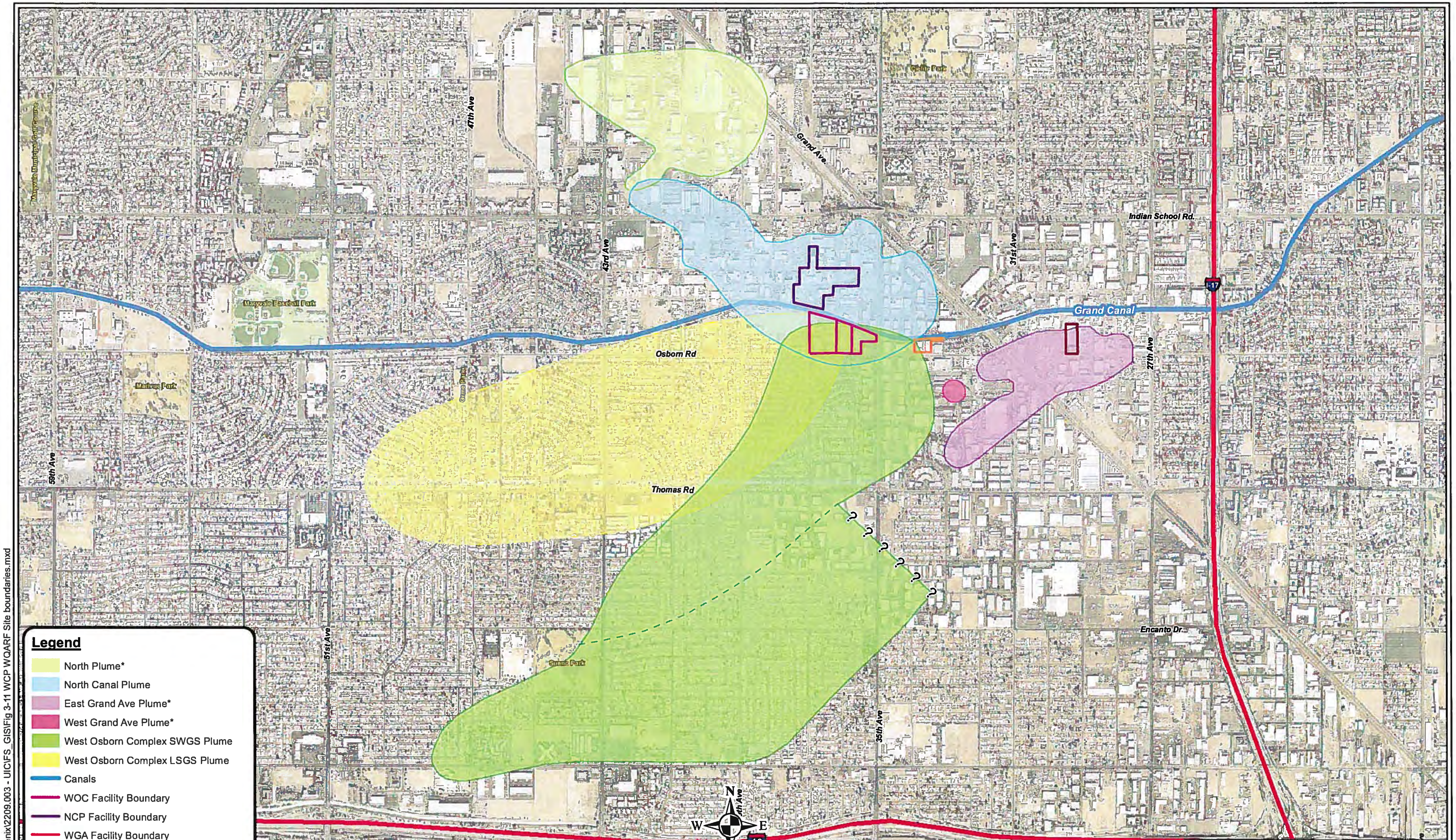
GeoTrans, Inc. A TETRA TECH COMPANY

FILE 2209.004

DATE 9/30/2011

FIGURE: 3-10

T:\GeoTrans Phoenix\2209.003 - UIC\FS_GIS\Fig 3-11 WCP WQARF Site boundaries.mxd



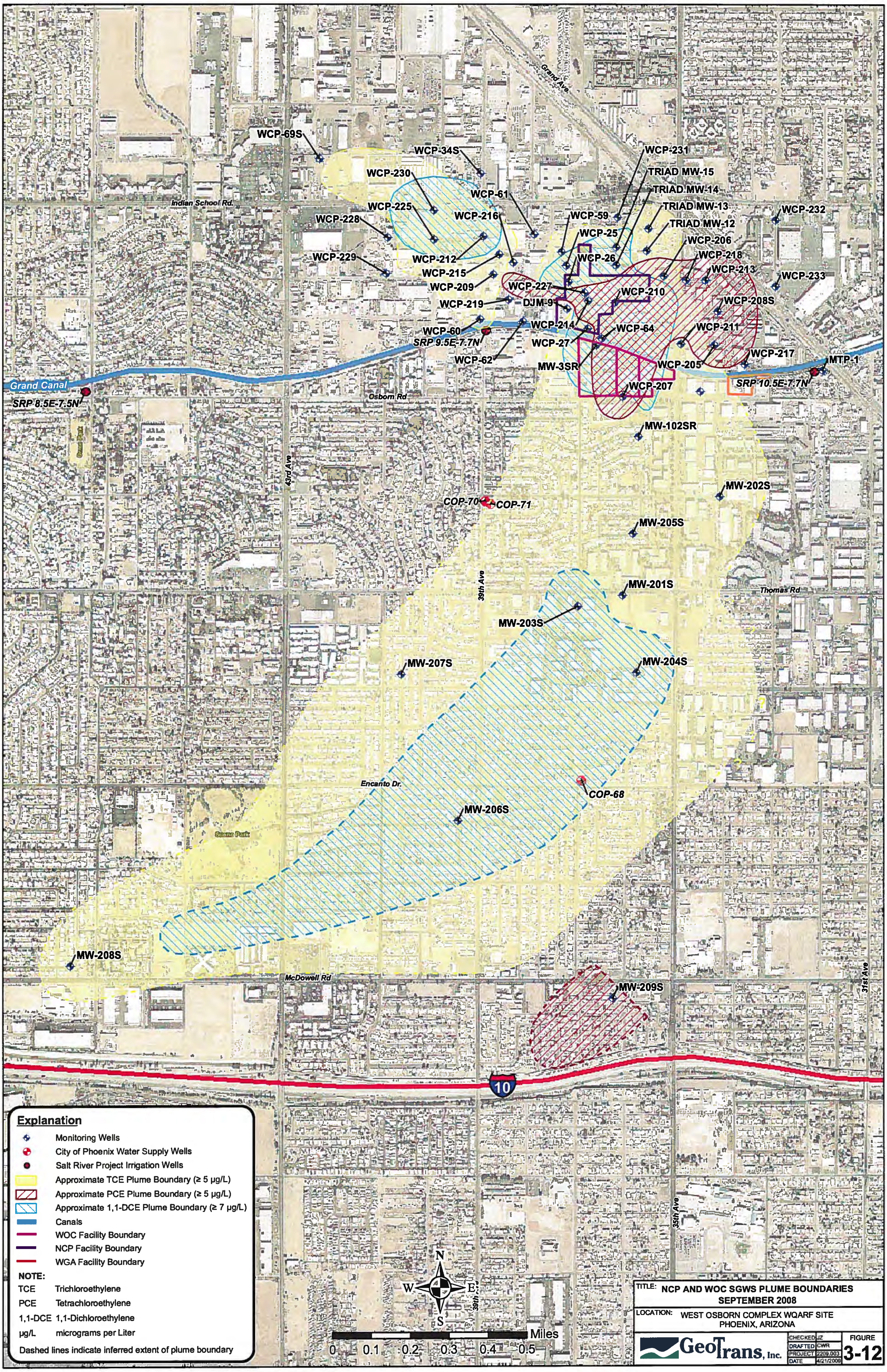
TITLE: WEST CENTRAL PHOENIX WQARF SITE BOUNDARIES

LOCATION: WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA

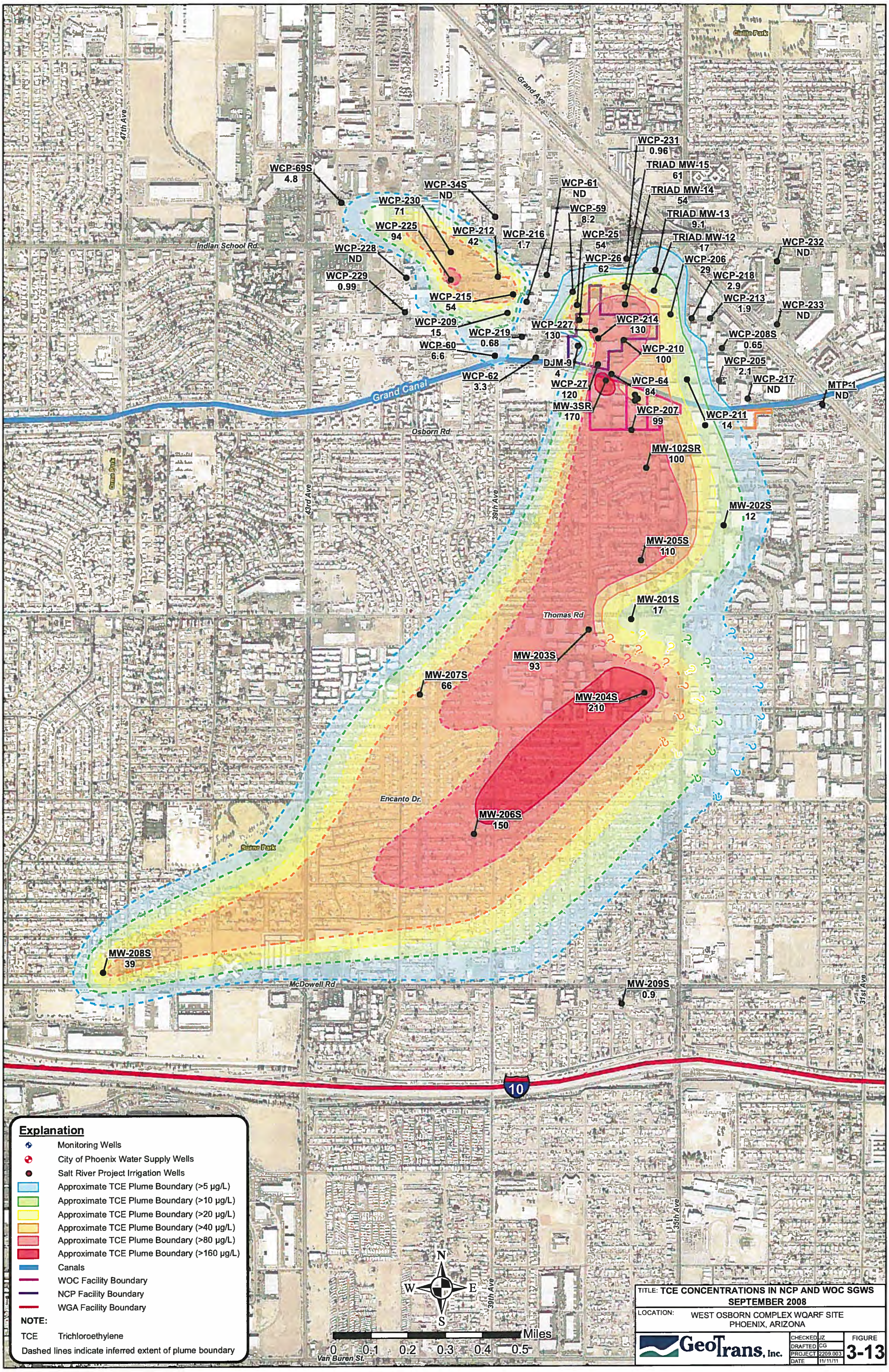
GeoTrans, Inc.

CHECKED	JZ
DRAFTED	LAD
PROJECT	2209.004
DATE	11/11/11

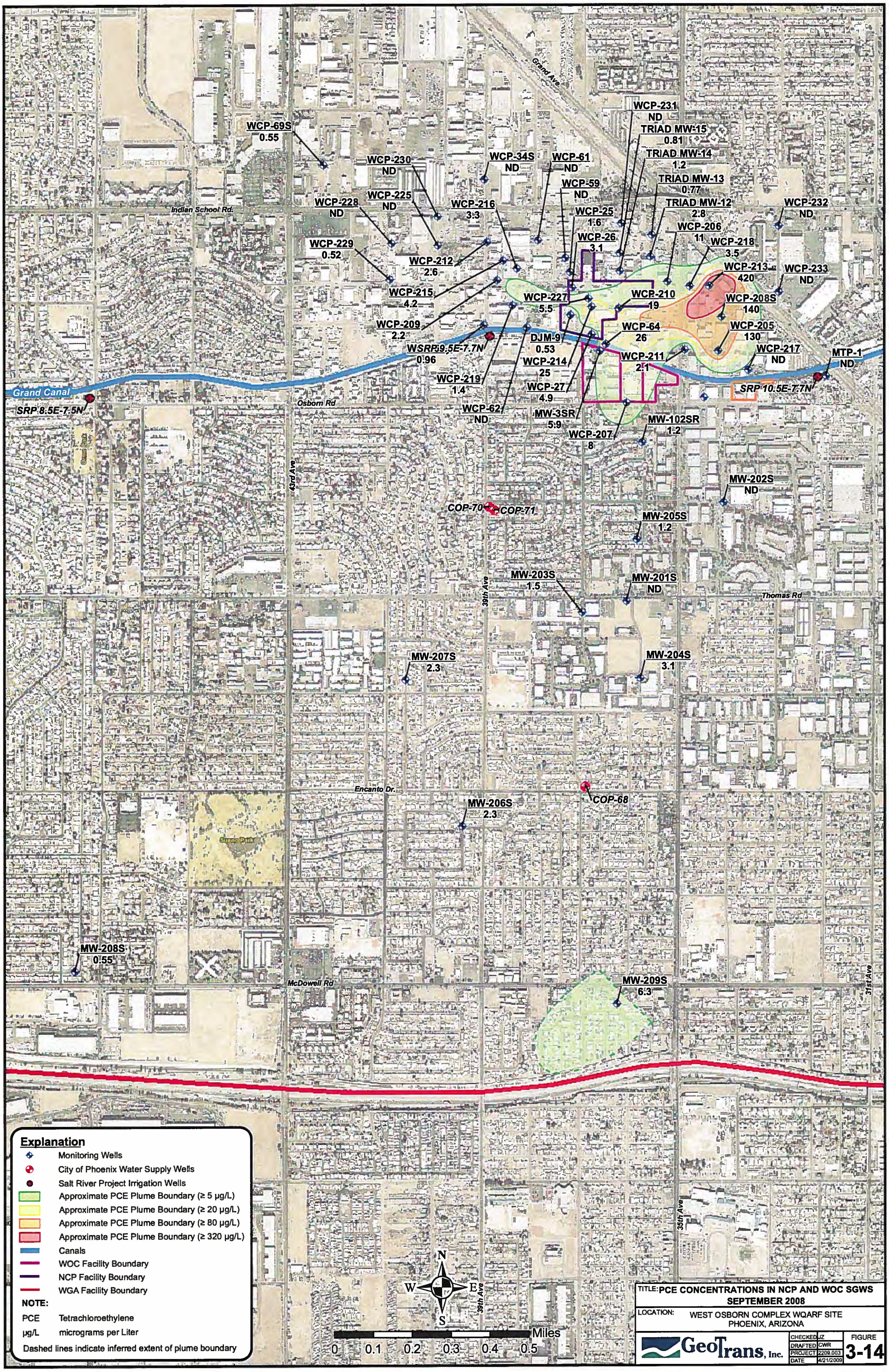
FIGURE 3-11



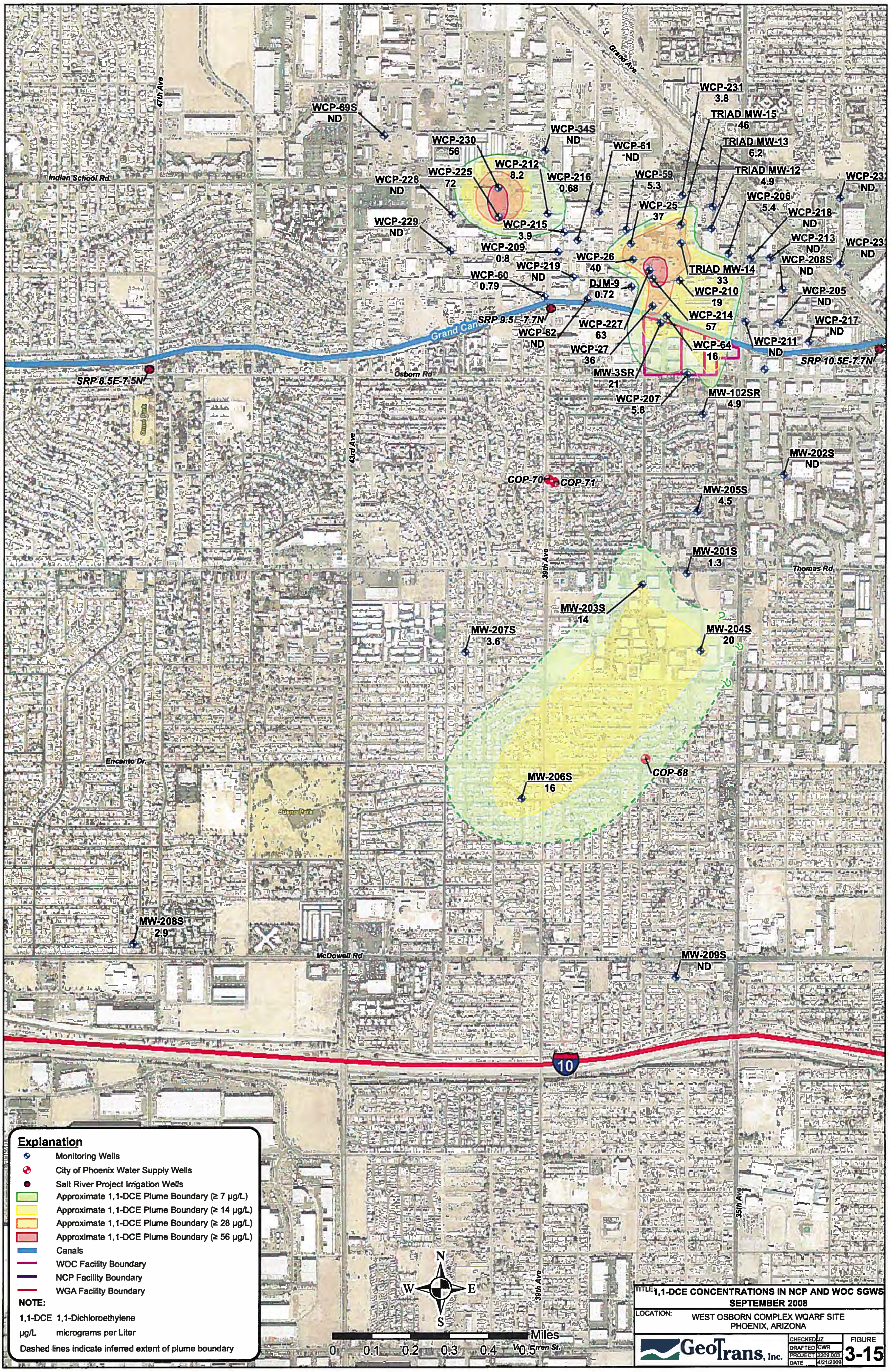
Grand Ave
WCP-69S
WCP-34S
WCP-230
WCP-231
TRIAD MW-15
TRIAD MW-14
TRIAD MW-13
TRIAD MW-12
Indian School Rd.
WCP-225
WCP-61
WCP-228
WCP-216
WCP-59
WCP-25
WCP-232
WCP-206
WCP-229
WCP-212
WCP-26
WCP-218
WCP-215
WCP-213
WCP-209
WCP-227
WCP-233
WCP-210
WCP-219
DJM-9
WCP-208S
WCP-214
WCP-64
WCP-211
WCP-60
SRP 9.5E-7.7N
WCP-27
WCP-62
MW-3SR
WCP-205
WCP-217
MTP-1
Grand Canal
SRP 8.5E-7.5N
Osborn Rd
WCP-207
SRP 10.5E-7.7N
MW-102SR
43rd Ave
COP-70
COP-71
MW-202S
MW-205S
MW-201S
Thomas Rd
39th Ave
MW-203S
MW-207S
MW-204S
Encanto Dr.
COP-68
MW-206S
MW-208S
McDowell Rd
MW-209S
31st Ave
10
35th Ave
Explanation
Monitoring Wells
City of Phoenix Water Supply Wells
Salt River Project Irrigation Wells
Approximate TCE Plume Boundary (≥ 5 µg/L)
Approximate PCE Plume Boundary (≥ 5 µg/L)
Approximate 1,1-DCE Plume Boundary (≥ 7 µg/L)
Canals
WOC Facility Boundary
NCP Facility Boundary
WGA Facility Boundary
NOTE:
TCE Trichloroethylene
PCE Tetrachloroethylene
1,1-DCE 1,1-Dichloroethylene
µg/L micrograms per Liter
Dashed lines indicate inferred extent of plume boundary
N
W
E
S
0 0.1 0.2 0.3 0.4 0.5 Miles
TITLE: NCP AND WOC SGWS PLUME BOUNDARIES
SEPTEMBER 2008
LOCATION: WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA
GeoTrans, Inc.
CHECKED JZ
DRAFTED CWR
PROJECT 2309.003
DATE 4/21/2009
FIGURE
3-12



Grand Ave
Indian School Rd.
Grand Canal
Osborn Rd
Thomas Rd
Encanto Dr.
McDowell Rd
Van Buren St
47th Ave
43rd Ave
39th Ave
35th Ave
31st Ave
10
WCP-69S
4.8
WCP-34S
ND
WCP-230
71
WCP-225
94
WCP-212
42
WCP-228
ND
WCP-229
0.99
WCP-215
54
WCP-209
15
WCP-219
0.68
WCP-60
6.6
WCP-62
3.3
WCP-216
1.7
WCP-61
ND
WCP-59
8.2
WCP-25
54
WCP-26
62
WCP-231
0.96
TRIAD MW-15
61
TRIAD MW-14
54
TRIAD MW-13
9.1
TRIAD MW-12
17
WCP-206
29
WCP-218
2.9
WCP-213
1.9
WCP-232
ND
WCP-233
ND
WCP-208S
0.65
WCP-205
2.1
WCP-217
ND
MTP-1
ND
WCP-227
130
WCP-214
130
WCP-210
100
DJM-9
4
WCP-27
120
WCP-64
84
MW-3SR
170
WCP-207
99
WCP-211
14
MW-102SR
100
MW-202S
12
MW-205S
110
MW-201S
17
MW-203S
93
MW-207S
66
MW-204S
210
MW-206S
150
MW-208S
39
MW-209S
0.9
Explanation
Monitoring Wells
City of Phoenix Water Supply Wells
Salt River Project Irrigation Wells
Approximate TCE Plume Boundary (>5 µg/L)
Approximate TCE Plume Boundary (>10 µg/L)
Approximate TCE Plume Boundary (>20 µg/L)
Approximate TCE Plume Boundary (>40 µg/L)
Approximate TCE Plume Boundary (>80 µg/L)
Approximate TCE Plume Boundary (>160 µg/L)
Canals
WOC Facility Boundary
NCP Facility Boundary
WGA Facility Boundary
NOTE:
TCE Trichloroethylene
Dashed lines indicate inferred extent of plume boundary
N
S
E
W
0 0.1 0.2 0.3 0.4 0.5 Miles
TITLE: TCE CONCENTRATIONS IN NCP AND WOC SGWS
SEPTEMBER 2008
LOCATION: WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA
GeoTrans, Inc.
CHECKED JZ
DRAFTED CG
PROJECT 2209.003
DATE 11/11/11
FIGURE
3-13



WCP-69S
0.55
WCP-230
ND
WCP-34S
ND
WCP-61
ND
WCP-231
ND
TRIAD MW-15
0.81
TRIAD MW-14
1.2
TRIAD MW-13
0.77
TRIAD MW-12
2.8
WCP-59
ND
WCP-228
ND
WCP-225
ND
WCP-216
3.3
WCP-25
1.6
WCP-232
ND
WCP-229
0.52
WCP-26
3.1
WCP-206
11
WCP-218
3.5
WCP-212
2.6
WCP-213
420
WCP-233
ND
WCP-215
4.2
WCP-227
5.5
WCP-210
19
WCP-208S
140
WCP-209
2.2
DJM-9
0.53
WCP-64
26
WCP-205
130
WSRP 9.5E-7.7N
0.96
WCP-214
25
WCP-211
2.1
WCP-217
ND
MTP-1
ND
WCP-219
1.4
WCP-27
4.9
SRP 10.5E-7.7N
Grand Canal
SRP 8.5E-7.5N
WCP-62
ND
MW-3SR
5.9
MW-102SR
1.2
WCP-207
8
Indian School Rd.
Grand Ave
Osborn Rd
43rd Ave
MW-202S
ND
COP-70
COP-71
MW-205S
1.2
MW-203S
1.5
MW-201S
ND
Thomas Rd
39th Ave
MW-207S
2.3
MW-204S
3.1
Encanto Dr.
COP-68
MW-206S
2.3
MW-208S
0.55
McDowell Rd
MW-209S
6.3
31st Ave
35th Ave
Explanation
Monitoring Wells
City of Phoenix Water Supply Wells
Salt River Project Irrigation Wells
Approximate PCE Plume Boundary (≥ 5 µg/L)
Approximate PCE Plume Boundary (≥ 20 µg/L)
Approximate PCE Plume Boundary (≥ 80 µg/L)
Approximate PCE Plume Boundary (≥ 320 µg/L)
Canals
WOC Facility Boundary
NCP Facility Boundary
WGA Facility Boundary
NOTE:
PCE Tetrachloroethylene
µg/L micrograms per Liter
Dashed lines indicate inferred extent of plume boundary
N
W
E
S
0 0.1 0.2 0.3 0.4 0.5 Miles
TITLE: PCE CONCENTRATIONS IN NCP AND WOC SGWS
SEPTEMBER 2008
LOCATION: WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA
GeoTrans, Inc.
CHECKED JZ
DRAFTED CWR
PROJECT 2209.003
DATE 4/21/2009
FIGURE
3-14

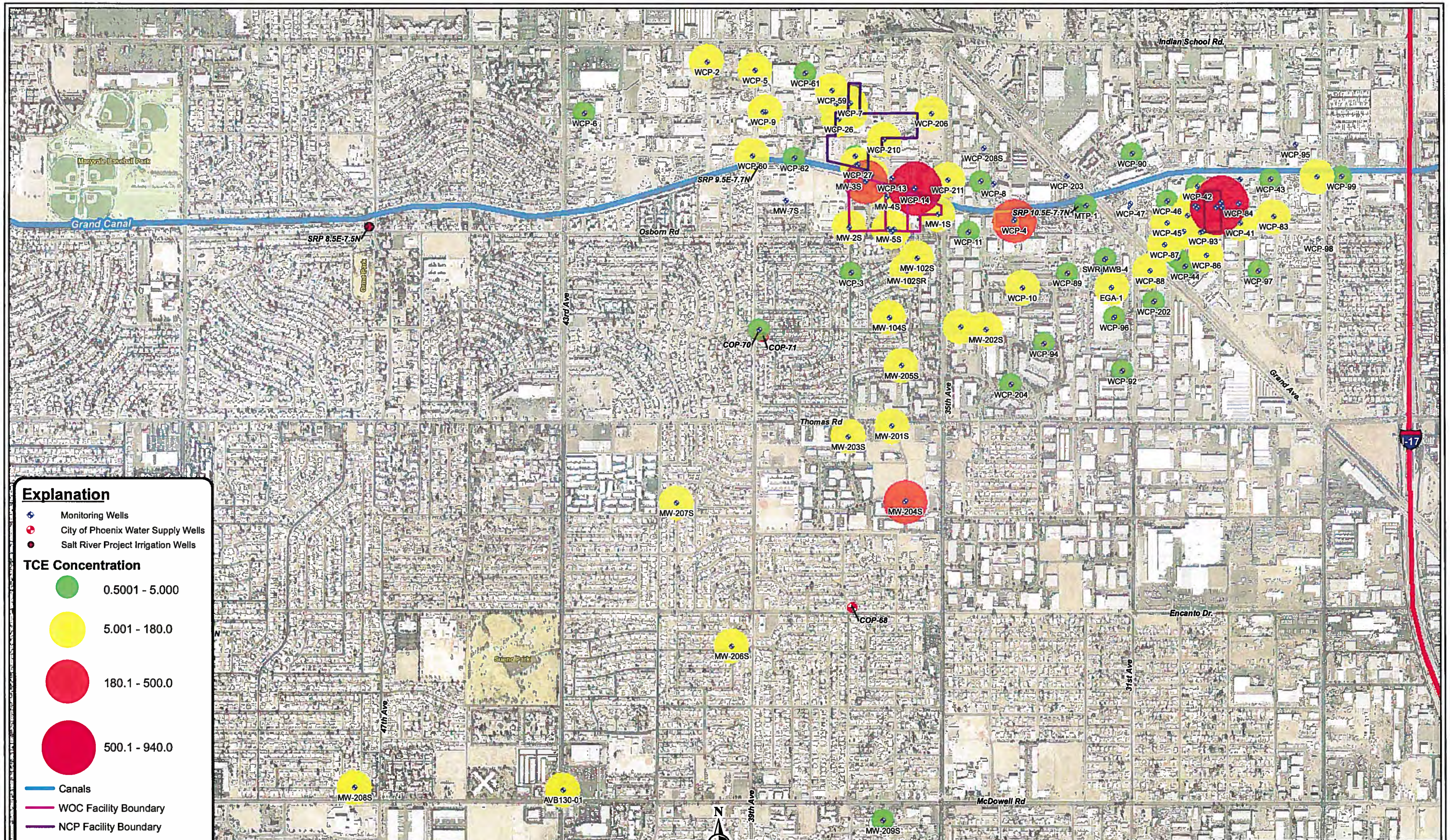


TITLE: 1,1-DCE CONCENTRATIONS IN NCP AND WOC SGWS SEPTEMBER 2008

LOCATION: WEST OSBORN COMPLEX WQARF SITE PHOENIX, ARIZONA

GeoTrans, Inc.

CHECKED	JZ	FIGURE
DRAFTED	CWR	3-15
PROJECT	2209.003	
DATE	4/21/2009	



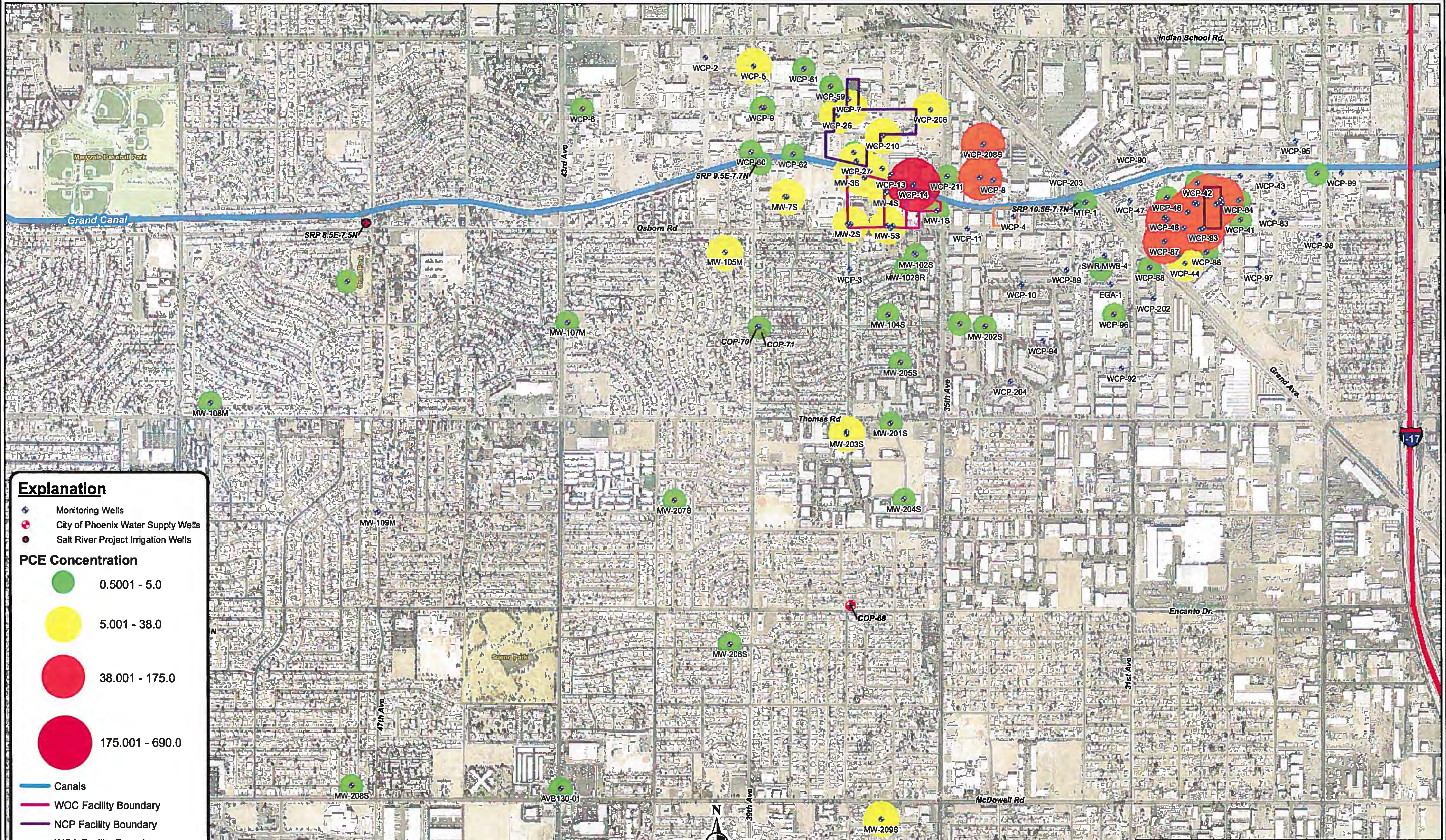
TITLE: **MAXIMUM RECORDED TCE CONCENTRATIONS IN WCP MONITORING WELLS, FROM MAY 1991 TO SEPTEMBER 2008**

LOCATION: WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA

GeoTrans, Inc.

CHECKED	JZ
DRAFTED	CWR
PROJECT	2209.003
DATE	4/21/2009

FIGURE **3-16**



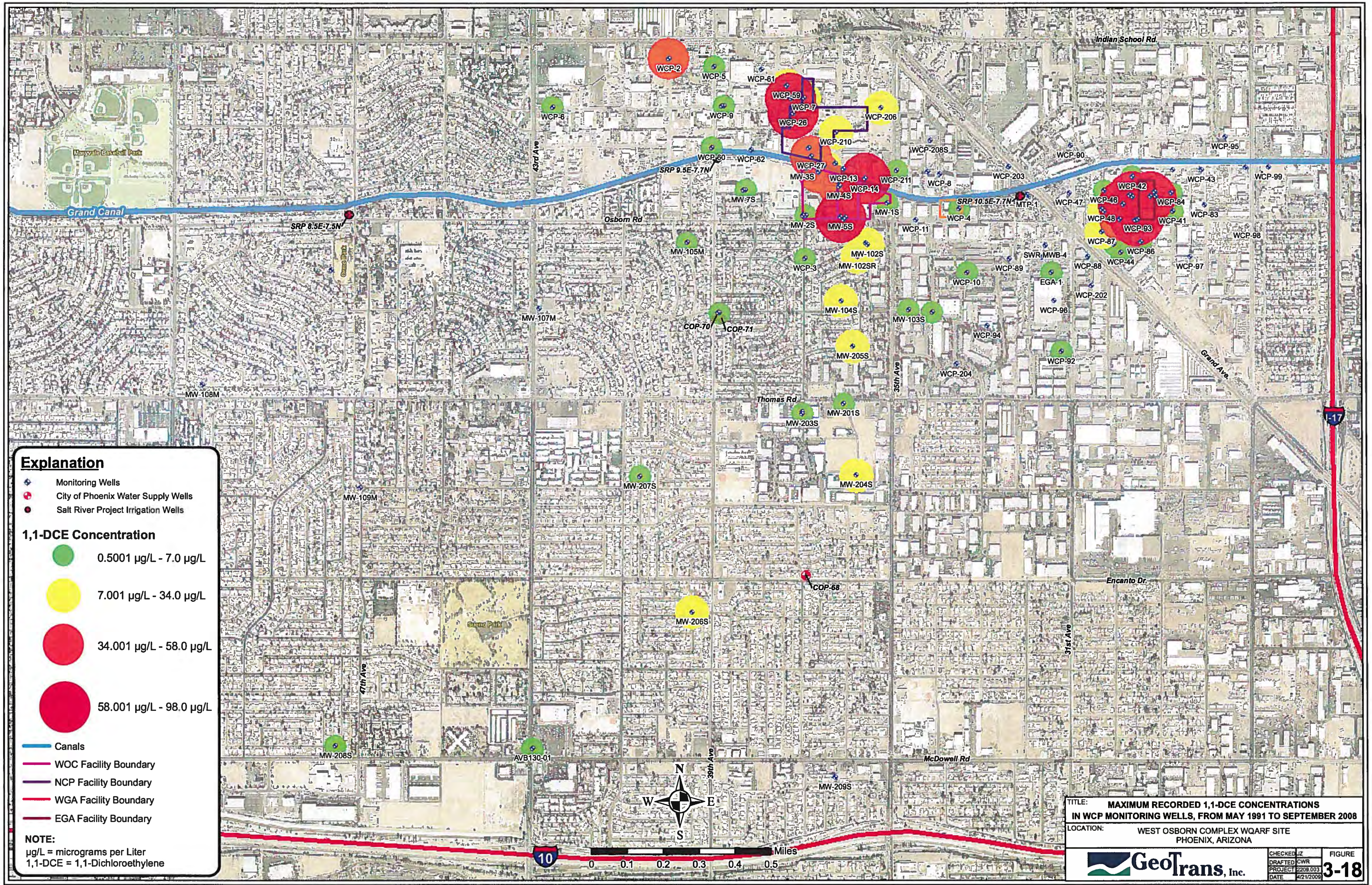
TITLE: **MAXIMUM RECORDED PCE CONCENTRATIONS IN WCP MONITORING WELLS, FROM MAY 1991 TO SEPTEMBER 2008**

LOCATION: WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA

GeoTrans, Inc.

CHECKED	JZ
DRAFTED	CWR
PROJECT	2209.003
DATE	4/21/2009

FIGURE **3-17**

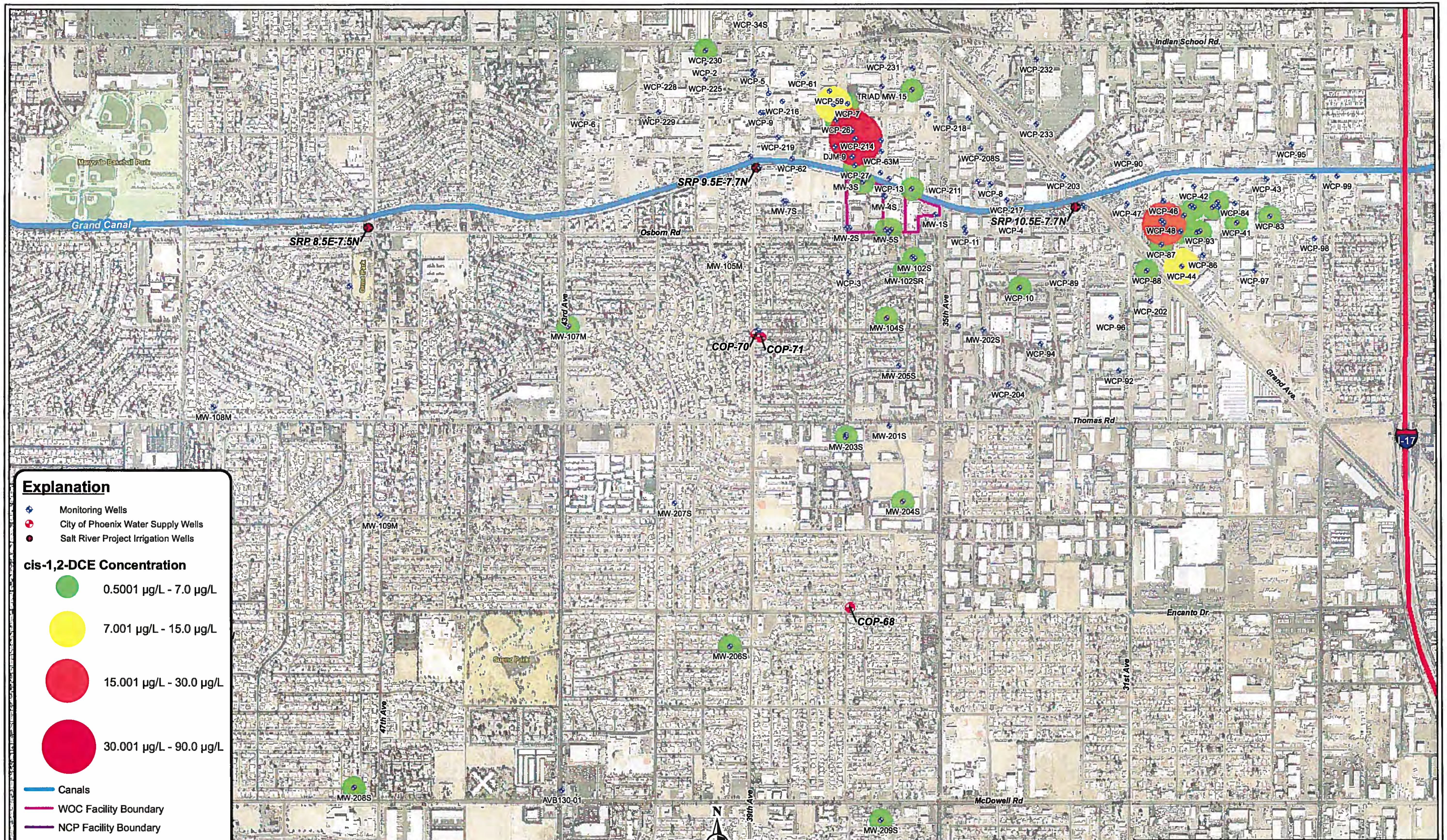


TITLE: MAXIMUM RECORDED 1,1-DCE CONCENTRATIONS IN WCP MONITORING WELLS, FROM MAY 1991 TO SEPTEMBER 2008

LOCATION: WEST OSBORN COMPLEX WQARF SITE, PHOENIX, ARIZONA

GeoTrans, Inc.

FIGURE 3-18



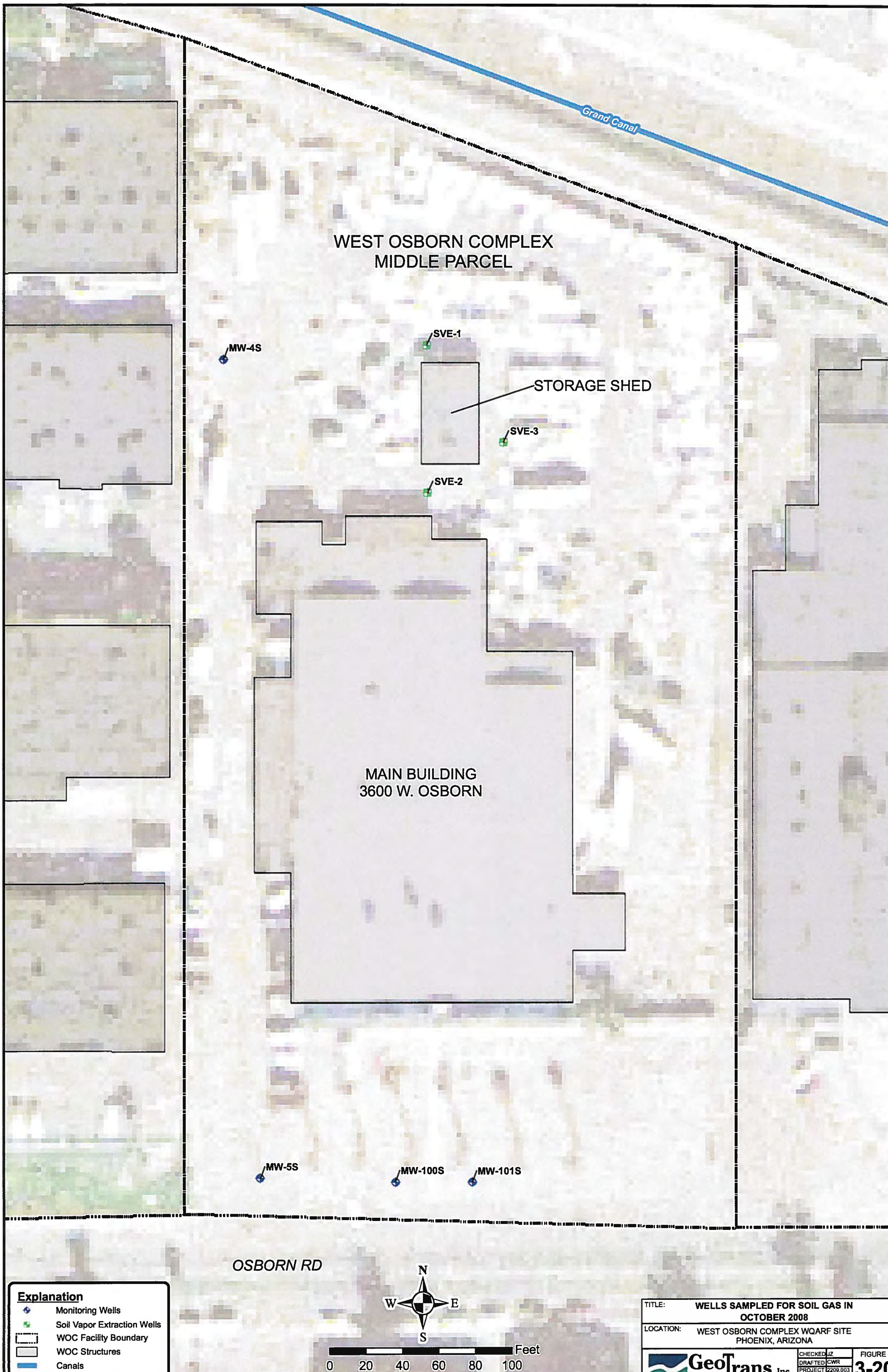
TITLE: **MAXIMUM RECORDED CIS-1,2-DCE CONCENTRATIONS IN WCP MONITORING WELLS, FROM MAY 1991 TO SEPTEMBER 2008**

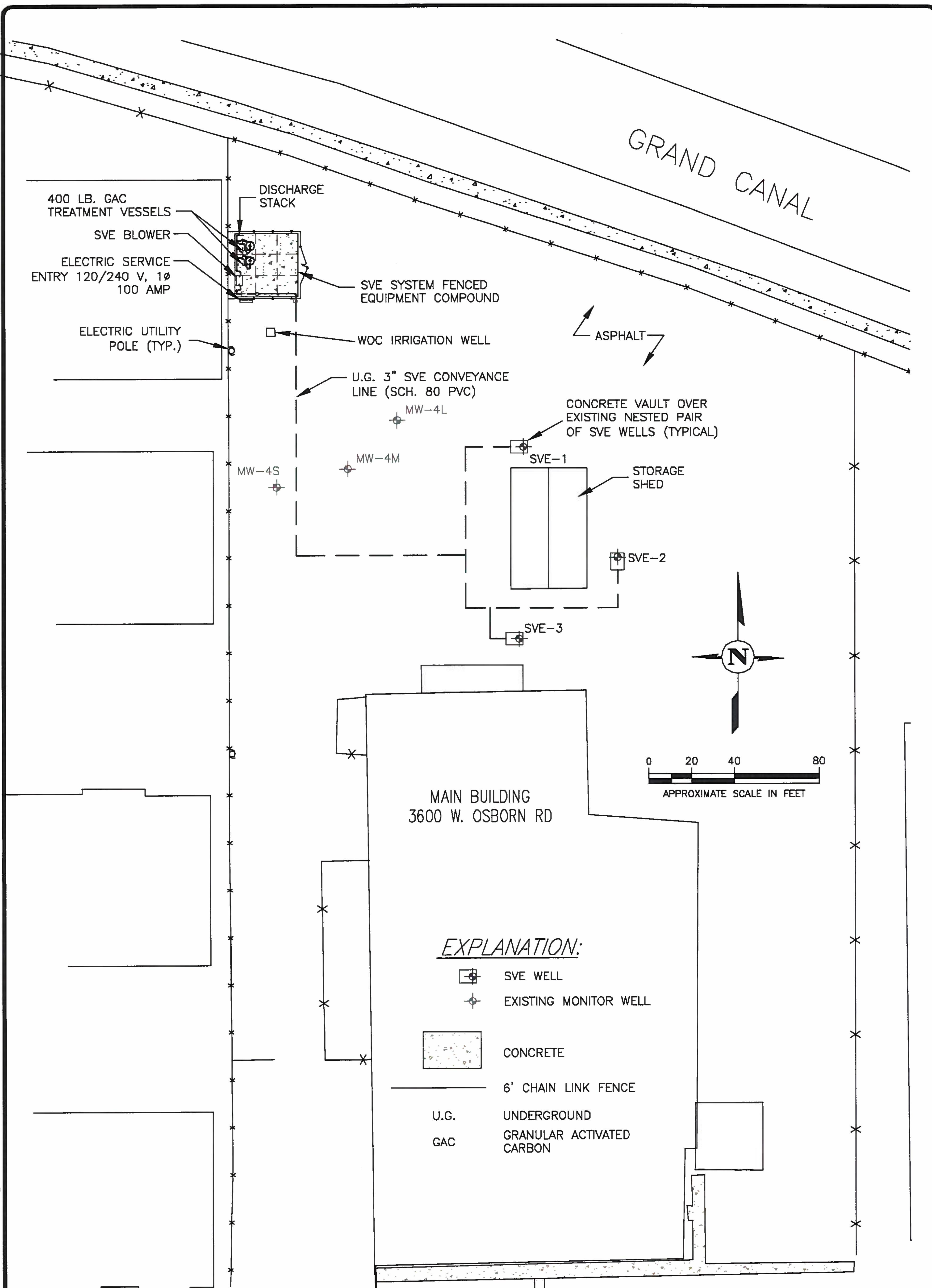
LOCATION: WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA

GeoTrans, Inc.

CHECKED	JZ
DRAFTED	CWR
PROJECT	2209.003
DATE	4/21/2009

FIGURE
3-19


WEST OSBORN COMPLEX
MIDDLE PARCEL
Grand Canal
SVE-1
MW-4S
STORAGE SHED
SVE-3
SVE-2
MAIN BUILDING
3600 W. OSBORN
MW-5S
MW-100S
MW-101S
OSBORN RD
N
W
E
S
Feet
0 20 40 60 80 100
Explanation
Monitoring Wells
Soil Vapor Extraction Wells
WOC Facility Boundary
WOC Structures
Canals
TITLE: WELLS SAMPLED FOR SOIL GAS IN OCTOBER 2008
LOCATION: WEST OSBORN COMPLEX WQARF SITE PHOENIX, ARIZONA
GeoTrans, Inc.
CHECKED JZ
DRAFTED CWR
PROJECT 2209.003
DATE 5/13/2009
FIGURE
3-20

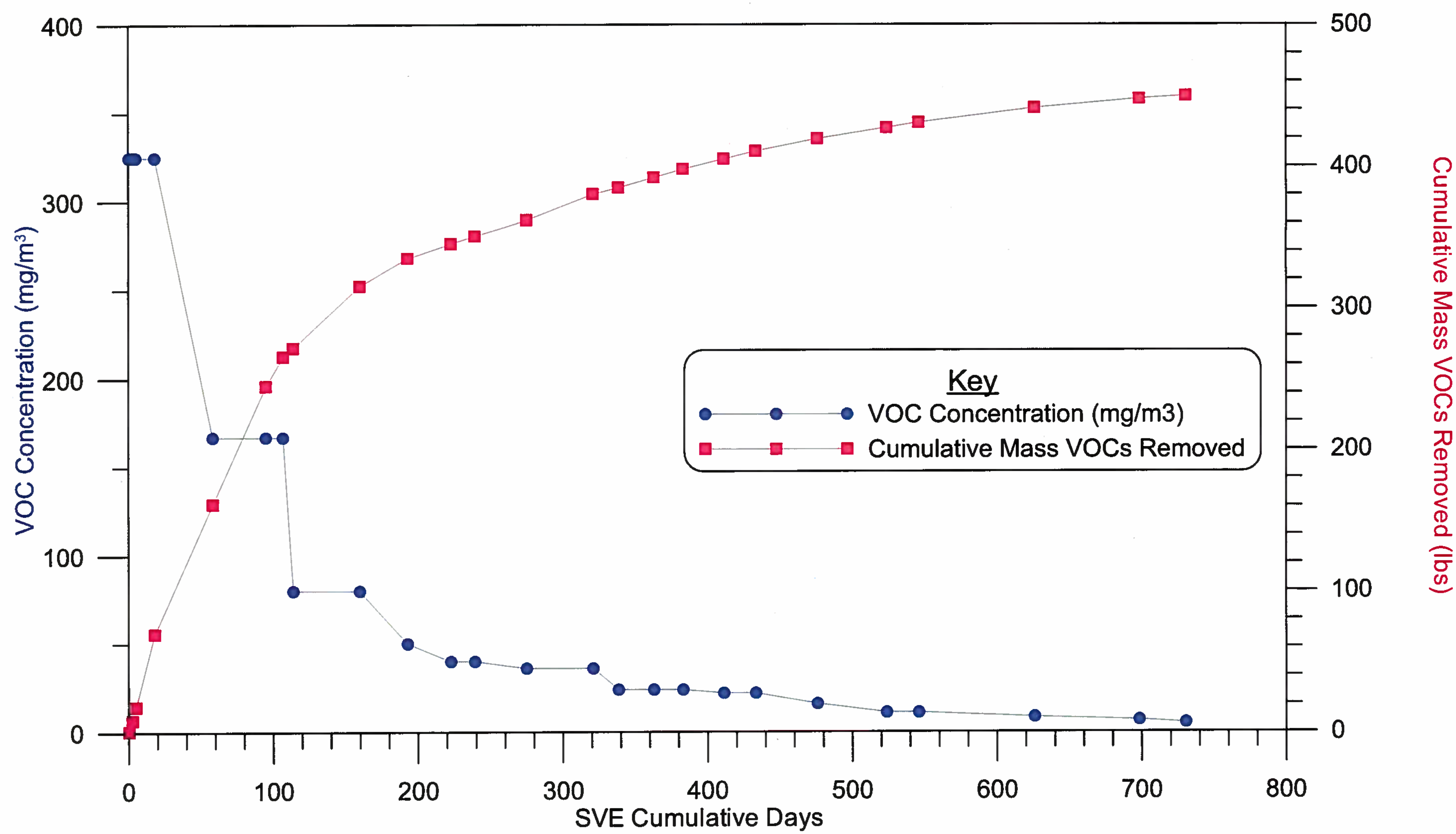


TITLE: **INTERIM SVE REMEDIATION SYSTEM LAYOUT**

LOCATION: WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA

GeoTrans, Inc. A TETRA TECH COMPANY

CHECKED	SB	FIGURE
DRAFTED	JLB	4-1
PROJECT	2209.003	
DATE	10/5/04	



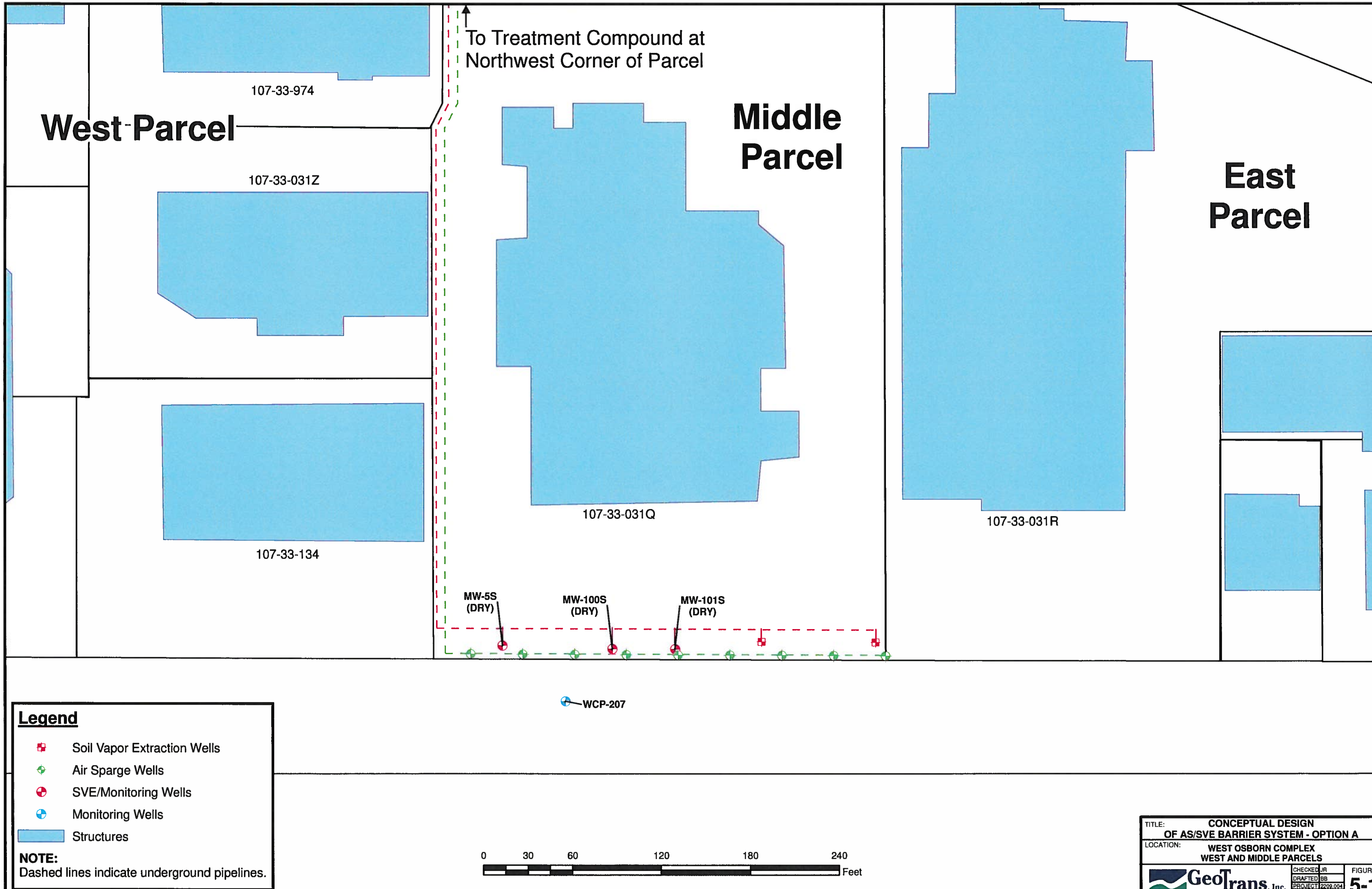
path: M:/GeoTrans Staff/Jeff/UIC/ | art: Gutmann | checked: Rackow

GeoTrans, Inc.

Interim SVE System Performance

WEST OSBORN COMPLEX WQARF
PHOENIX, ARIZONA

Figure
4-2



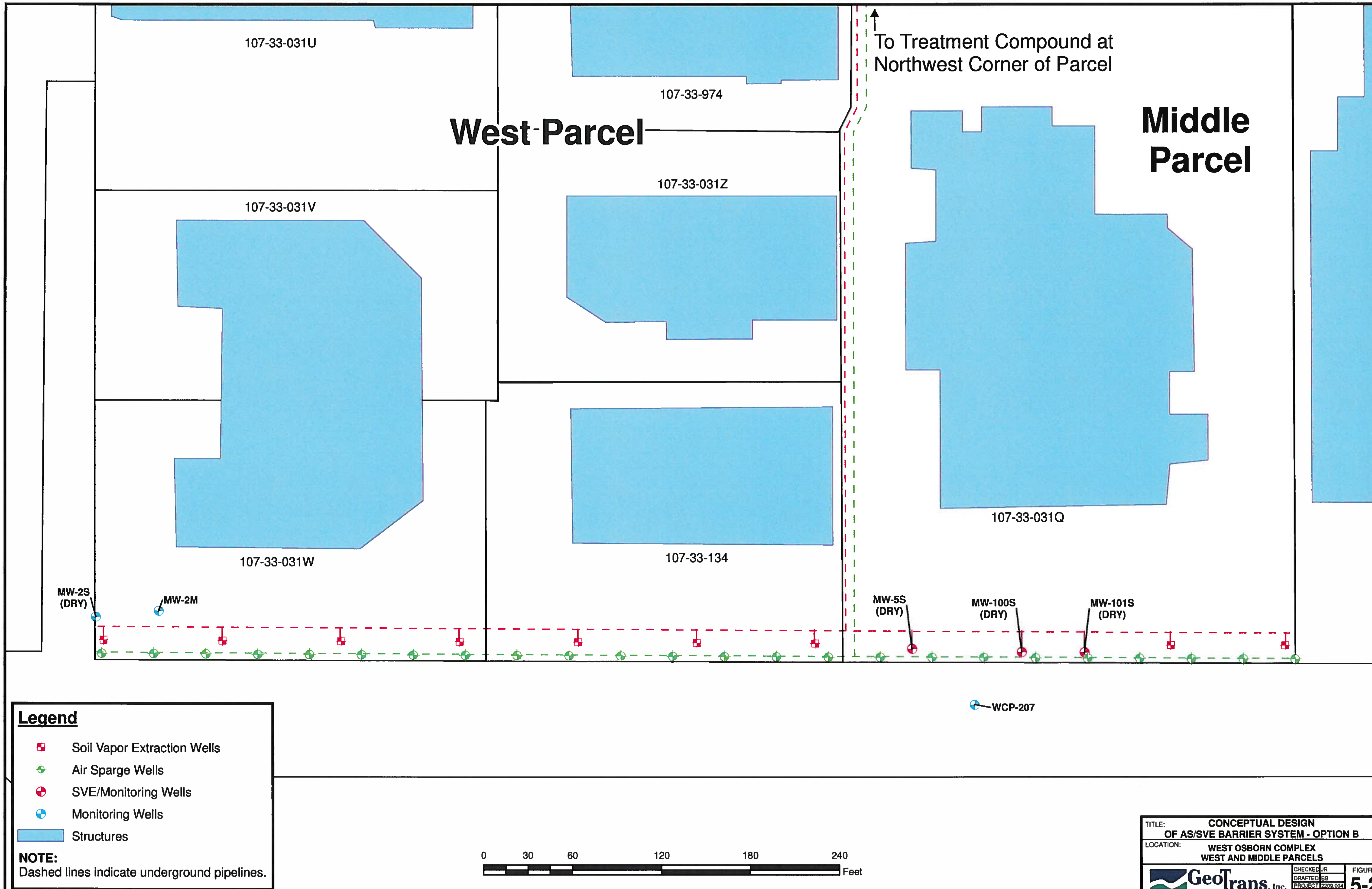
TITLE: CONCEPTUAL DESIGN OF AS/SVE BARRIER SYSTEM - OPTION A

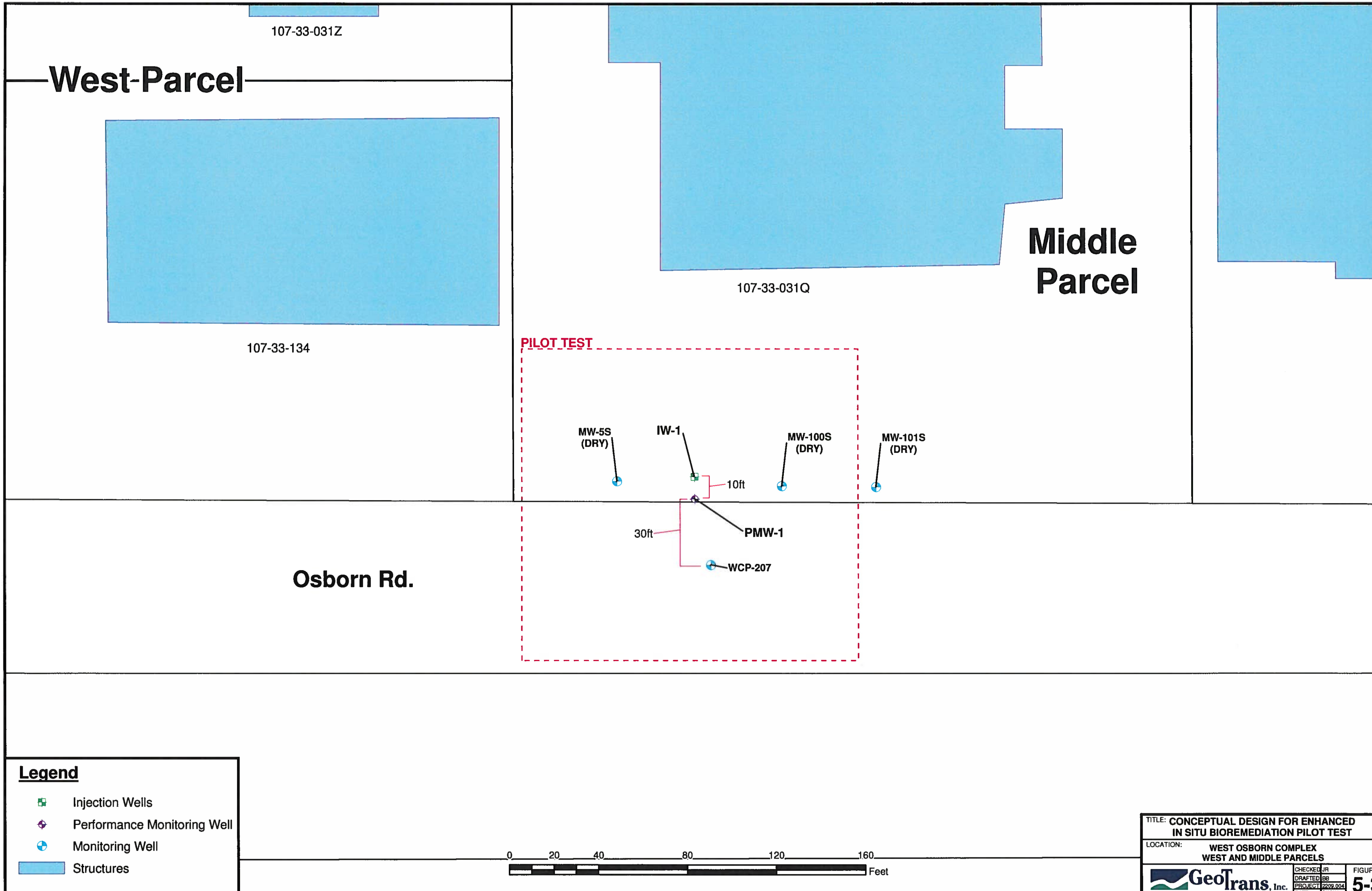
LOCATION: WEST OSBORN COMPLEX WEST AND MIDDLE PARCELS

GeoTrans, Inc.

CHECKED JR
DRAFTED BB
PROJECT 2209.004
DATE 6/15/11

FIGURE 5-1


107-33-031U
107-33-974
To Treatment Compound at Northwest Corner of Parcel
West Parcel
Middle Parcel
107-33-031V
107-33-031Z
107-33-031Q
107-33-031W
107-33-134
MW-2S (DRY)
MW-2M
MW-5S (DRY)
MW-100S (DRY)
MW-101S (DRY)
WCP-207
Legend
Soil Vapor Extraction Wells
Air Sparge Wells
SVE/Monitoring Wells
Monitoring Wells
Structures
NOTE:
Dashed lines indicate underground pipelines.
0
30
60
120
180
240
Feet
TITLE: CONCEPTUAL DESIGN OF AS/SVE BARRIER SYSTEM - OPTION B
LOCATION: WEST OSBORN COMPLEX WEST AND MIDDLE PARCELS
GeoTrans, Inc.
FIGURE 5-2



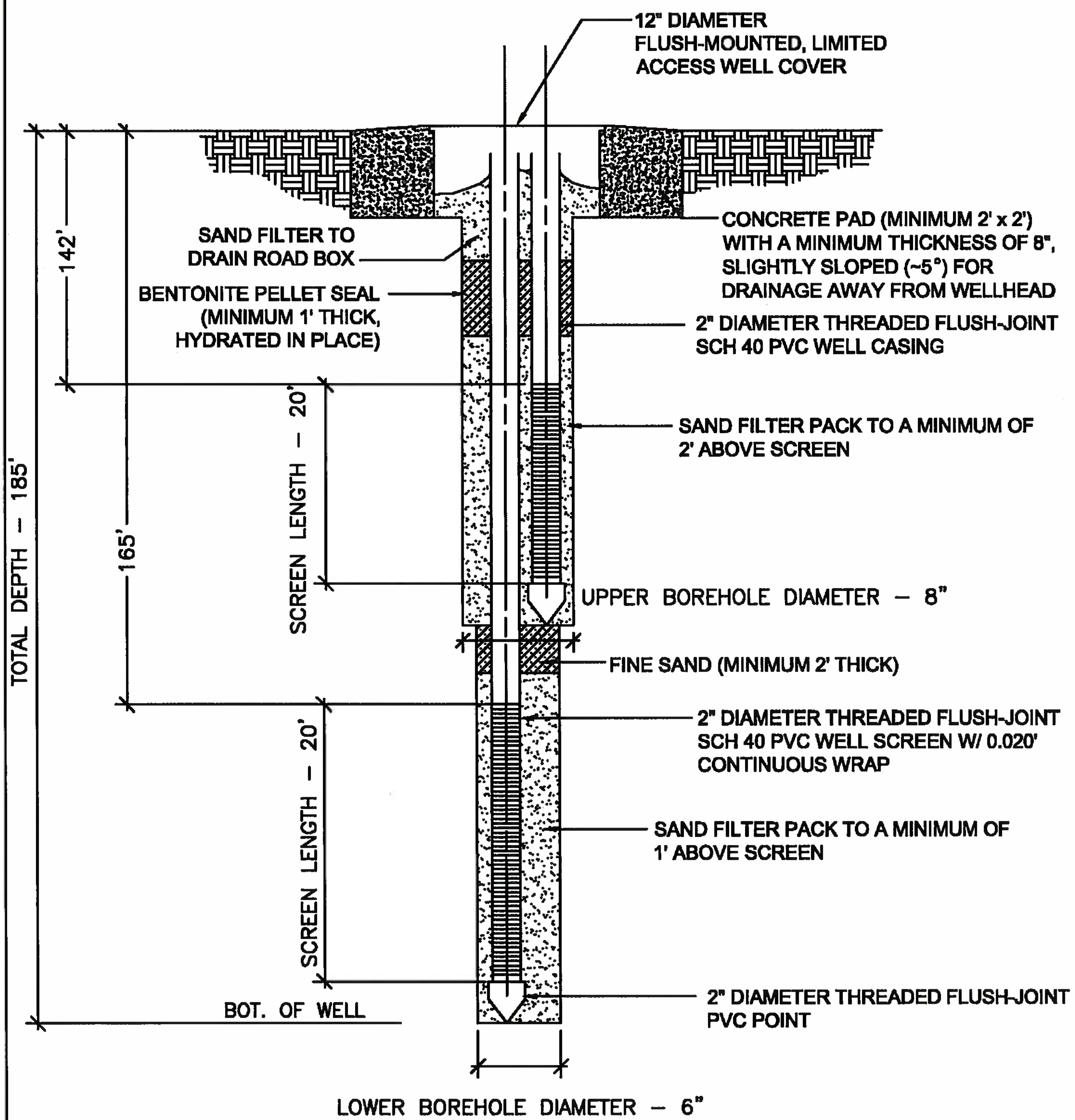
TITLE: CONCEPTUAL DESIGN FOR ENHANCED IN SITU BIOREMEDIATION PILOT TEST

LOCATION: WEST OSBORN COMPLEX WEST AND MIDDLE PARCELS

GeoTrans, Inc.

CHECKED JR
DRAFTED BB
PROJECT 2209.004
DATE 6/16/11

FIGURE 5-3



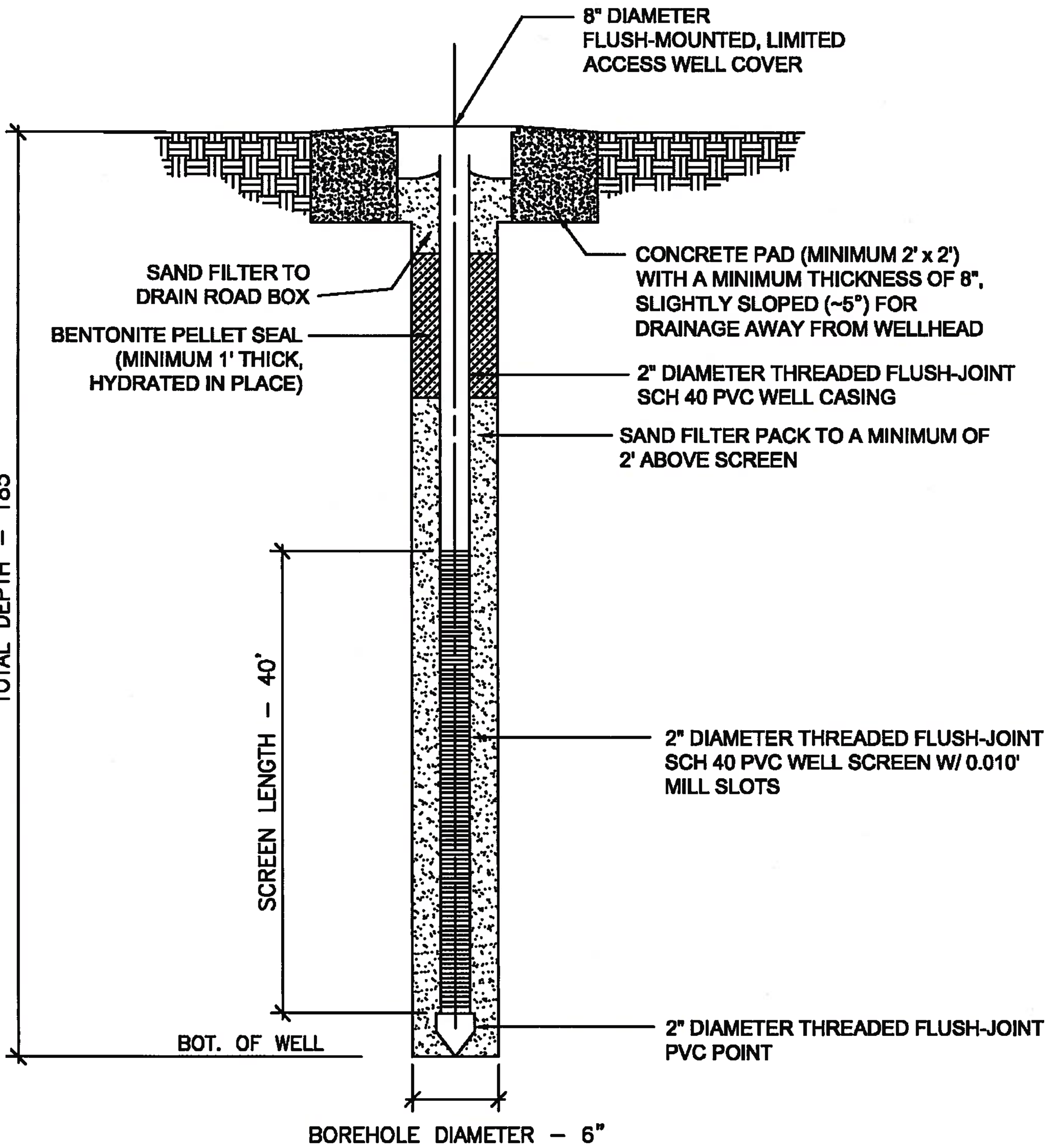
FLUSH GRADE INJECTION WELL DETAIL

NO SCALE

P:\PROJECTS\TEXTRON\IW DETAIL.DWG 02/23/09 DRB 1

GeoTrans, Inc. A TETRA TECH COMPANY

CHECKED: JR / DATE: 6/20/11	FEASIBILITY STUDY WEST OSBORN COMPLEX PHOENIX, ARIZONA INJECTION WELL DETAIL FOR ENHANCED IN SITU BIOREMEDIATION	FIGURE 5-4



FLUSH GRADE MONITORING WELL DETAIL

NO SCALE

GeoTrans, Inc.
A TETRA TECH COMPANY

FEASIBILITY STUDY
WEST OSBORN COMPLEX
PHOENIX, ARIZONA

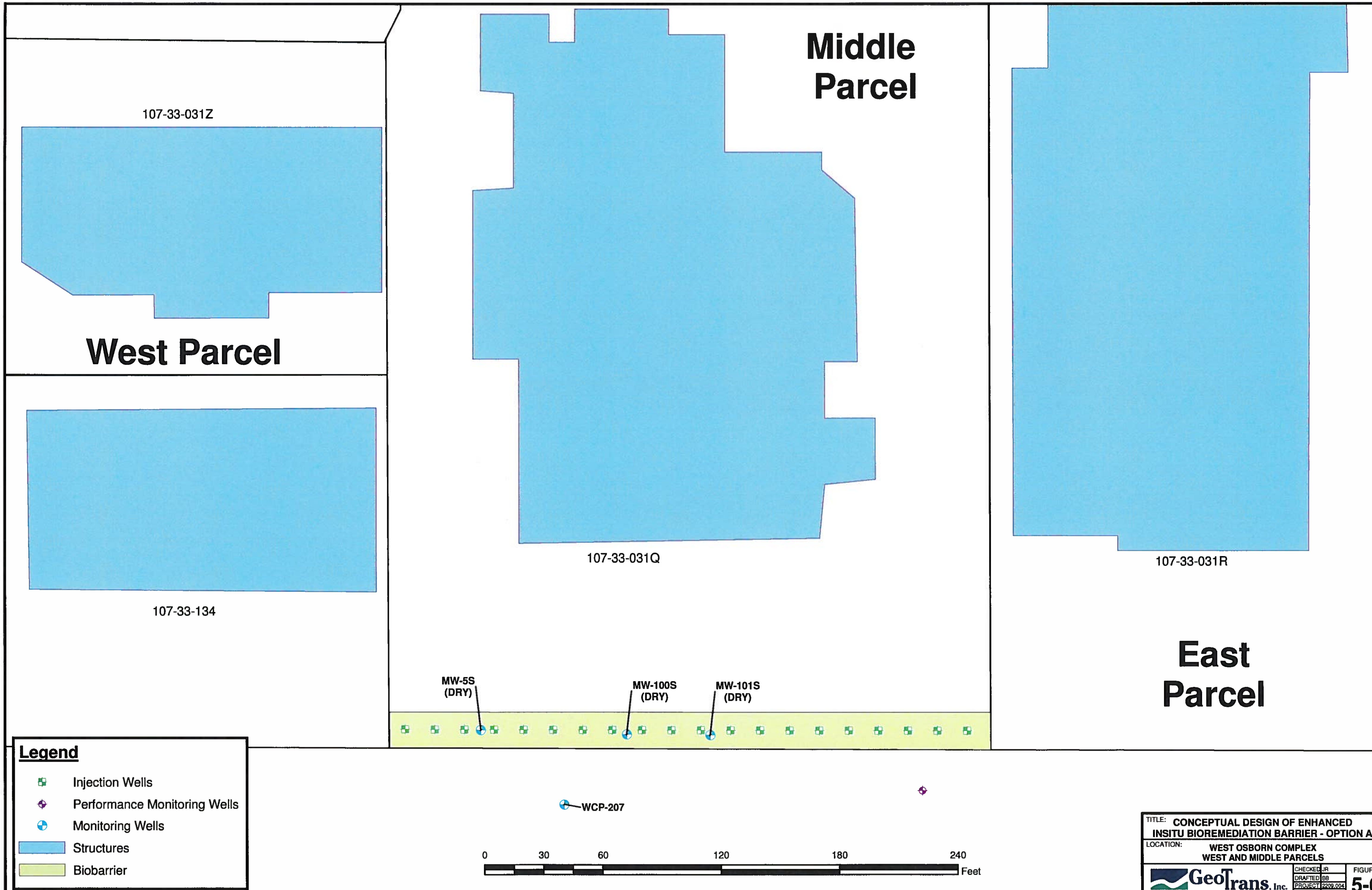
PERFORMANCE MONITORING WELL DETAIL

FIGURE 5-5

CHECKED: JR

DATE: 6/20/11

P:\PROJECTS\TEXTRON\MW DETAIL.DWG 02/22/09 DRB 1



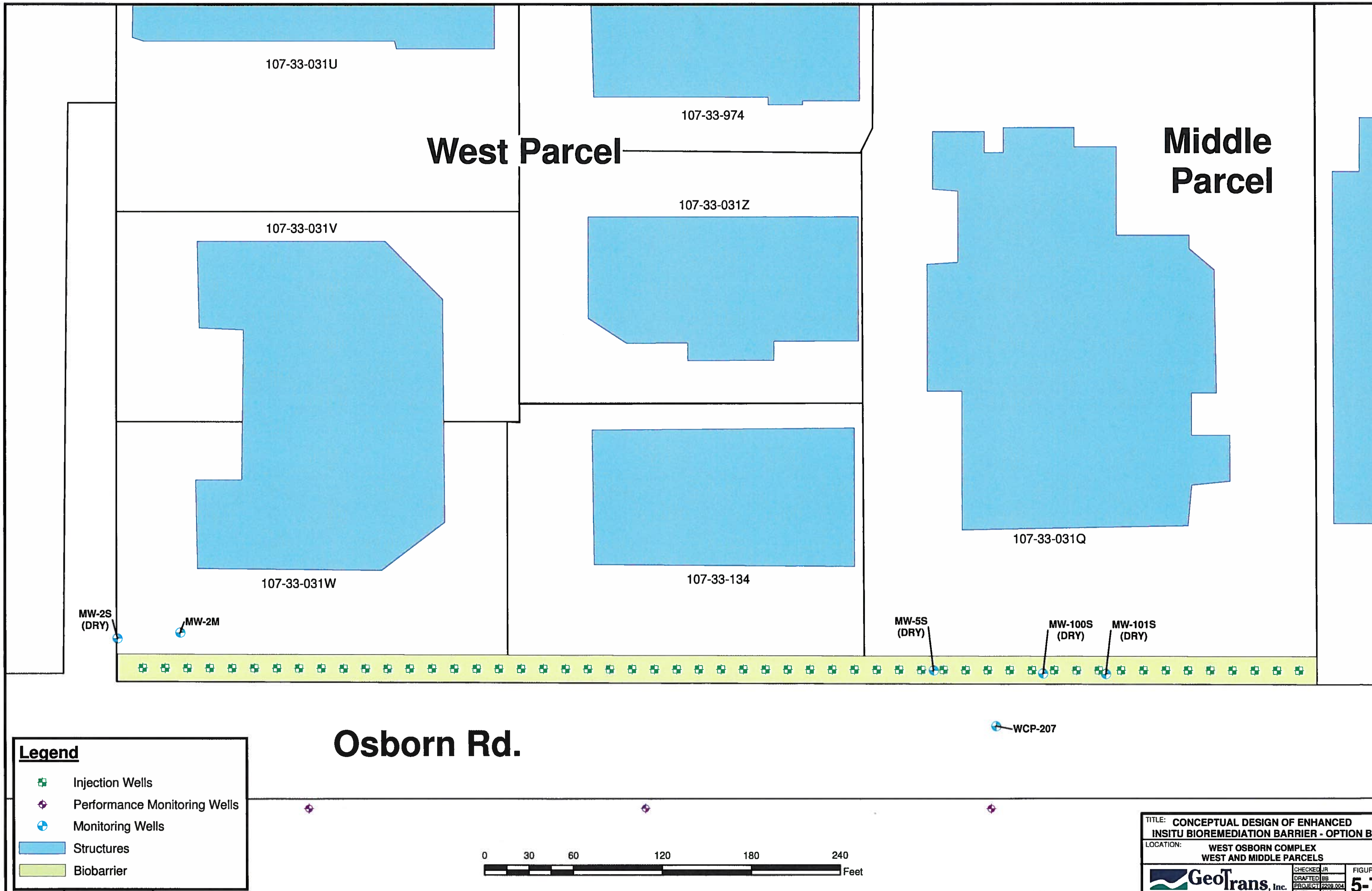
TITLE: CONCEPTUAL DESIGN OF ENHANCED INSITU BIOREMEDIATION BARRIER - OPTION A

LOCATION: WEST OSBORN COMPLEX WEST AND MIDDLE PARCELS

GeoTrans, Inc.

CHECKED	JR
DRAFTED	BB
PROJECT	2209.004
DATE	6/16/11

FIGURE 5-6



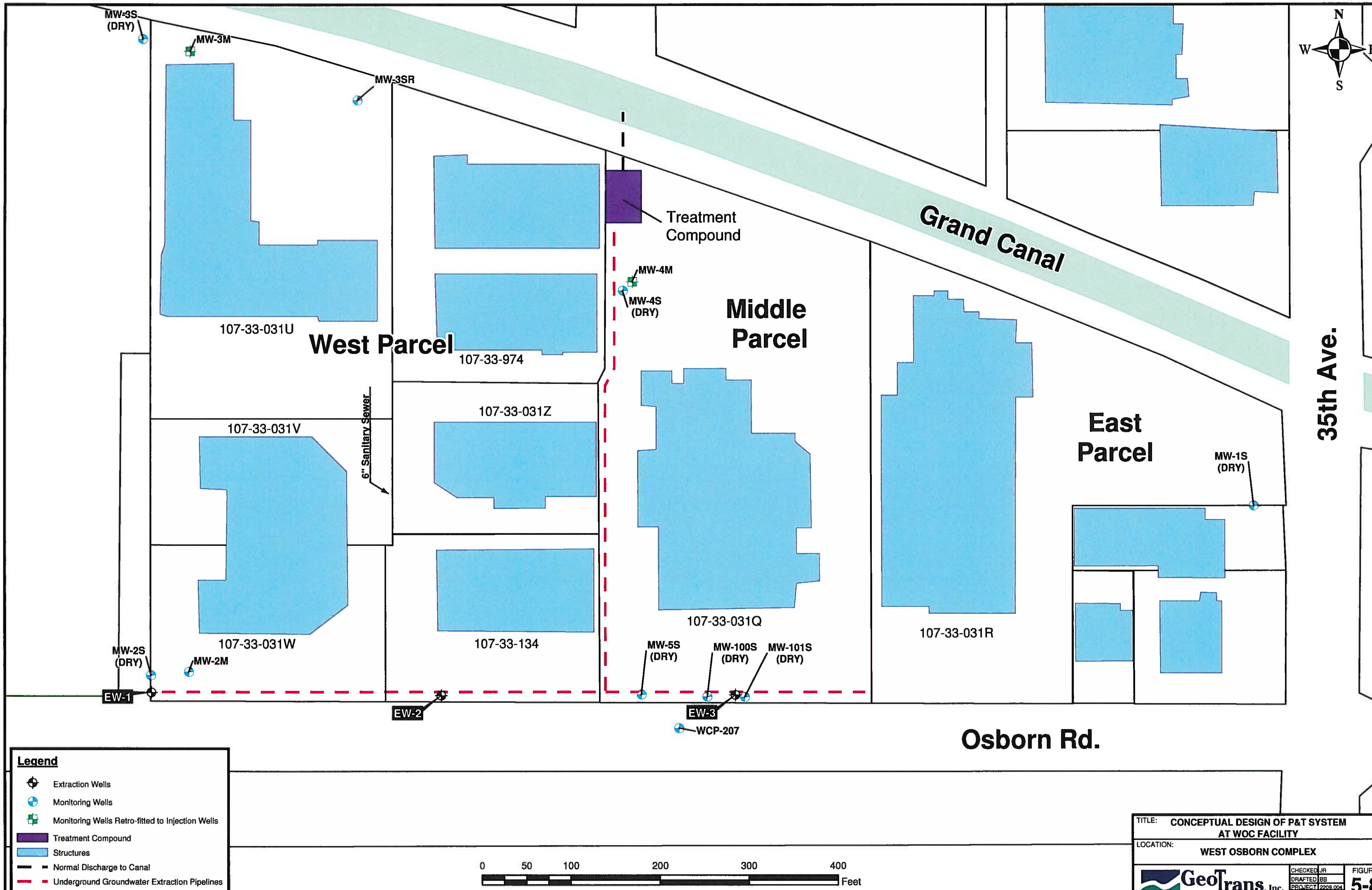
TITLE: CONCEPTUAL DESIGN OF ENHANCED INSITU BIOREMEDIATION BARRIER - OPTION B

LOCATION: WEST OSBORN COMPLEX WEST AND MIDDLE PARCELS

GeoTrans, Inc.

CHECKED JR | DRAFTED BB | PROJECT 2209.004 | DATE 6/16/11

FIGURE 5-7



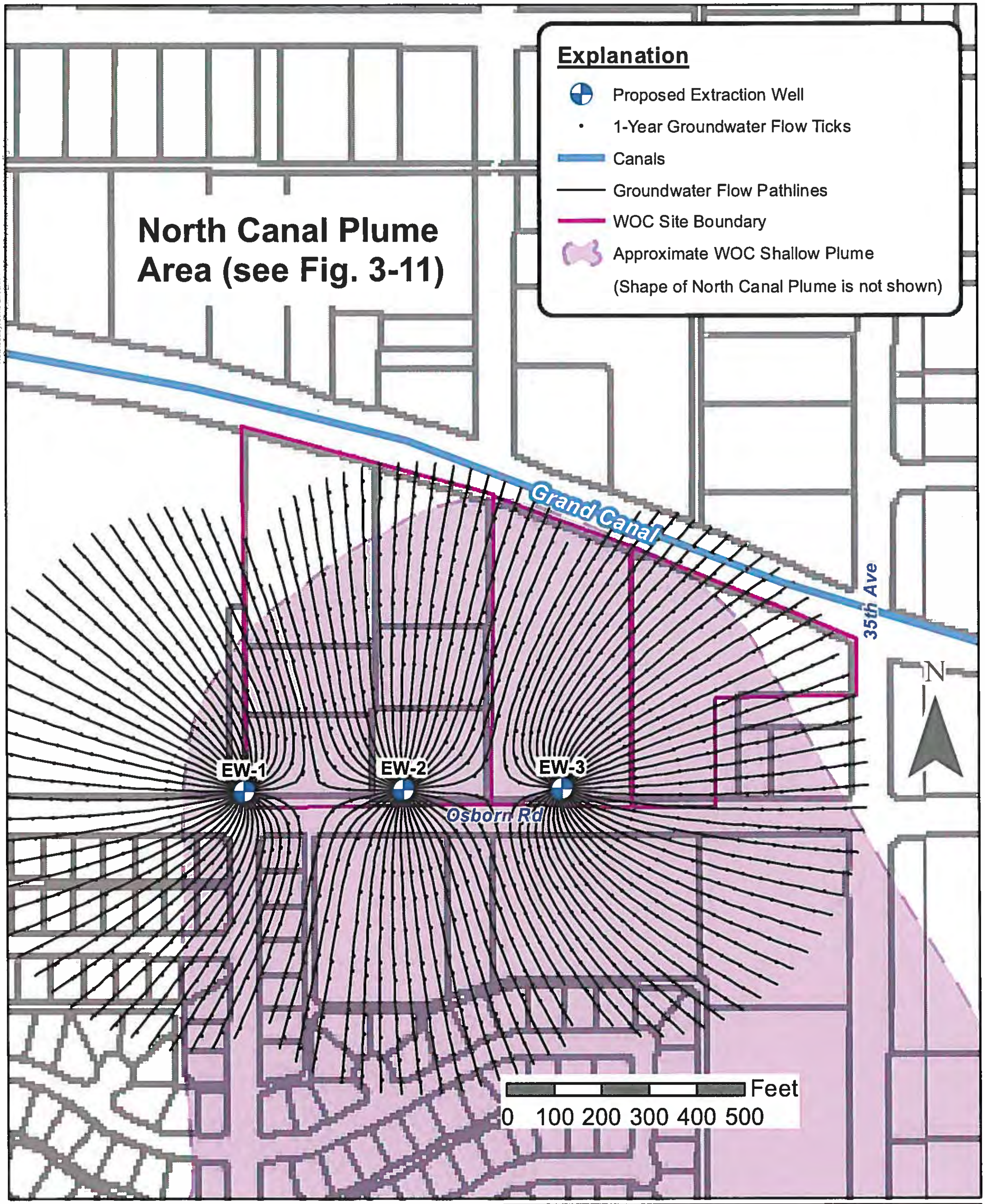
TITLE: CONCEPTUAL DESIGN OF P&T SYSTEM AT WOC FACILITY

LOCATION: WEST OSBORN COMPLEX

GeoTrans, Inc.

CHECKED	JR
DRAFTED	BB
PROJECT	2209.004
DATE	6/14/11

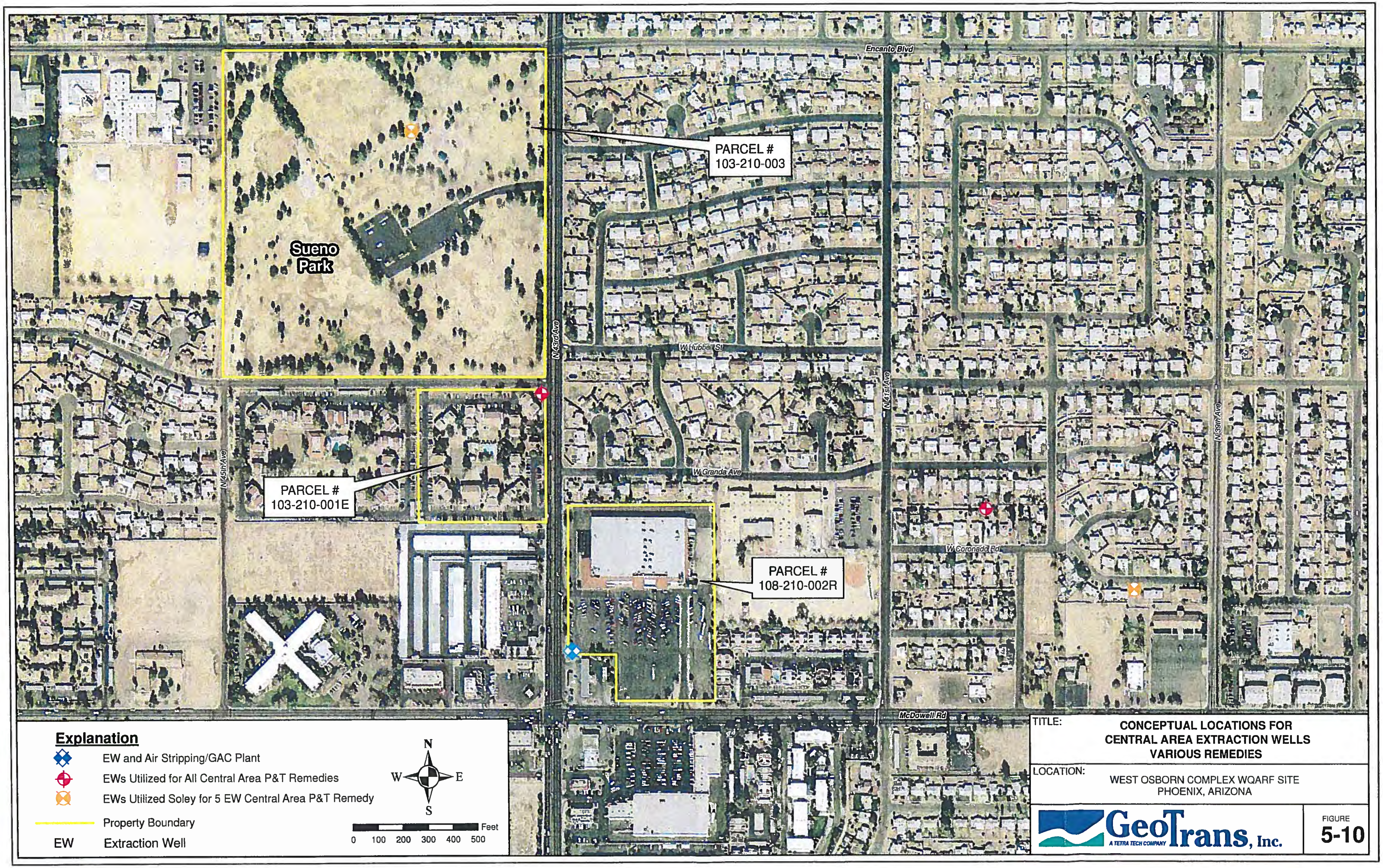
FIGURE 5-8



All Treatment Wells pump at 10 gallons per minute with approximately 330 foot spacing

Model Parameters
Hydraulic Conductivity: 1.5 feet per day
Porosity: 25%
Hydraulic Gradient: 0.0028 feet/foot

TITLE: MODELED CAPTURE ZONES, 3 EXTRACTION WELLS, WOC FACILITY	
LOCATION: WEST OSBORN COMPLEX WQARF SITE PHOENIX, ARIZONA	
GeoTrans, Inc. A TETRA TECH COMPANY	FIGURE 5-9

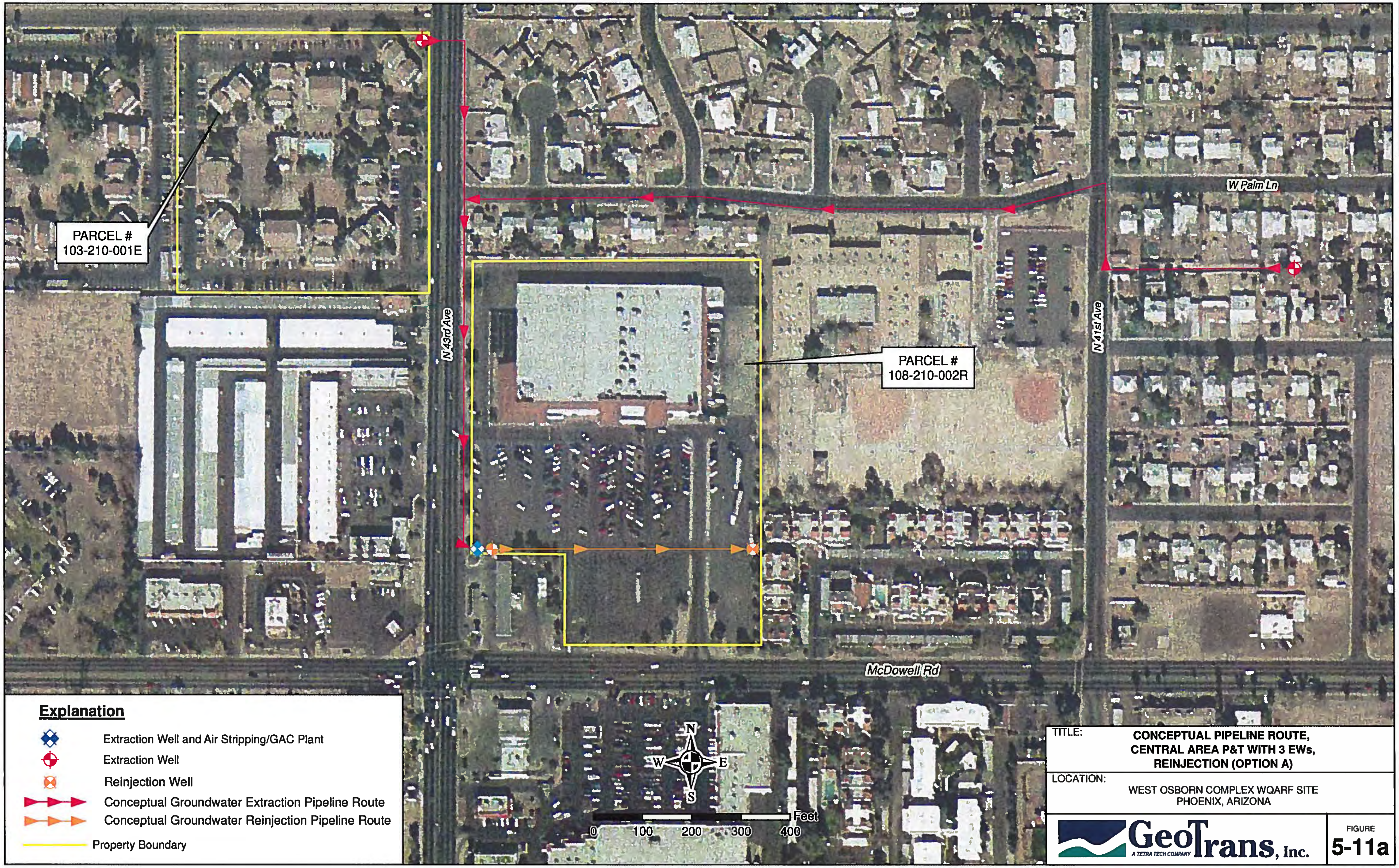


TITLE: CONCEPTUAL LOCATIONS FOR CENTRAL AREA EXTRACTION WELLS VARIOUS REMEDIES

LOCATION: WEST OSBORN COMPLEX WQARF SITE PHOENIX, ARIZONA

GeoTrans, Inc. A TETRA TECH COMPANY

FIGURE 5-10

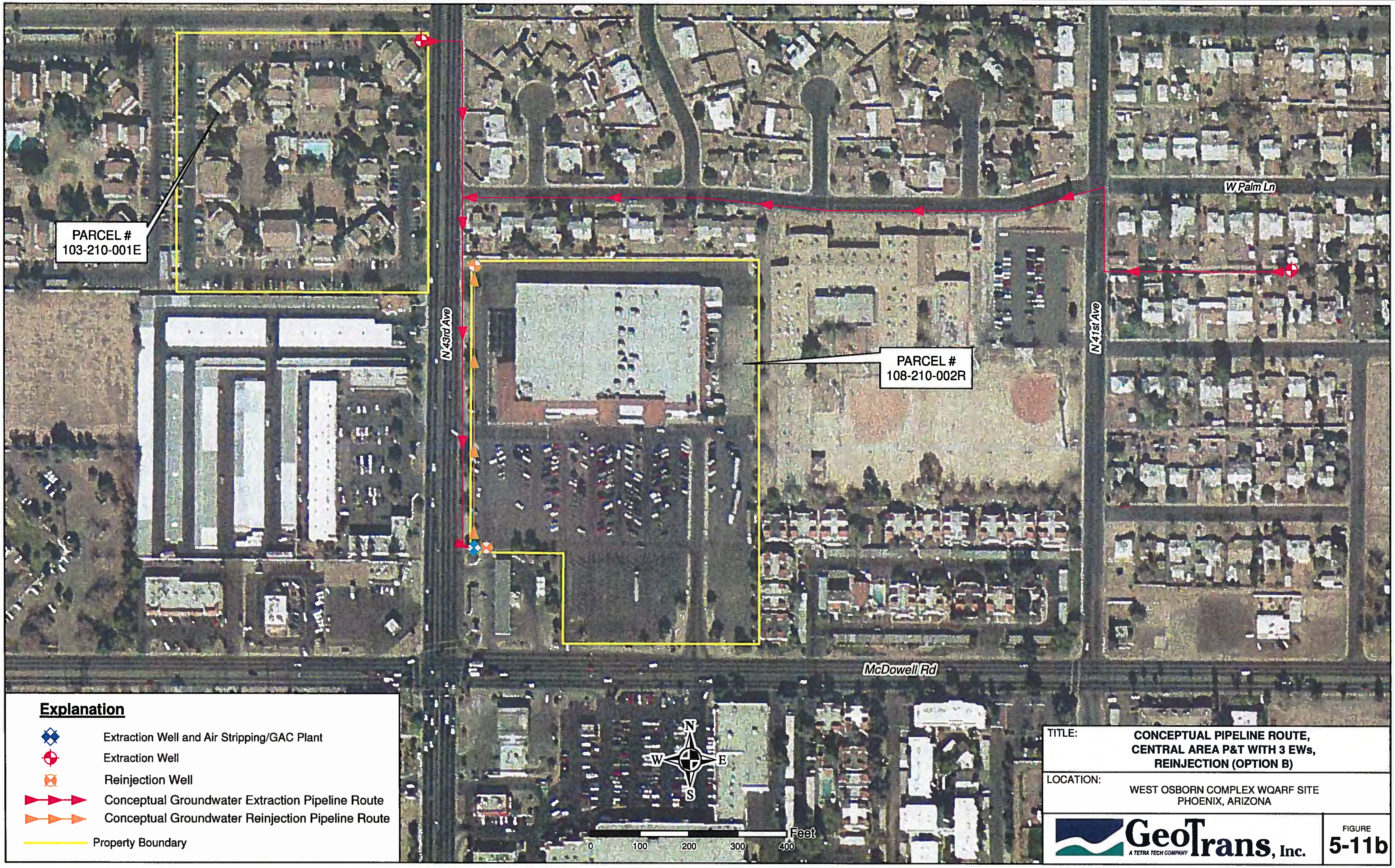


TITLE:
CONCEPTUAL PIPELINE ROUTE, CENTRAL AREA P&T WITH 3 EWs, REINJECTION (OPTION A)

LOCATION:
WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA

GeoTrans, Inc.
A TETRA TECH COMPANY

FIGURE
5-11a



Explanation

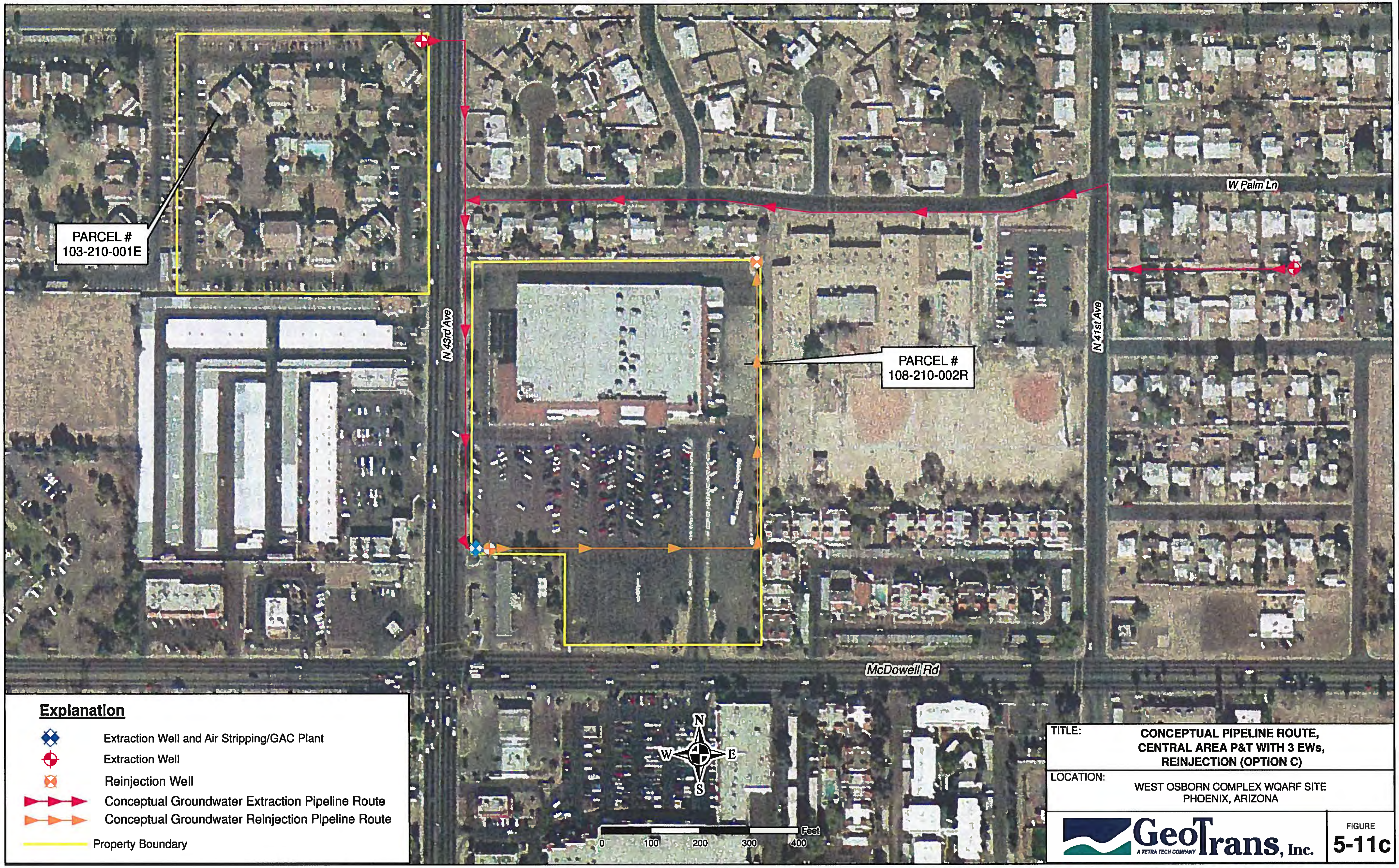
- Extraction Well and Air Stripping/GAC Plant
- Extraction Well
- Reinjection Well
- Conceptual Groundwater Extraction Pipeline Route
- Conceptual Groundwater Reinjection Pipeline Route
- Property Boundary

TITLE: **CONCEPTUAL PIPELINE ROUTE, CENTRAL AREA P&T WITH 3 EWs, REINJECTION (OPTION B)**

LOCATION: WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA

GeoTrans, Inc.
A TETRA TECH COMPANY

FIGURE
5-11b

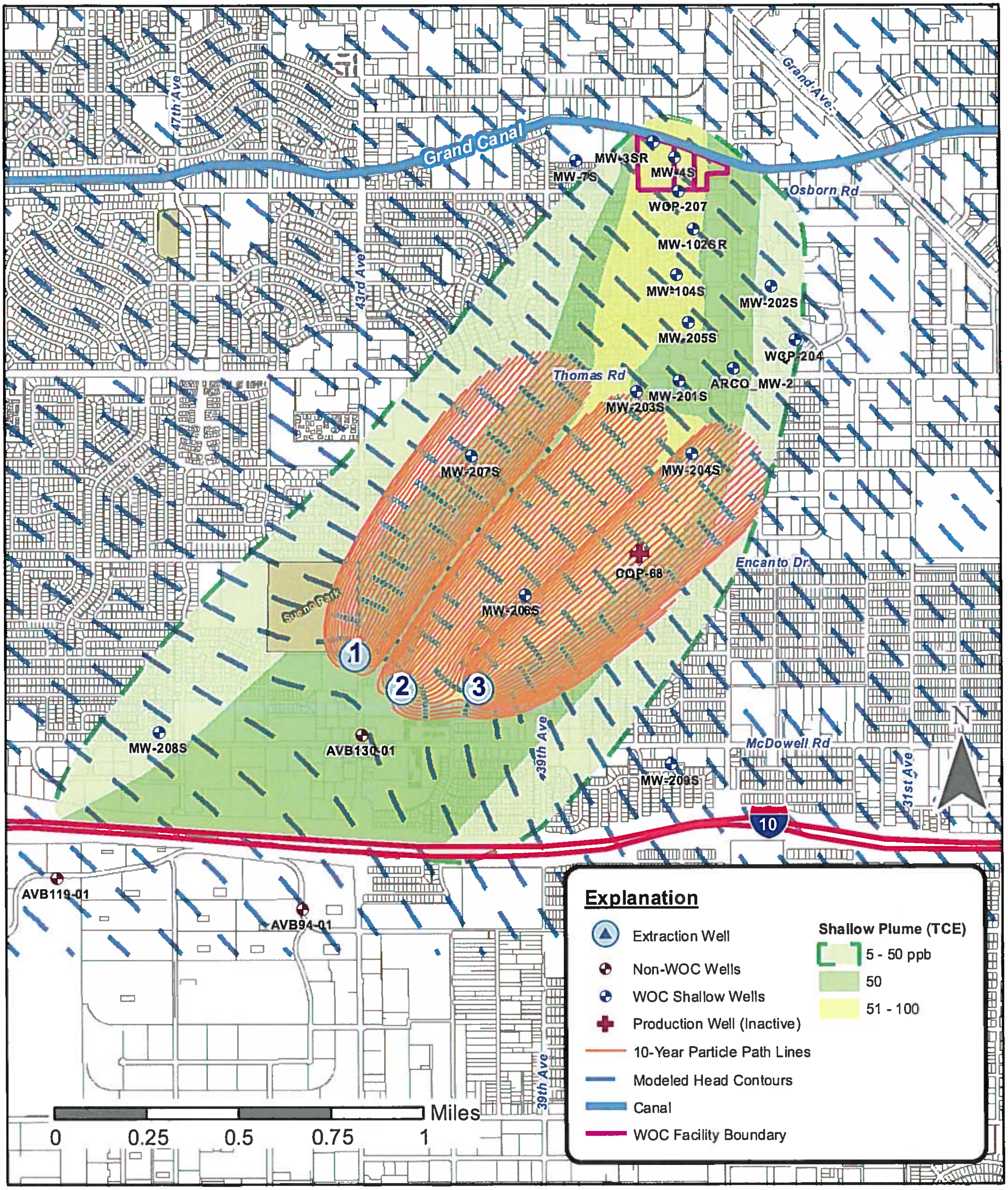


TITLE: CONCEPTUAL PIPELINE ROUTE, CENTRAL AREA P&T WITH 3 EWs, REINJECTION (OPTION C)

LOCATION: WEST OSBORN COMPLEX WQARF SITE PHOENIX, ARIZONA

GeoTrans, Inc. A TETRA TECH COMPANY

FIGURE 5-11c



Wells 1 - 3 pump at 100 gpm

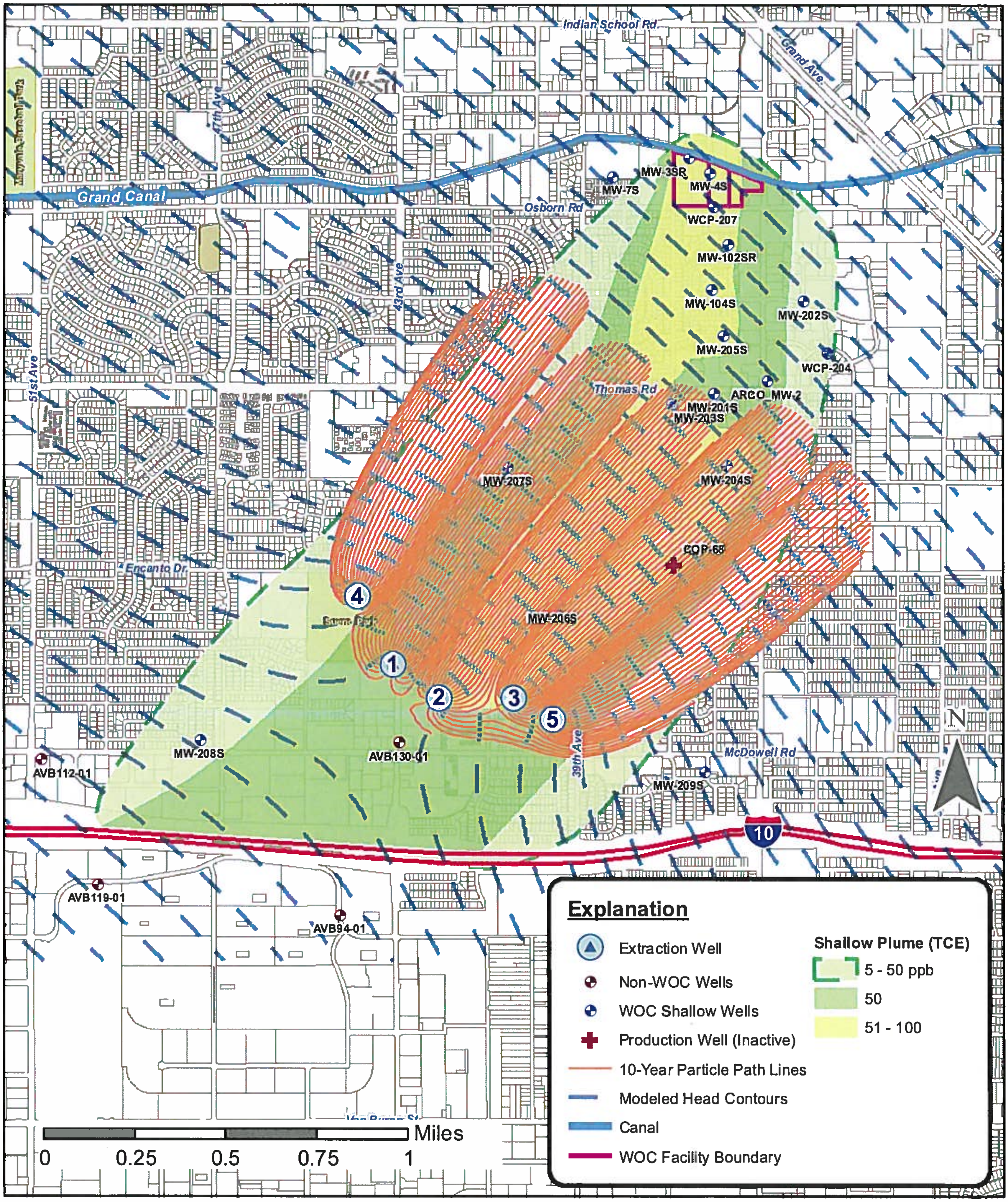
Model Parameters
Hydraulic Conductivity: 130 feet per day (ft/d)
Porosity: 25%
Hydraulic Gradient: 0.0021 feet/foot

TITLE: **Modeled Capture Zones, Central Area Pump and Treat with 3 Extraction Wells**

LOCATION: WEST OSBORN COMPLEX WQARF SITE, PHOENIX, ARIZONA

GeoTrans, Inc. A TETRA TECH COMPANY

FIGURE 5-12



Wells 1 - 5 pump at 100 gpm

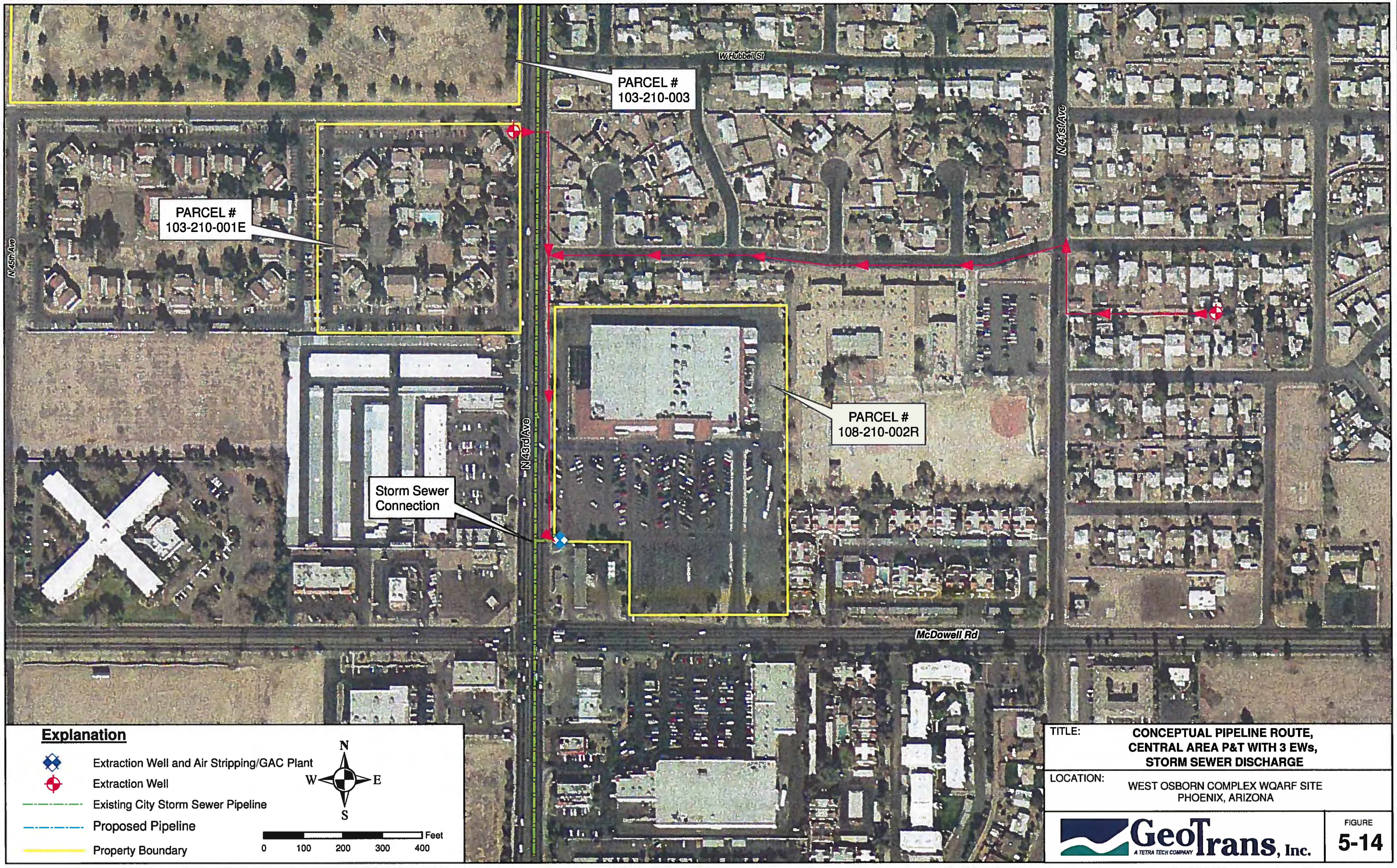
Model Parameters

Hydraulic Conductivity: 130 feet per day (ft/d)

Porosity: 25%

Hydraulic Gradient: 0.0021 feet/foot

TITLE:	**Modeled Capture Zones, Central Area Pump and Treat with 5 Extraction Wells**
LOCATION:	WEST OSBORN COMPLEX WQARF SITE, PHOENIX, ARIZONA
GeoTrans, Inc. A TETRA TECH COMPANY	FIGURE **5-13**



Explanation

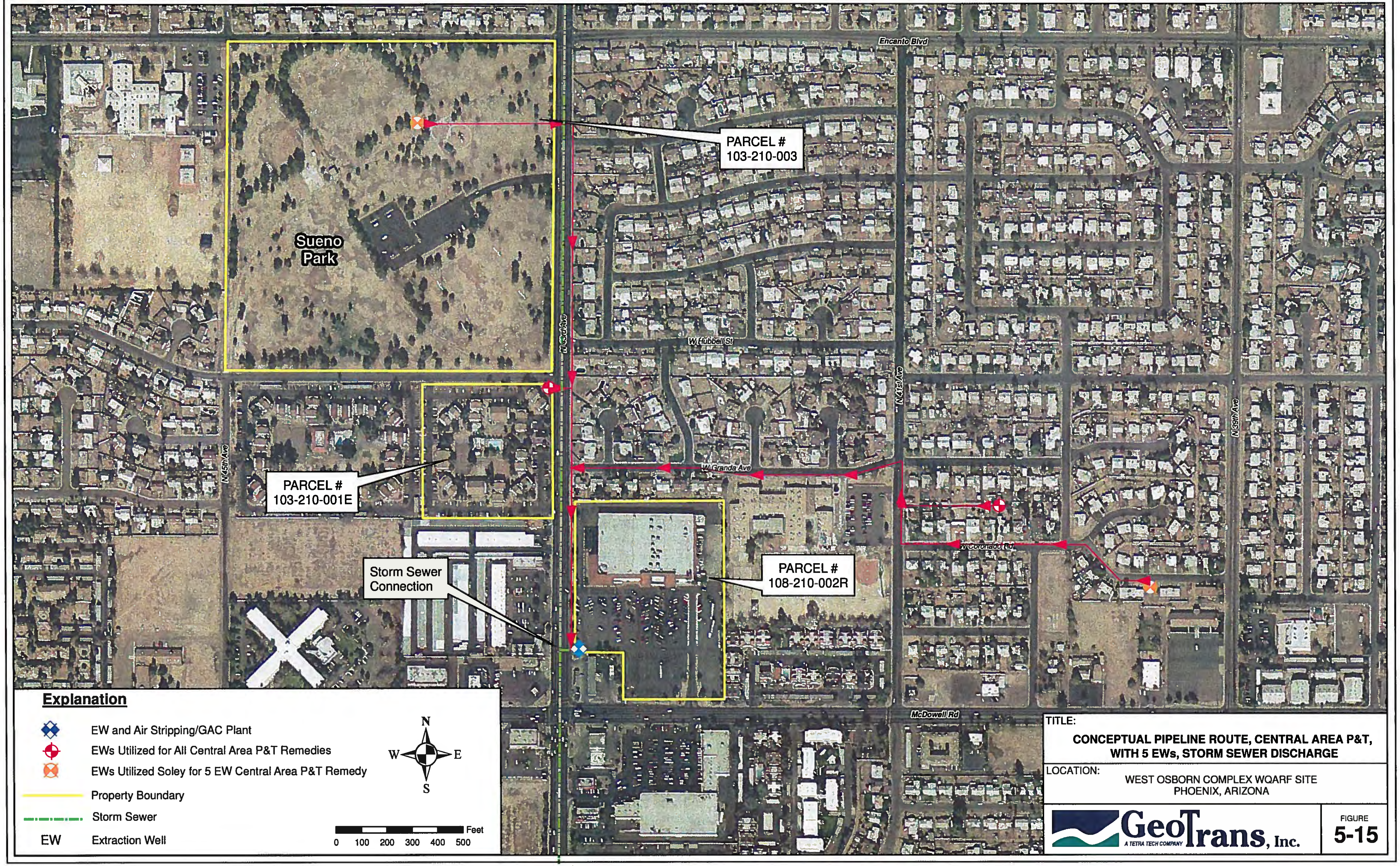
- Extraction Well and Air Stripping/GAC Plant
- Extraction Well
- Existing City Storm Sewer Pipeline
- Proposed Pipeline
- Property Boundary

TITLE: **CONCEPTUAL PIPELINE ROUTE, CENTRAL AREA P&T WITH 3 EWs, STORM SEWER DISCHARGE**

LOCATION: WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA

GeoTrans, Inc.
A TETRA TECH COMPANY

FIGURE
5-14



Explanation

- EW and Air Stripping/GAC Plant
- EWs Utilized for All Central Area P&T Remedies
- EWs Utilized Soley for 5 EW Central Area P&T Remedy
- Property Boundary
- Storm Sewer
- EW Extraction Well

N W E S

0 100 200 300 400 500 Feet

TITLE:

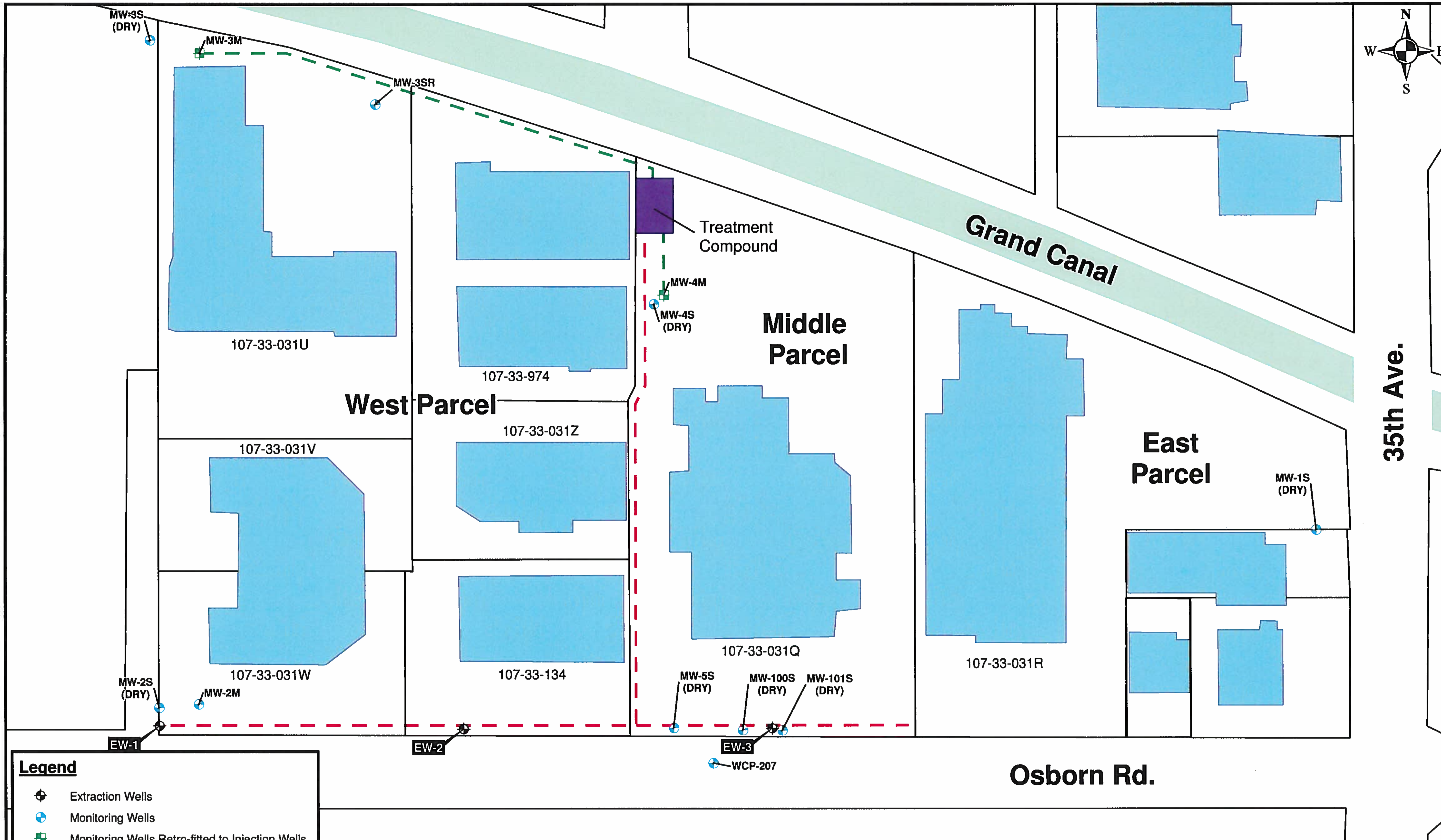
CONCEPTUAL PIPELINE ROUTE, CENTRAL AREA P&T, WITH 5 EWs, STORM SEWER DISCHARGE

LOCATION:

WEST OSBORN COMPLEX WQARF SITE
PHOENIX, ARIZONA

GeoTrans, Inc. A TETRA TECH COMPANY

FIGURE
5-15

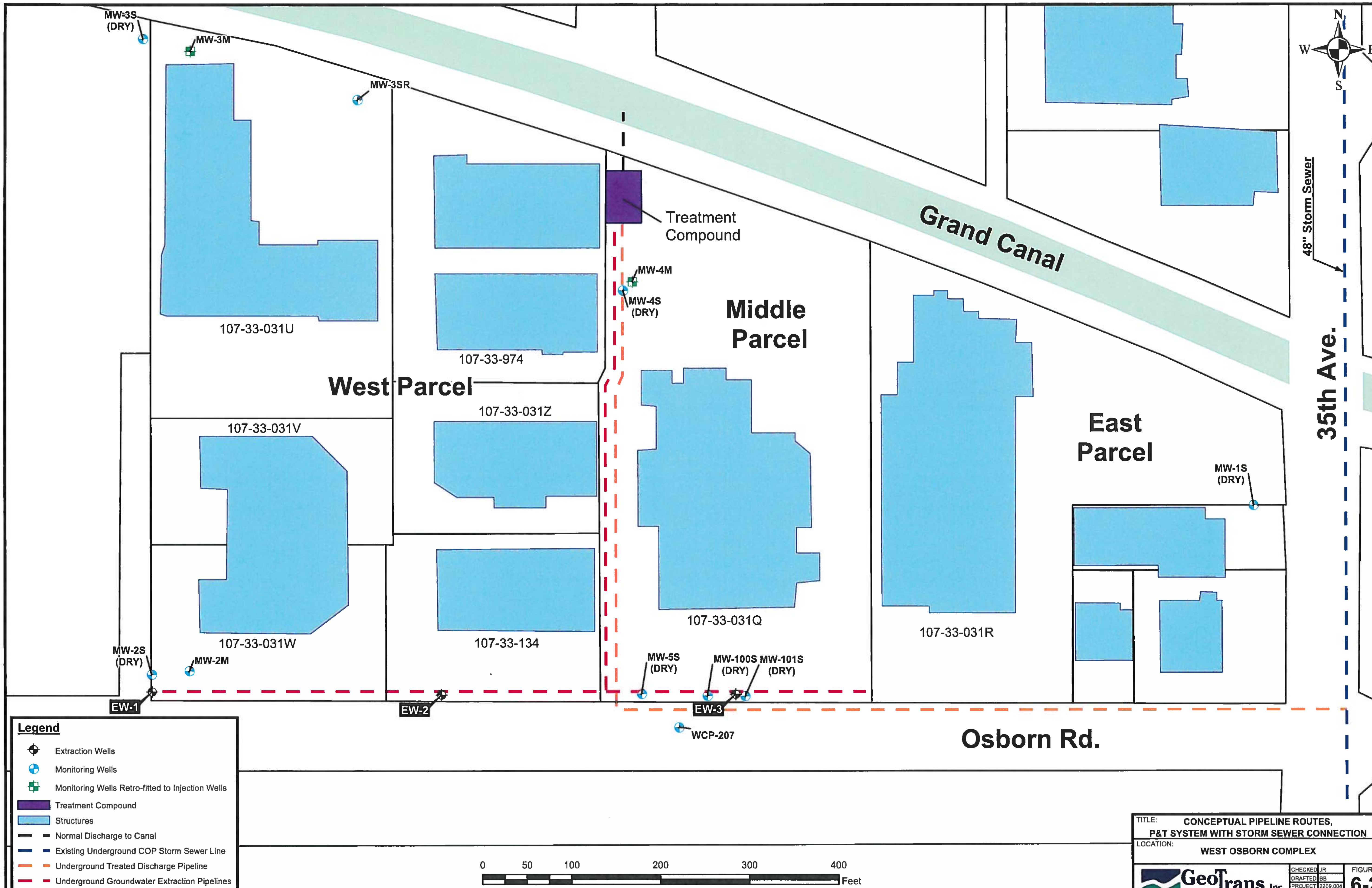


TITLE:	CONCEPTUAL PIPELINE ROUTES, P&T SYSTEM WITH INJECTION WELLS
LOCATION:	WEST OSBORN COMPLEX

GeoTrans, Inc.

CHECKED	JR
DRAFTED	BB
PROJECT	2209.004
DATE	6/14/11

FIGURE 6-1



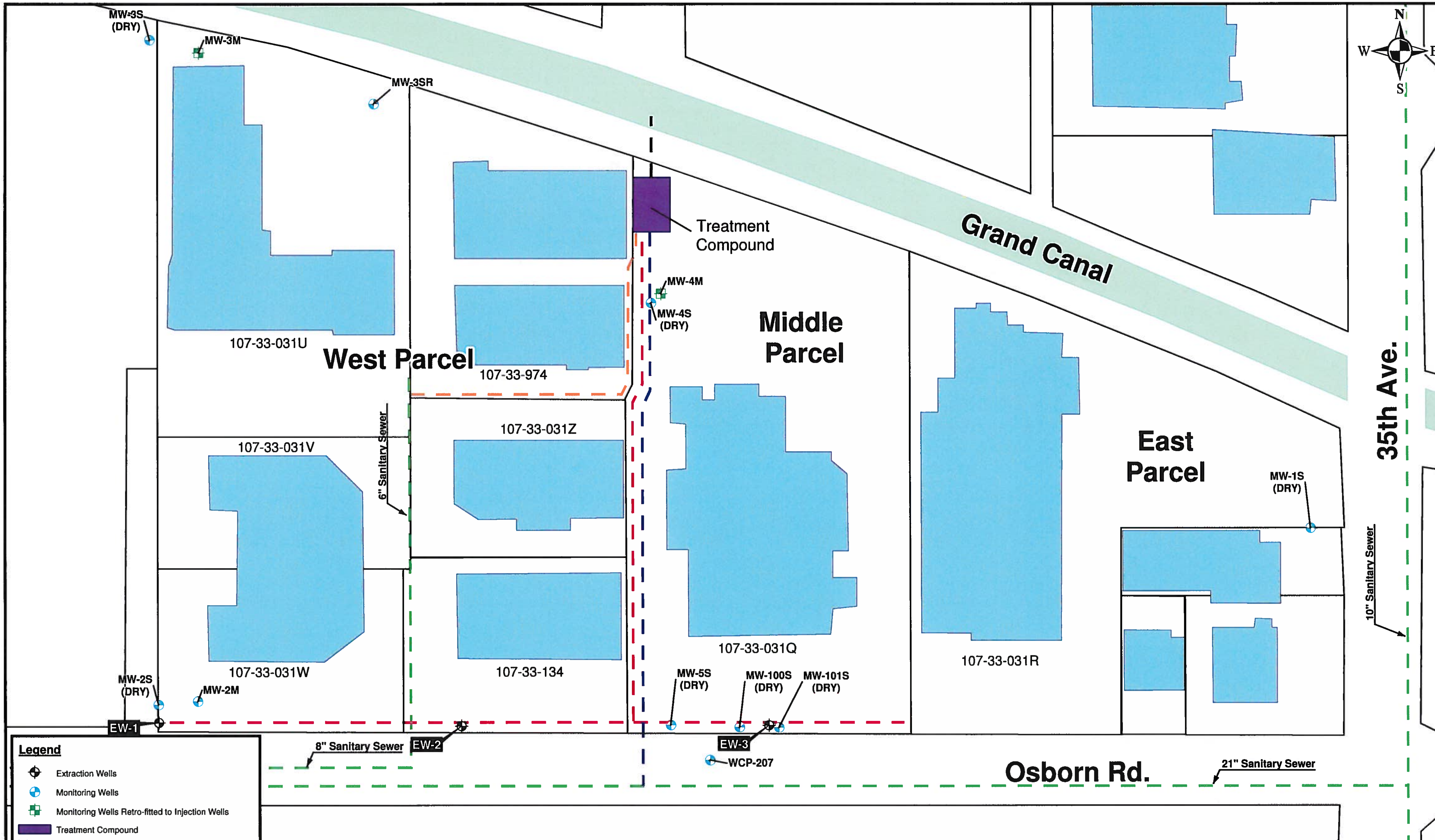
TITLE: CONCEPTUAL PIPELINE ROUTES, P&T SYSTEM WITH STORM SEWER CONNECTION

LOCATION: WEST OSBORN COMPLEX

GeoTrans, Inc.

CHECKED	JR
DRAFTED	BB
PROJECT	2209.004
DATE	6/14/11

FIGURE 6-2



TITLE: CONCEPTUAL PIPELINE ROUTES, P&T SYSTEM WITH SANITARY SEWER CONNECTION

LOCATION: WEST OSBORN COMPLEX

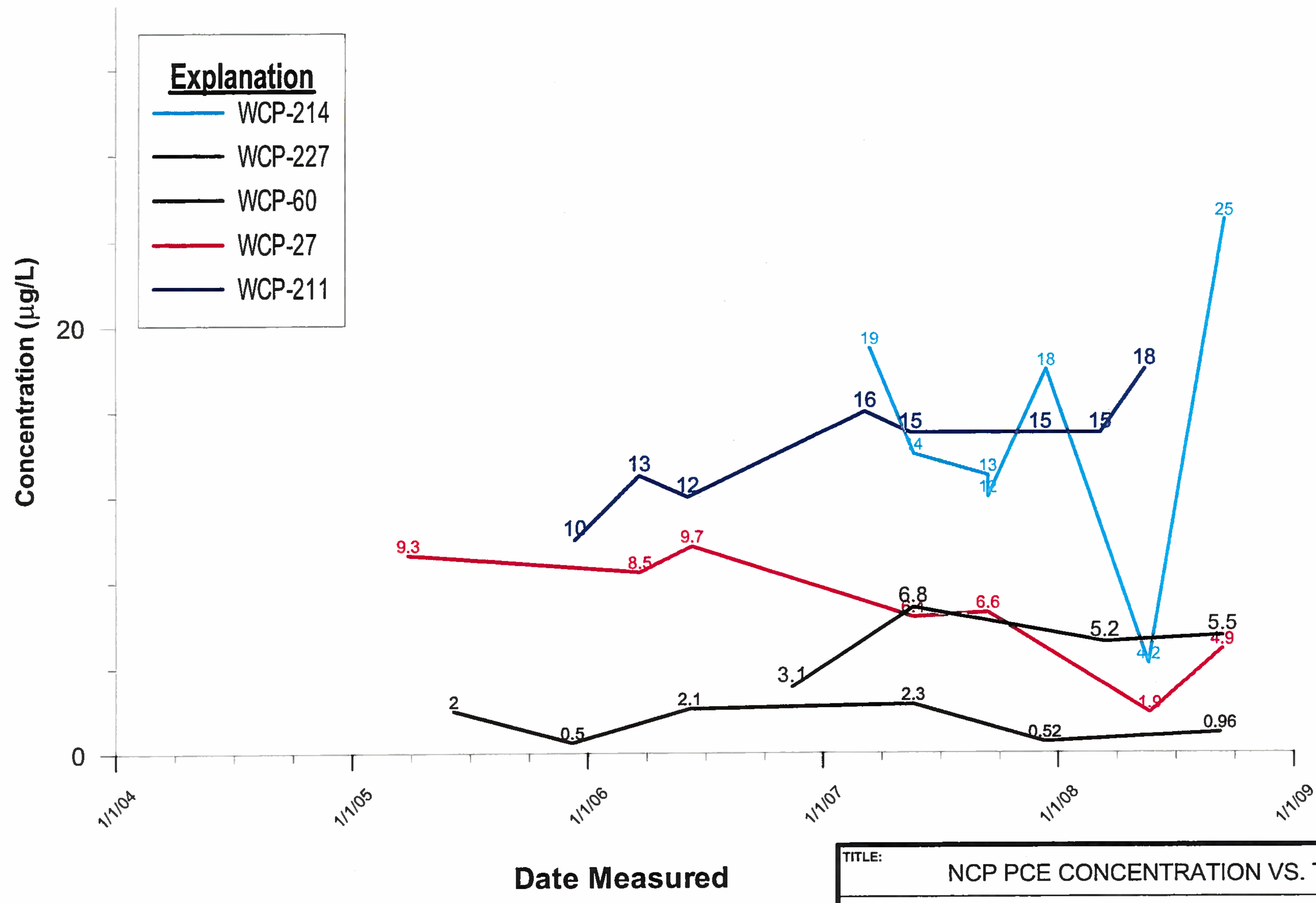
GeoTrans, Inc.

CHECKED JR
DRAFTED BB
PROJECT 2209.004
DATE 8/14/11

FIGURE 6-3

APPENDIX A

TIME SERIES PLOTS – WOC SGWS AND NCP WELLS



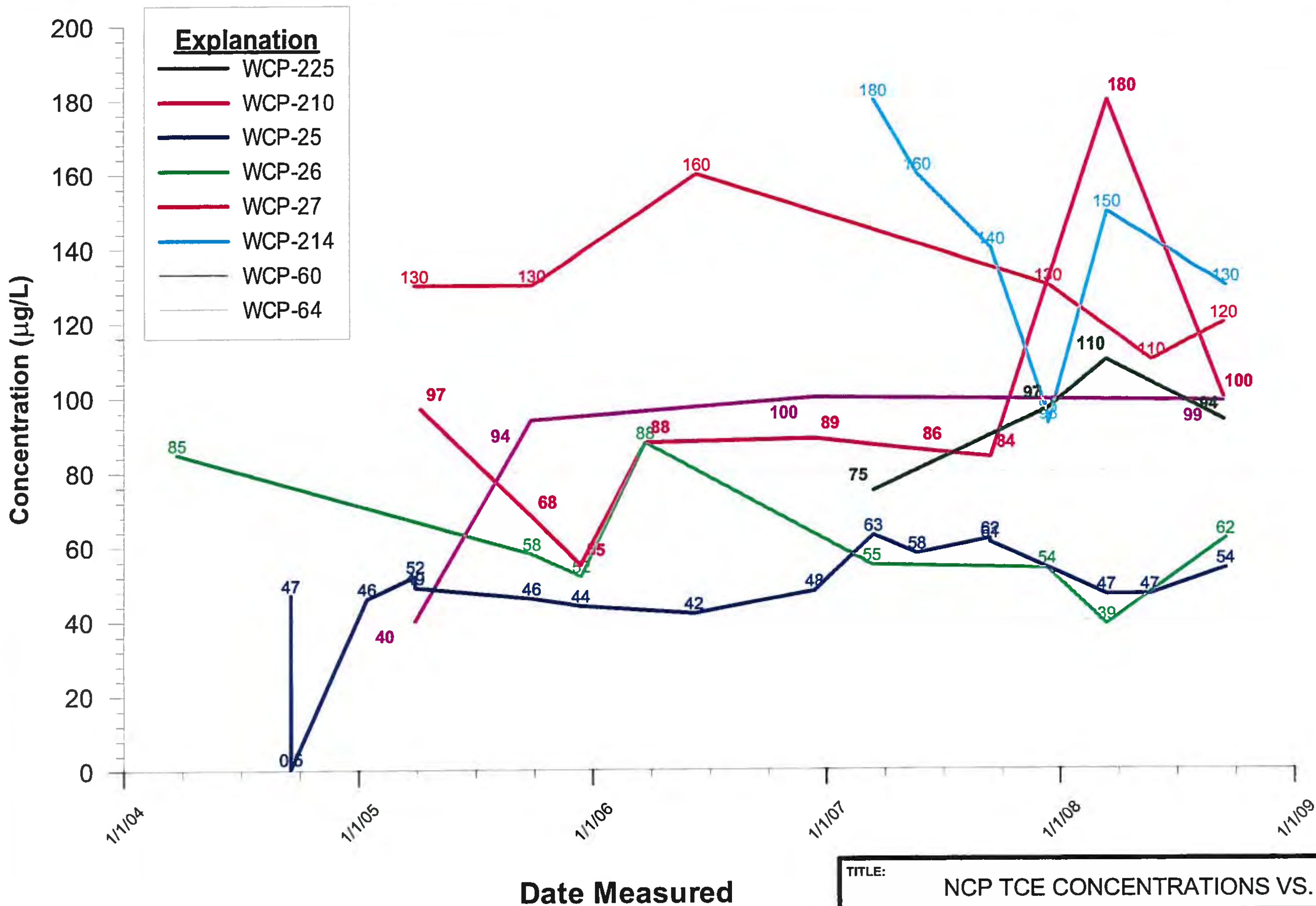
Note:
Grand Canal was lined in January 1998.

TITLE: NCP PCE CONCENTRATION VS. TIME

LOCATION: WEST OSBORN COMPLEX WQARF SITE, PHOENIX, ARIZONA

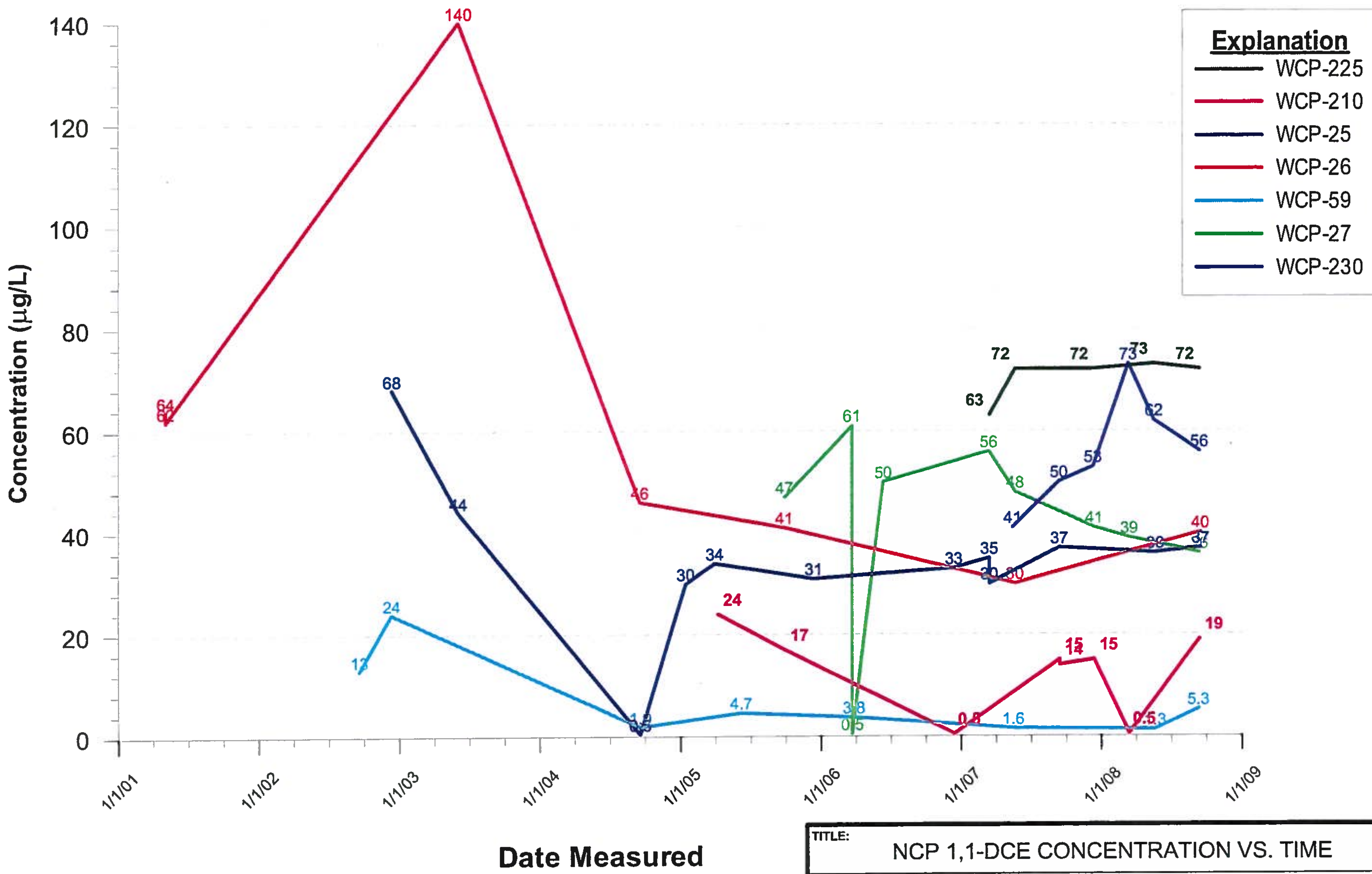
GeoTrans, Inc.

CHECKED	JZ	CHART:
DRAFTED	TD	A-1
PROJECT	2209.003	
DATE	05/13/09	



Note:
Grand Canal was lined in January 1998.

TITLE: NCP TCE CONCENTRATIONS VS. TIME			
LOCATION: WEST OSBORN COMPLEX WQARF SITE, PHOENIX, ARIZONA			
GeoTrans, Inc.	CHECKED	JZ	CHART:
	DRAFTED	TD	A-2
	PROJECT	2209.003	
	DATE	05/13/09	

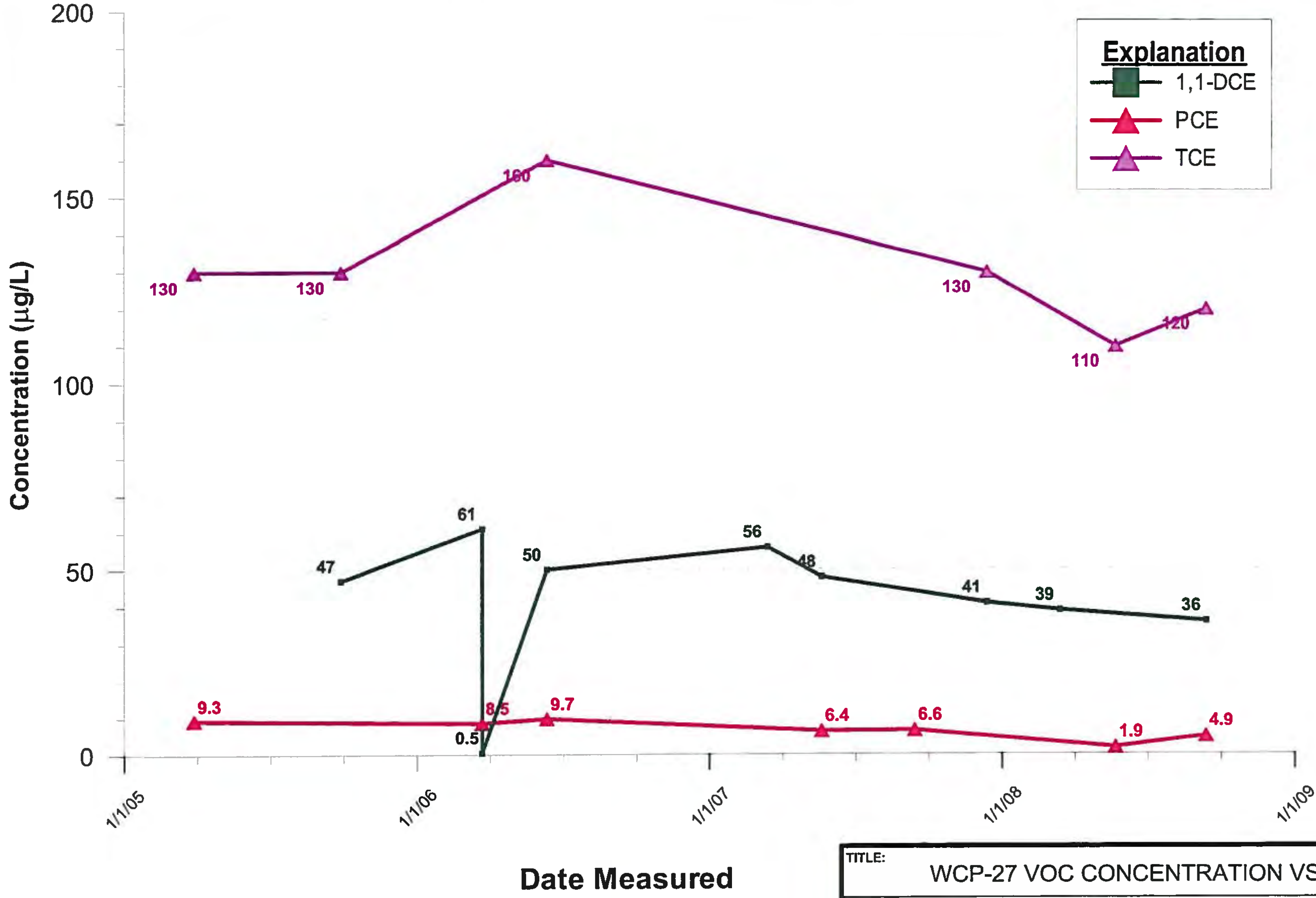


Note:
Grand Canal was lined in January 1998.

TITLE:	NCP 1,1-DCE CONCENTRATION VS. TIME
LOCATION:	WEST OSBORN COMPLEX WQARF SITE, PHOENIX, ARIZONA

GeoTrans, Inc.

CHECKED	JZ	CHART:
DRAFTED	TD	A-3
PROJECT	2209.003	
DATE	05/13/09	

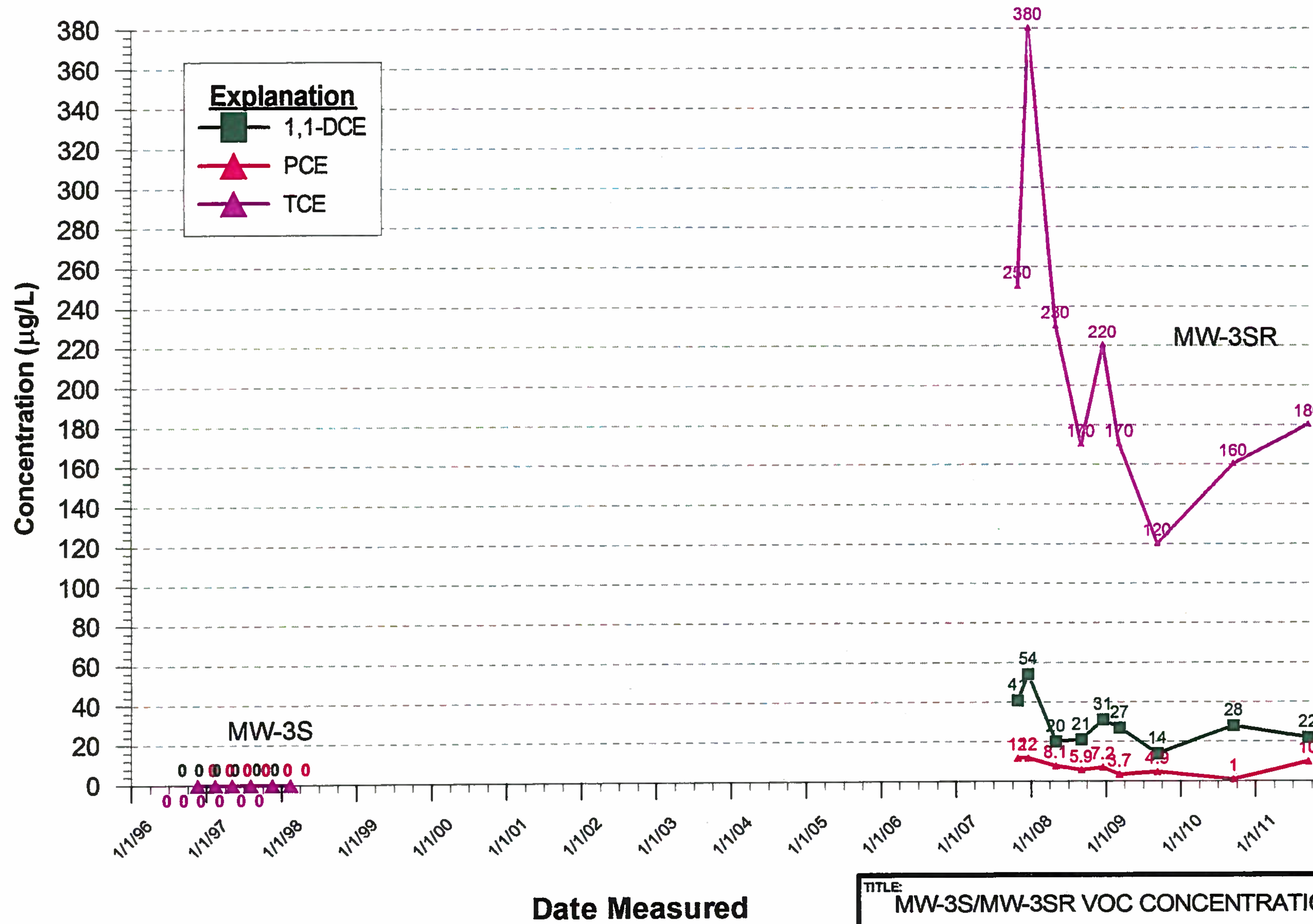


Note:
Grand Canal was lined in January 1998.

TITLE:	WCP-27 VOC CONCENTRATION VS. TIME
LOCATION:	WEST OSBORN COMPLEX WQARF SITE, PHOENIX, ARIZONA

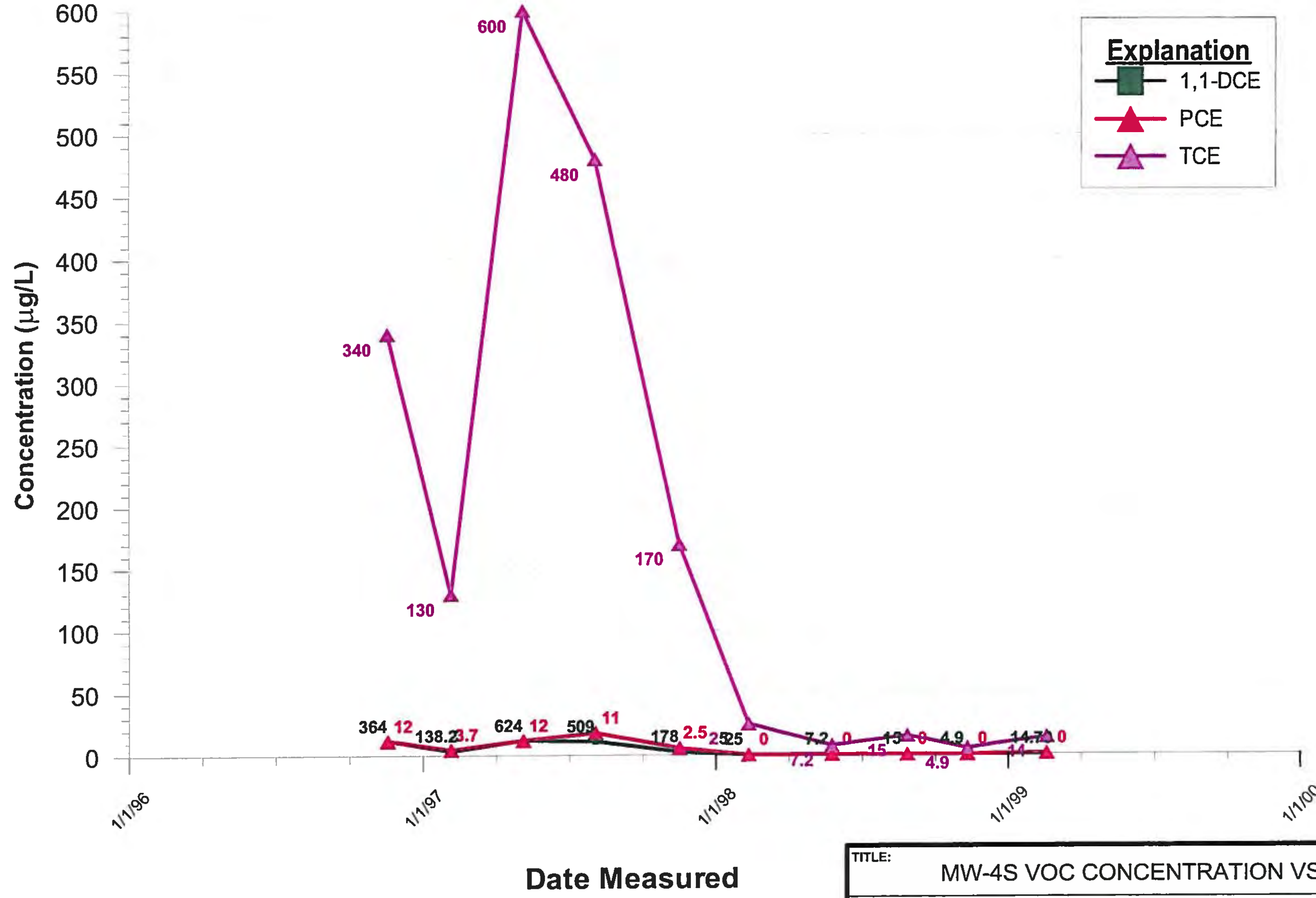
GeoTrans, Inc.

CHECKED	JZ	CHART:
DRAFTED	TD	A-4
PROJECT	2209.003	
DATE	05/13/09	



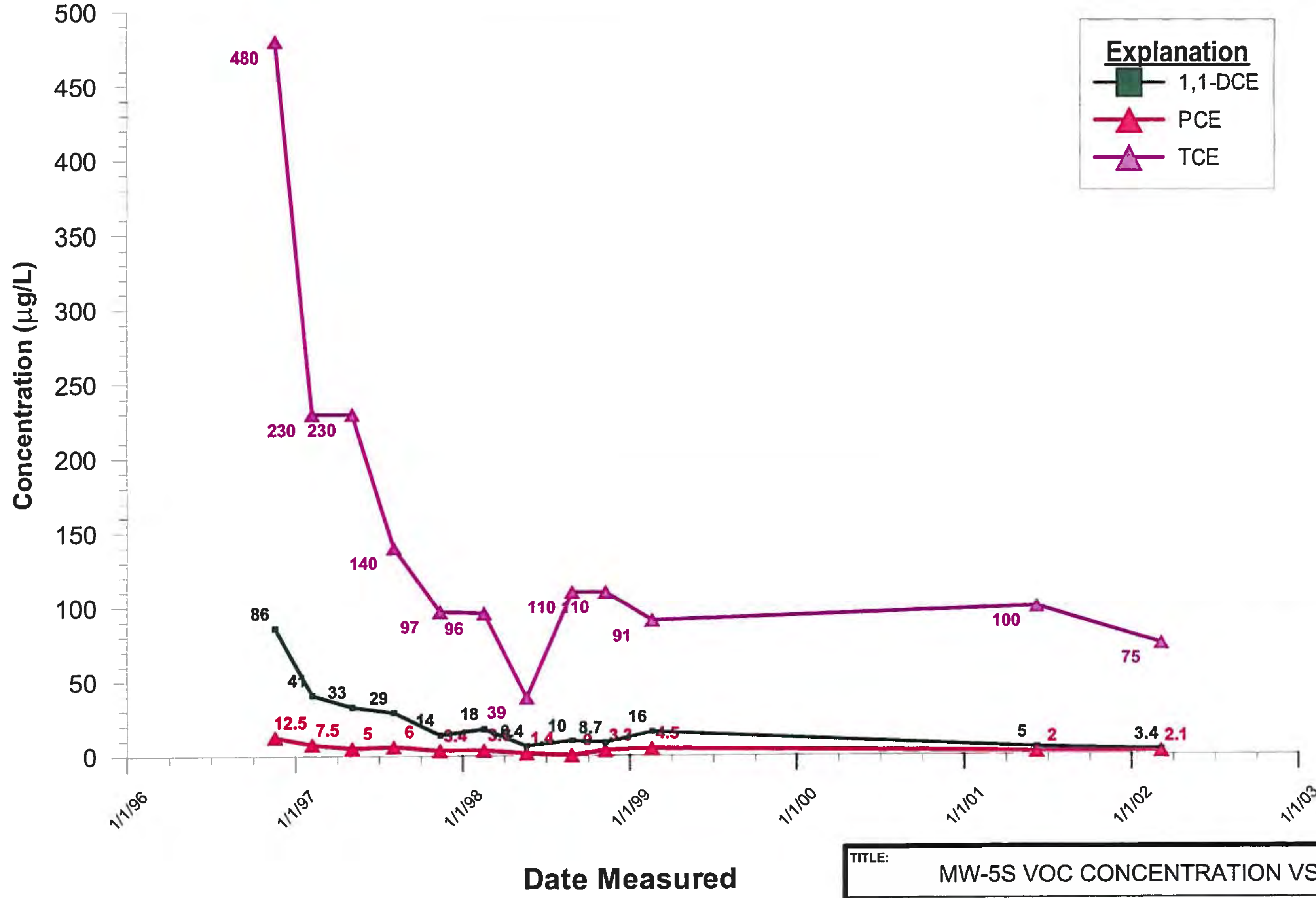
Note:
Grand Canal was lined in January 1998.
Well MW-3S went dry in February 1998.
Replacement Well MW-3SR was installed in October 2007.

TITLE: MW-3S/MW-3SR VOC CONCENTRATIONS VS. TIME				
LOCATION: WEST OSBORN COMPLEX WQARF SITE, PHOENIX, ARIZONA				
GeoTrans, Inc.	CHECKED	JZ	CHART:	A-5
	DRAFTED	TD/MO		
	PROJECT	2209.003		
	DATE	11/02/11		



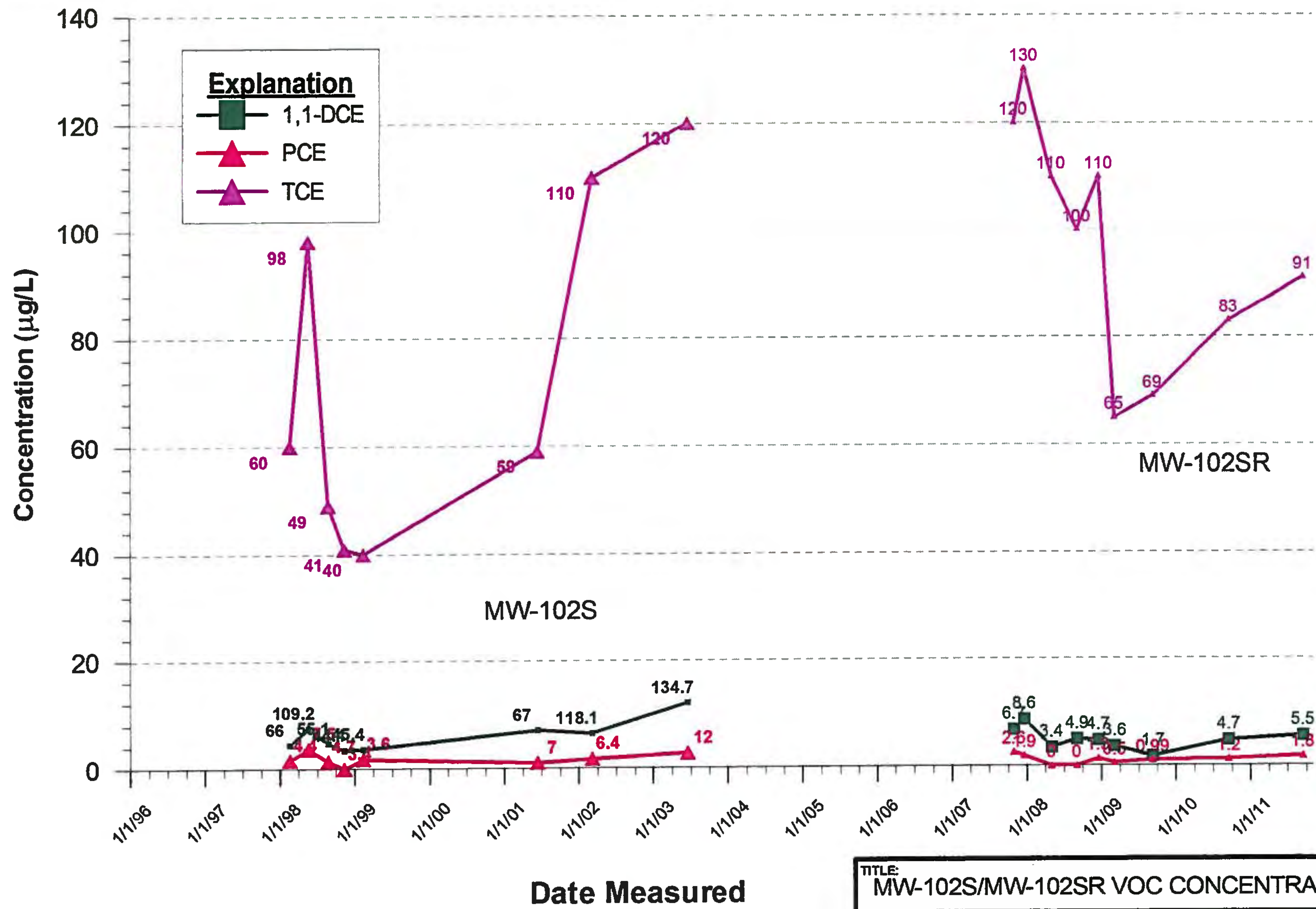
Note:
Grand Canal was lined in January 1998.
Well MW-4S went dry in August 2001.

TITLE: MW-4S VOC CONCENTRATION VS. TIME	
LOCATION: WEST OSBORN COMPLEX WQARF SITE, PHOENIX, ARIZONA	
GeoTrans, Inc.	CHECKED: JZ; DRAFTED: TD; PROJECT: 2209.003; DATE: 05/13/09 — CHART: A-6



Note:
Grand Canal was lined in January 1998.
Well MW-5S went dry in May 2003.

TITLE: MW-5S VOC CONCENTRATION VS. TIME			
LOCATION: WEST OSBORN COMPLEX WQARF SITE, PHOENIX, ARIZONA			
GeoTrans, Inc.	CHECKED	JZ	CHART: A-7
	DRAFTED	TD	
	PROJECT	2209.003	
	DATE	05/13/09	



Note:
Grand Canal was lined in January 1998.
Well MW-102S went dry in January 2004.
Replacement Well MW-102SR was installed in October 2007.

TITLE: MW-102S/MW-102SR VOC CONCENTRATION VS. TIME			
LOCATION: WEST OSBORN COMPLEX WQARF SITE, PHOENIX, ARIZONA			
GeoTrans, Inc.	CHECKED	JZ	CHART: A-8
	DRAFTED	TD/MO	
	PROJECT	2209.003	
	DATE	11/02/11	

APPENDIX B

VENDOR MODELING RESULTS FOR LQAC AND AIR STRIPPING

ShallowTray® low profile air strippers

System Performance Estimate

Client and Proposal Information:

Tetra Tech Geo (GeoTrans)

Series chosen:	2300	
Water Flow Rate:	30 gpm	6.8 m3/hr
Air Flow Rate:	300 scfm	510 m3/hr
Water Temp:	65 °F	18 °C
Air Temp:	65 °F	18 °C
A/W Ratio:	75 :1	
Safety Factor:	0%	

Contaminant	Untreated Influent / Effluent Target	Model 2311 Effluent lbs/hr	ppmv	Model 2321 Effluent lbs/hr	ppmv	SELECTED MODEL Model 2331 Effluent lbs/hr	ppmv	Model 2341 Effluent lbs/hr	ppmv	Model 2351 Effluent lbs/hr	ppmv
		%removal		%removal		%removal		%removal		%removal	
1,1-Dichloroethylene	15 ppb	<1 ppb		<1 ppb		<1 ppb		<1 ppb		<1 ppb	
Solubility 500 ppm	0.1 ppb	0.00	0.05	0.00	0.05	0.00	0.05	0.00	0.05	0.00	0.05
Mwt 96.94		97.04%		99.91%		100.00%		100.00%		100.00%	
Tetrachloroethylene	15 ppb	1 ppb		<1 ppb		<1 ppb		<1 ppb		<1 ppb	
Solubility 150 ppm	0.1 ppb	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.03
Mwt 165.83		93.06%		99.52%		99.97%		100.00%		100.00%	
Trichloroethylene	200 ppb	16 ppb		1 ppb		<1 ppb		<1 ppb		<1 ppb	
Solubility 1100 ppm	1 ppb	0.00	0.44	0.00	0.48	0.00	0.48	0.00	0.48	0.00	0.48
Mwt 131.5		92.21%		99.39%		99.95%		100.00%		100.00%	
Total ppb	230 ppb	17 ppb		1 ppb		0 ppb		0 ppb		0 ppb	
Total VOC lbs/hr - ppmv		0.00	0.52	0.00	0.56	0.00	0.56	0.00	0.56	0.00	0.56
Total		92.58%		99.44%		99.96%		100.00%		100.00%	

Report Generated: 1/16/2012 Modeler V6.12e 5/24/2001

ShallowTray®
low profile air strippers

HIGH FLOW

System Performance Estimate

Client and Proposal Information:

Tetra Tech Geo (GeoTrans)

Series chosen:	31200	
Water Flow Rate:	300 gpm	68.2 m3/hr
Air Flow Rate:	1800 scfm	3060 m3/hr
Water Temp:	65 °F	18 °C
Air Temp:	65 °F	18 °C
A/W Ratio:	45 :1	
Safety Factor:	0%	

Contaminant	Untreated Influent / Effluent Target	Model 31211 Effluent lbs/hr	Model 31211 ppmv / %removal	Model 31221 Effluent lbs/hr	Model 31221 ppmv / %removal	Model 31231 Effluent lbs/hr	Model 31231 ppmv / %removal	SELECTED MODEL Model 31241 Effluent lbs/hr	Model 31241 ppmv / %removal	Model 31251 Effluent lbs/hr	Model 31251 ppmv / %removal
1,1-Dichloroethylene	20 ppb	2 ppb		<1 ppb		<1 ppb		<1 ppb		<1 ppb	
Solubility 500 ppm	0.1 ppb	0.00	0.10	0.00	0.11	0.00	0.11	0.00	0.11	0.00	0.11
Mwt 96.94			90.04%		99.01%		99.90%		99.99%		100.00%
Tetrachloroethylene	5 ppb	1 ppb		<1 ppb		<1 ppb		<1 ppb		<1 ppb	
Solubility 150 ppm	0.1 ppb	0.00	0.01	0.00	0.02	0.00	0.02	0.00	0.02	0.00	0.02
Mwt 165.83			77.77%		95.06%		98.90%		99.76%		99.95%
Trichloroethylene	150 ppb	38 ppb		10 ppb		2 ppb		<1 ppb		<1 ppb	
Solubility 1100 ppm	1 ppb	0.02	0.45	0.02	0.56	0.02	0.59	0.02	0.60	0.02	0.60
Mwt 131.5			74.57%		93.53%		98.36%		99.58%		99.89%
Total ppb	175 ppb	41 ppb		10 ppb		3 ppb		1 ppb		0 ppb	
Total VOC lbs/hr - ppmv		0.02	0.56	0.02	0.69	0.03	0.72	0.03	0.73	0.03	0.73
Total			76.43%		94.20%		98.55%		99.63%		99.91%

Report Generated: 1/16/2012 Modeler V6.12e 5/24/2001

ShallowTray®
low profile air strippers

System Performance Estimate

Client and Proposal Information:

Tetra Tech Geo (GeoTrans)

HIGH FLOW

Series chosen:	41200	
Water Flow Rate:	500 gpm	113.6 m3/hr
Air Flow Rate:	2400 scfm	4080 m3/hr
Water Temp:	65 °F	18 °C
Air Temp:	65 °F	18 °C
A/W Ratio:	36 :1	
Safety Factor:	0%	

SELECT LARGER MODEL

Contaminant	Untreated Influent Effluent Target	Model 41211 Effluent lbs/hr ppmv %removal	Model 41221 Effluent lbs/hr ppmv %removal	Model 41231 Effluent lbs/hr ppmv %removal	Model 41241 Effluent lbs/hr ppmv %removal	Model 41251 Effluent lbs/hr ppmv %removal
1,1-Dichloroethylene Solubility 500 ppm Mwt 96.94	20 ppb 0.1 ppb	7 ppb 0.00 0.09 86.26%	2 ppb 0.00 0.12 88.62%	<1 ppb 0.00 0.13 96.16%	<1 ppb 0.00 0.13 98.70%	<1 ppb 0.00 0.14 99.56%
Tetrachloroethylene Solubility 150 ppm Mwt 165.83	3.5 ppb 0.1 ppb	1 ppb 0.00 0.01 63.57%	<1 ppb 0.00 0.01 86.73%	<1 ppb 0.00 0.01 95.16%	<1 ppb 0.00 0.01 98.24%	<1 ppb 0.00 0.01 99.36%
Trichloroethylene Solubility 1100 ppm Mwt 131.5	135 ppb 1 ppb	61 ppb 0.02 0.37 54.68%	28 ppb 0.03 0.54 79.46%	13 ppb 0.03 0.61 90.69%	6 ppb 0.03 0.65 95.78%	3 ppb 0.03 0.67 98.09%
Total ppb	159 ppb	69 ppb	30 ppb	14 ppb	6 ppb	3 ppb
Total VOC lbs/hr - ppmv		0.02 0.47	0.03 0.67	0.04 0.76	0.04 0.80	0.04 0.81
Total		56.34%	80.78%	91.48%	96.20%	98.30%

Report Generated: 1/16/2012 Modeler V6.12e 5/24/2001

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VAPOR PHASE ACTIVATED CARBON USAGE SUMMARY & EQUIPMENT COST			
	GAC USAGE (LBS/DAY)	EQUIPMENT COST	EQUIPMENT
300-SCFM	5.44-LBS/DAY	$8,650.00	PS-VAP-500-48C
1,800-SCFM	41.3-LBS/DAY	$23,895.00	PS-VAP-3000-48C
2,400-SCFM	60-LBS/DAY	$32,250.00	PS-VAP-5000-48C

VAPOR PHASE ACTIVATED CARBON CHANGE OUT FREQUENCY			
FLOWRATE (SCFM)	EQUIPMENT	LBS GAC PER FILTER	# CHANGE OUTS PER YEAR
300-SCFM	PS-VAP-500-48C	500-LBS	4
1,800-SCFM	PS-VAP-3000-48C	3,000-LBS	6
2,400-SCFM	PS-VAP-5000-48C	5,000-LBS	6

Notes:

1. Equipment includes two (2) GAC Filters filled with GAC. No interconnecting piping.
2. GAC Quoted is Virgin 4 X 8 Coconut Shell GAC, which is the same GAC Used for Estimating the GAC Usage Rates.
3. Pricing Excludes applicable sales tax.
4. Pricing Excludes Transportation to the Site and Off-Loading.

PROMINENT
SYSTEMS INC
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Client: Mr. Jeff W. Rackow, P.E. , Tetra Tech, Inc.
Report Date: 01/16/11 2:09PM PST

VAPOR PHASE ISOTHERM REPORT

Influent Conditions

Flowrate (SFCM)	300.0	**Flowrate (ACFM)**	232.7
Temperature (F)	65.0	**Temperature (R)**	524.7
Pressure (PSIG)	4.500	**Pressure (PSIA)**	19.2
Relative Humidity (%)	50.0	**Site Elevation (FT)**	Sea Level

Adsorbate	Concentration ppmV	% Loading (lb VOC /lb GAC)	Mass Flowrate (lbs VOC / Day)	GAC Usage Rate (lbs GAC / Day)
Trichloroethene	0.48	0.060907	0.09279	1.523
Tetrachloroethene	0.03	0.097411	0.00733	0.075
1,1-Dichloroethene	0.05	0.005329	0.00714	1.339
				2.938

(Total Activated Carbon Usage Rate Mulitiplied by 1.85)

Estimated Activated Carbon Usage Rate (Lbs Carbon / Day) 5.44

Note: Standard Temperature 60°F, and Standard Pressure 14.7-PSIA

Activated Carbon Usage Rates have been estimated using Prominent Systems, Inc.'s proprietary predictive software based upon empirical and predictive modeling. Actual Activated Carbon Usage Rates may differ from this estimate due to fluctuating influent concentrations, background compounds not included in this report, along with many other factors. No expressed or implied warranty in regards to the applicability or suitability of the information contained in this report.

VAPOR PHASE ISOTHERM DESIGN PARAMETERS

System Temperature	70.00000 °F
Air Flow Rate	300.00000 SCFM
System Pressure	14.70000 psi
Relative Humidity	50.0000 %

VAPOR PHASE DESIGN

Component Name	*Concentration*	*Q [Wt %]*	*#GAC/day at Saturation*
ETHENE,TRICHLORO- (TCE)	0.4800 ppmv	5.2345	1.3447
ETHENE,TETRACHLORO- (PCE)	0.0300 ppmv	6.8910	0.0806
ETHENE,1,1-DICHLORO-	0.0500 ppmv	0.3747	1.4446

Total Carbon Usage Estimated at Breakthrough
5.0224 #GAC/day

(Total has been multiplied by a factor of 1.75)

* indicates that Relative Humidity was calculated
~ indicates that Relative Humidity was approximated

The above carbon usage estimates are based on both experimental data as well as predictive models. Actual carbon usage rates observed at various stages of breakthrough depend on many factors, and may therefore differ from the above estimates. Please contact Westates Carbon Products for further assisitance.

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Client: Mr. Jeff W. Rackow, P.E. , Tetra Tech, Inc.
Report Date: 01/16/11 2:09PM PST

VAPOR PHASE ISOTHERM REPORT

Influent Conditions

Flowrate (SFCM)	1800.0	**Flowrate (ACFM)**	1396.2
Temperature (F)	65.0	**Temperature (R)**	524.7
Pressure (PSIG)	4.500	**Pressure (PSIA)**	19.2
Relative Humidity (%)	50.0	**Site Elevation (FT)**	Sea Level

Adsorbate	**Concentration** ppmV	**% Loading** (lb VOC /lb GAC)	**Mass Flowrate** (lbs VOC / Day)	**GAC Usage Rate** (lbs GAC / Day)
Trichloroethene	0.60	0.066178	0.69592	10.516
Tetrachloroethene	0.02	0.085936	0.02930	0.341
1,1-Dichloroethene	0.11	0.008232	0.09421	11.445
				22.302

(Total Activated Carbon Usage Rate Mulitiplied by 1.85)

Estimated Activated Carbon Usage Rate (Lbs Carbon / Day) 41.26

Note: Standard Temperature 60°F, and Standard Pressure 14.7-PSIA

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VAPOR PHASE ISOTHERM DESIGN PARAMETERS

System Temperature	70.00000 °F
Air Flow Rate	1800.00000 SCFM
System Pressure	14.70000 psi
Relative Humidity	50.0000 %

VAPOR PHASE DESIGN

Component Name	Concentration	Q [Wt %]	#GAC/day at Saturation
ETHENE,TRICHLORO- (TCE)	0.6000 ppmv	5.7171	9.2340
ETHENE,TETRACHLORO- (PCE)	0.0200 ppmv	6.0221	0.3688
ETHENE,1,1-DICHLORO-	0.1100 ppmv	0.5746	12.4362

Total Carbon Usage Estimated at Breakthrough
38.5682 #GAC/day

(Total has been multiplied by a factor of 1.75)

* indicates that Relative Humidity was calculated
~ indicates that Relative Humidity was approximated

The above carbon usage estimates are based on both experimental data as well as predictive models. Actual carbon usage rates observed at various stages of breakthrough depend on many factors, and may therefore differ from the above estimates. Please contact Westates Carbon Products for further assisitance.

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Client: Mr. Jeff W. Rackow, P.E., Tetra Tech, Inc.
Report Date: 01/16/11 2:09PM PST

VAPOR PHASE ISOTHERM REPORT

Influent Conditions

Flowrate (SFCM)	2400.0	**Flowrate (ACFM)**	1861.7
Temperature (F)	65.0	**Temperature (R)**	524.7
Pressure (PSIG)	4.500	**Pressure (PSIA)**	19.2
Relative Humidity (%)	50.0	**Site Elevation (FT)**	Sea Level

Adsorbate	**Concentration** ppmV	**% Loading** (lb VOC /lb GAC)	**Mass Flowrate** (lbs VOC / Day)	**GAC Usage Rate** (lbs GAC / Day)
Trichloroethene	0.67	0.068910	1.03615	15.036
Tetrachloroethene	0.01	0.068745	0.01953	0.284
1,1-Dichloroethene	0.14	0.009362	0.15988	17.078
				32.398

(Total Activated Carbon Usage Rate Mulitiplied by 1.85)

Estimated Activated Carbon Usage Rate (Lbs Carbon / Day) 59.94

Note: Standard Temperature 60°F, and Standard Pressure 14.7-PSIA

Activated Carbon Usage Rates have been estimated using Prominent Systems, Inc.'s proprietary predictive software based upon empirical and predictive modeling. Actual Activated Carbon Usage Rates may differ from this estimate due to fluctuating influent concentrations, background compounds not included in this report, along with many other factors. No expressed or implied warranty in regards to the applicability or suitability of the information contained in this report.

VAPOR PHASE ISOTHERM DESIGN PARAMETERS

System Temperature	70.00000 °F
Air Flow Rate	2400.00000 SCFM
System Pressure	14.70000 psi
Relative Humidity	50.0000 %

VAPOR PHASE DESIGN

Component Name	Concentration	Q [Wt %]	#GAC/day at Saturation
ETHENE,TRICHLORO- (TCE)	0.6700 ppmv	5.9686	13.1691
ETHENE,TETRACHLORO- (PCE)	0.0100 ppmv	4.7420	0.3122
ETHENE,1,1-DICHLORO-	0.1400 ppmv	0.6522	18.5917

Total Carbon Usage Estimated at Breakthrough
56.1279 #GAC/day

(Total has been multiplied by a factor of 1.75)

* indicates that Relative Humidity was calculated
~ indicates that Relative Humidity was approximated

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LIQUID PHASE ACTIVATED CARBON USAGE SUMMARY & EQUIPMENT COST			
FLOWRATE (GPM)	**GAC USAGE (LBS/DAY)**	**EQUIPMENT COST**	**EQUIPMENT**
30-GPM	5.44-LBS/DAY	$14,000.00	PS-LIQ-1000-1230C
300-GPM	46.1-LBS/DAY	$34,900.00	PS-LIQ-3000-1230C
500-GPM	74.2-LBS/DAY	$80,500.00	PS-LIQ-10000-1230C

LIQUID PHASE ACTIVATED CARBON CHANGE OUT FREQUENCY			
FLOWRATE (GPM)	**EQUIPMENT**	**LBS GAC PER FILTER**	**# CHANGE OUTS PER YEAR**
30-GPM	PS-LIQ-1000-1230C	1,000-LBS	2
300-GPM	PS-LIQ-3000-1230C	3,000-LBS	6
500-GPM	PS-LIQ-10000-1230C	10,000-LBS	3

Notes:

1. Equipment includes two (2) GAC Filters filled with GAC. Interconnecting piping included.
2. GAC Quoted is Virgin 12 x 30 Coconut Shell GAC, which is the same GAC Used for Estimating the GAC Usage Rates.
3. Pricing Excludes applicable sales tax.
4. Pricing Excludes Transportation to the Site and Off-Loading.

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Client: Mr. Jeff W. Rackow, P.E. , Tetra Tech, Inc.
Report Date: 1/16/2012 4:59:52 PM

LIQUID PHASE ISOTHERM REPORT

Influent Conditions

Flowrate (GPM)	30.0	**Pressure (PSIG)**	75.0
Temperature (F)	65.0	**Pressure (PSIA)**	89.7

Adsorbate	**Concentration** ug/L	**% Loading** (lb VOC /lb GAC)	**Mass Flowrate** (lbs VOC / Day)	**GAC Usage Rate** (lbs GAC / Day)
Trichloroethene	200.00	0.030000	0.071971200	2.399
Tetrachloroethene	15.00	0.035000	0.005397840	0.154
1,1-Dichloroethene	15.00	0.015000	0.005397840	0.360
				2.913

(Total Activated Carbon Usage Rate Mulitiplied by 1.85)

Estimated Activated Carbon Usage Rate (Lbs Carbon / Day) **5.39**

Note: Standard Temperature 60°F, and Standard Pressure 14.7-PSIA

Activated Carbon Usage Rates have been estimated using Prominent Systems, Inc., proprietary predictive software based upon empirical and predictive modeling. Actual Activated Carbon Usage Rates may differ from this estimate due to fluctuating influent concentrations, background compounds not included in this report, along with many other factors. No expressed or implied warranty in regards to the applicability or suitability of the information contained in this report.

LIQUID PHASE ISOTHERM DESIGN PARAMETERS

Water Flow Rate 30.00000 gpm

LIQUID PHASE DESIGN

Component Name	Concentration	Q [Wt %]	#GAC/1000 gallons of water	Suitability
ETHENE,TRICHLORO- (TCE)	200.0000 ppbw	2.5794	0.0646	In Range
ETHENE,TETRACHLORO- (PCE)	15.0000 ppbw	1.6103	0.0078	In Range
ETHENE,1,1-DICHLORO-	15.0000 ppbw	0.1858	0.0673	In Range

Total Carbon Usage Estimated at Breakthrough

10.5624 #GAC/day

0.2445 #GAC/1000 gallons of water

(Both totals have been multiplied by a factor of 1.75)

The above carbon usage estimates are based on both experimental data as well as predictive models. Actual carbon usage rates observed at various stages of breakthrough depend on many factors, and may therefore differ from the above estimates. Please contact Westates Carbon Products for further assisitance.

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Client: Mr. Jeff W. Rackow, P.E., Tetra Tech, Inc.
Report Date: 1/16/2012 5:01:58 PM

LIQUID PHASE ISOTHERM REPORT

Influent Conditions

Flowrate (GPM)	300.0	**Pressure (PSIG)**	75.0
Temperature (F)	65.0	**Pressure (PSIA)**	89.7

Adsorbate	Concentration	% Loading	Mass Flowrate	GAC Usage Rate
	ug/L	(lb VOC /lb GAC)	(lbs VOC / Day)	(lbs GAC / Day)
Trichloroethene	150.00	0.028000	0.539784000	19.278
Tetrachloroethene	5.00	0.022000	0.017992800	0.818
1,1-Dichloroethene	20.00	0.015000	0.071971200	4.798
				24.894

(Total Activated Carbon Usage Rate Mulitiplied by 1.85)

Estimated Activated Carbon Usage Rate (Lbs Carbon / Day) **46.05**

Note: Standard Temperature 60°F, and Standard Pressure 14.7-PSIA

Activated Carbon Usage Rates have been estimated using Prominent Systems, Inc., proprietary predictive software based upon empirical and predictive modeling. Actual Activated Carbon Usage Rates may differ from this estimate due to fluctuating influent concentrations, background compounds not included in this report, along with many other factors. No expressed or implied warranty in regards to the applicability or suitability of the information contained in this report.

LIQUID PHASE ISOTHERM DESIGN PARAMETERS

Water Flow Rate 300.00000 gpm

LIQUID PHASE DESIGN

Component Name	Concentration	Q [Wt %]	#GAC/1000 gallons of water	Suitability
ETHENE,TRICHLORO- (TCE)	150.0000 ppbw	2.2467	0.0557	In Range
ETHENE,TETRACHLORO- (PCE)	5.0000 ppbw	0.9095	0.0046	In Range
ETHENE,1,1-DICHLORO-	20.0000 ppbw	0.2158	0.0773	In Range

Total Carbon Usage Estimated at Breakthrough

103.9624 #GAC/day

0.2407 #GAC/1000 gallons of water

(Both totals have been multiplied by a factor of 1.75)

The above carbon usage estimates are based on both experimental data as well as predictive models. Actual carbon usage rates observed at various stages of breakthrough depend on many factors, and may therefore differ from the above estimates. Please contact Westates Carbon Products for further assisitance.

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Client: Mr. Jeff W. Rackow, P.E. , Tetra Tech, Inc.
Report Date: 1/16/2012 5:04:20 PM

LIQUID PHASE ISOTHERM REPORT

Influent Conditions

Flowrate (GPM)	500.0	**Pressure (PSIG)**	75.0
Temperature (F)	65.0	**Pressure (PSIA)**	89.7

Adsorbate	**Concentration** ug/L	**% Loading** (lb VOC /lb GAC)	**Mass Flowrate** (lbs VOC / Day)	**GAC Usage Rate** (lbs GAC / Day)
Trichloroethene	135.00	0.028000	0.809676000	28.917
Tetrachloroethene	3.50	0.018000	0.020991600	1.166
1,1-Dichloroethene	20.00	0.012000	0.119952000	9.996
				40.079

(Total Activated Carbon Usage Rate Mulitiplied by 1.85)

Estimated Activated Carbon Usage Rate (Lbs Carbon / Day) **74.15**

Note: Standard Temperature 60°F, and Standard Pressure 14.7-PSIA

Activated Carbon Usage Rates have been estimated using Prominent Systems, Inc., proprietary predictive software based upon empirical and predictive modeling. Actual Activated Carbon Usage Rates may differ from this estimate due to fluctuating influent concentrations, background compounds not included in this report, along with many other factors. No expressed or implied warranty in regards to the applicability or suitability of the information contained in this report.

LIQUID PHASE ISOTHERM DESIGN PARAMETERS

Water Flow Rate 500.00000 gpm

LIQUID PHASE DESIGN

Component Name	***Concentration***	***Q [Wt %]***	***#GAC/1000 gallons of water***	***Suitability***
ETHENE,TRICHLORO- (TCE)	135.0000 ppbw	2.1359	0.0527	In Range
ETHENE,TETRACHLORO- (PCE)	3.5000 ppbw	0.7555	0.0039	Conc. Too Low
ETHENE,1,1-DICHLORO-	20.0000 ppbw	0.2158	0.0773	In Range

Total Carbon Usage Estimated at Breakthrough

168.6230 #GAC/day

0.2342 #GAC/1000 gallons of water

(Both totals have been multiplied by a factor of 1.75)

The above carbon usage estimates are based on both experimental data as well as predictive models. Actual carbon usage rates observed at various stages of breakthrough depend on many factors, and may therefore differ from the above estimates. Please contact Westates Carbon Products for further assisitance.

LIQUID PHASE ISOTHERM DESIGN PARAMETERS

Water Flow Rate 30.00000 gpm

LIQUID PHASE DESIGN

Component Name	Concentration	Q [Wt %]	#GAC/1000 gallons of water	Suitability
ETHENE,TRICHLORO- (TCE)	1.0000 ppbw	0.2028	0.0041	Conc. Too Low
ETHENE,TETRACHLORO- (PCE)	0.1000 ppbw	0.1189	7.0093e-04	Conc. Too Low
ETHENE,1,1-DICHLORO-	0.1000 ppbw	0.0137	0.0061	Conc. Too Low

Total Carbon Usage Estimated at Breakthrough

0.8231 #GAC/day

0.0191 #GAC/1000 gallons of water

(Both totals have been multiplied by a factor of 1.75)

The above carbon usage estimates are based on both experimental data as well as predictive models. Actual carbon usage rates observed at various stages of breakthrough depend on many factors, and may therefore differ from the above estimates. Please contact Westates Carbon Products for further assisitance.

LIQUID PHASE ISOTHERM DESIGN PARAMETERS

Water Flow Rate 300.00000 gpm

LIQUID PHASE DESIGN

Component Name	***Concentration***	***Q [Wt %]***	***#GAC/1000 gallons of water***	***Suitability***
ETHENE,TRICHLORO- (TCE)	1.0000 ppbw	0.2028	0.0041	Conc. Too Low
ETHENE,TETRACHLORO- (PCE)	0.0500 ppbw	0.0829	5.0255e-04	Conc. Too Low
ETHENE,1,1-DICHLORO-	0.0500 ppbw	0.0096	0.0044	Conc. Too Low

Total Carbon Usage Estimated at Breakthrough

6.7808 #GAC/day

0.0157 #GAC/1000 gallons of water

(Both totals have been multiplied by a factor of 1.75)

The above carbon usage estimates are based on both experimental data as well as predictive models. Actual carbon usage rates observed at various stages of breakthrough depend on many factors, and may therefore differ from the above estimates. Please contact Westates Carbon Products for further assisitance.

LIQUID PHASE ISOTHERM DESIGN PARAMETERS

Water Flow Rate 500.00000 gpm

LIQUID PHASE DESIGN

Component Name	Concentration	Q [Wt %]	#GAC/1000 gallons of water	Suitability
ETHENE,TRICHLORO- (TCE)	1.0000 ppbw	0.2028	0.0041	Conc. Too Low
ETHENE,TETRACHLORO- (PCE)	0.1000 ppbw	0.1189	7.0093e-04	Conc. Too Low
ETHENE,1,1-DICHLORO-	0.1000 ppbw	0.0137	0.0061	Conc. Too Low

Total Carbon Usage Estimated at Breakthrough

13.7176 #GAC/day

0.0191 #GAC/1000 gallons of water

(Both totals have been multiplied by a factor of 1.75)

The above carbon usage estimates are based on both experimental data as well as predictive models. Actual carbon usage rates observed at various stages of breakthrough depend on many factors, and may therefore differ from the above estimates. Please contact Westates Carbon Products for further assisitance.

APPENDIX C

DISCUSSION OF WHAEM MODELING RESULTS

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Date:	April 14, 2009
From:	Christopher Gutmann Senior Hydrogeologist
Recipients: **Address:**	Jeff Rackow, PE.; Jasenka Zbozinek, Ph.D. 4801 East Washington St, Suite 260, Phoenix Arizona 85034
Subject:	Remedial Groundwater Pumping Contaminant Evaluation for the West Osborn Complex WQARF Site Middle Fine-Grained Subunit of the Upper Alluvial Unit

The purpose of this letter is evaluate the spacing, pumping rates and locations necessary to capture the volatile organic compound (VOC) contaminated groundwater present in the Middle Fine-Grained Subunit (MFGS) of the Upper Alluvial Unit (UAU) aquifer beneath the West Osborn Complex (WOC) Water Quality Assurance Revolving Fund (WQARF) Site in Phoenix, Arizona. Work conducted by HSI GeoTrans, Inc. (now GeoTrans, Inc) in January 2000, titled *A Model of 3-Dimensional Groundwater Flow and TCE Transport at the West Osborn Complex Phoenix, Arizona*, summarized the data available at the time as applicable to the construction of a fate and transport groundwater model of the area. Additional supplementary information regarding the aquifer characteristics for the UAU was obtained from ADWR Modeling Report #8, *A Regional Groundwater Flow Model of the Salt River Valley, Phase II Phoenix Active Management Area Numerical Model, Calibration and Recommendations*, 1994 (the SRV Model).

REVIEW OF AVAILABLE DATA

WCP-227 Aquifer Testing

Recent aquifer testing (2008) conducted at well WCP-227 located approximately 550 feet north of the Grand Canal and the West Parcel of the WOC has provided additional understanding of the hydrogeologic characteristics of the MFGS, which is impacted by chlorinated hydrocarbons including trichloroethene (TCE), tetrachloroethene (PCE), and 1,1-dichloroethene (1,1-DCE). Results of the analysis of the aquifer testing were presented in the March 10, 2008 report by Locus Technologies titled "*Aquifer Pumping Test, Former Southwest Metals Industries Facility*." WCP-227 is constructed of 4-inch diameter PVC casing with a screen from 130 to 165 feet below ground surface (bgs). This interval is consistent with the impacted depth interval at the WOC, found at the Site to be present extending from the water table at 140 to 185 feet bgs. The modeling report referenced above describes this depth interval as the MFGS of the UAU, separating the underlying Lower Sand and Gravel Subunit (LSGS) of the UAU from the overlying Upper Coarse-Grained Subunit of the UAU. The MFGS is described in the modeling report as having a conductivity of 0.1 to 3 feet per day (ft/d). The data evaluation for the recent aquifer testing of WCP-227 indicated a hydraulic-conductivity range of values of 1.6 to 8.7 ft/d, based on observation well, and whether the analysis was for pumping or well recovery.

MW-206S Limited-Scale Aquifer Testing

The length of the WOC plume appears incongruous with aquifer hydraulic-conductivity values in the range suggested by aquifer testing at WCP-227. Preliminary model simulations using the EPA software package WhAEM2000 using hydraulic-conductivity values of 0.1 to 3 ft/d indicated that porosity values of less than 10% would be necessary for the plume to have migrated south to

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I-10. This incongruity indicated the need for further aquifer testing in the vicinity of the area of the plume targeted for consideration of remedy groundwater pumping wells.

A limited-duration aquifer test was conducted at MW-206S (location shown on Figure 1), on March 19, 2009. A temporary groundwater pump was installed in MW-206S along with a pressure transducer, and pumping was conducted for a period of 2 hours and 18 minutes at a rate of 24 gallons per minute (gpm). As measured by the transducer, during this time water-level drawdown of approximately 0.47 feet was observed in MW-206S after 2 hours of pumping (Figure 2). Following pumping, water levels were observed to recover to pre-pumping levels within minutes of shutting off the pump. Detailed recovery monitoring was not conducted. While the drawdown observed and the duration of pumping are not considered to be adequate to fully characterize the nature of the MFGS, they indicate that the hydraulic conductivity of the unit increases south of the canal. Analysis of the available data is presented in Figure 3, and suggests that hydraulic-conductivity values may be as much as two orders-of-magnitude higher than aquifer testing at WCP-227 indicated.

Results of the unconfined Cooper-Jacob analysis of the aquifer testing conducted at MW-206S indicate that in the immediate vicinity of the well, a hydraulic-conductivity value of 130 ft/d represents a good approximation for the aquifer characteristics (Figure 3). Although the typical saturated thickness of the MFGS in the vicinity of the WOC VOC plume is believed to be approximately 40 feet, the MFGS unit at MW-206S was observed to be approximately 70 feet thick. A transmissivity value was obtained by matching the apparent trend in data collected following the first 20 minutes of pumping. This value was then normalized by the saturated thickness of 70 feet to obtain a hydraulic-conductivity value of approximately 130 ft/d. It was observed that pumping conducted following a brief cessation of pumping (from elapsed minute 69 to minute 74 after the start of the test), drawdown began increasing at a slightly higher rate than prior to the cessation, although pumping rates were identified as unchanged. Aquifer test analysis was only conducted on the data obtained prior to the pump being shut off due to the uncertainty of the pumping rates and the apparent change in drawdown rate following reinitiation of pumping. It is assumed that pumping rates were greater than the initial 24 gpm rate, causing increased rates of drawdown. Alternatively, this may indicate that water begins to be produced from lower permeability sediment after drawdown propagates a certain distance from the well. If this behavior is representative of overall aquifer characteristics in the area, then the hydraulic conductivity of the aquifer in the area may be somewhat lower than 130 ft/d. This short-term aquifer test indicates that aquifer conditions vary from those observed in WCP-227, and that more complete characterization may be necessary. Further aquifer testing, involving higher pumping rates of 50-100 gpm is recommended for groundwater extraction wells which may be installed.

Remedial Groundwater Modeling

For the purposes of evaluating the locations, spacing, and pumping rates necessary to remediate the MFGS in the vicinity of the WOC, the MFGS can be represented in a simple model as homogeneous, infinitely continuous, unconfined and uniformly 40 feet thick. South of Osborn Road, aquifer parameters are assumed to be equivalent to those measured in MW-206S. Hydraulic conductivity is estimated to be 130 ft/d, with a storativity of 0.15. North of Osborn Road, aquifer parameters are assumed to be between those measured at WCP-227 and at MW-206S. Hydraulic conductivity at the WOC is estimated to be 40 ft/d, with a storativity of 0.15.

Groundwater modeling of the impact of proposed extraction wells was conducted using WhAEM2000 to model remedial pumping using two separate simulations. The first simulation was conducted for pumping wells located north of Osborn Road at the WOC Facility, and the second simulation for a line of pumping wells south of MW-206S. Modeled impacts to groundwater and associated pathlines travelled by captured groundwater for both simulations are shown on Figures 6-1 to 6-5. The first modeling simulation indicated that two wells, located adjacent to the existing monitoring wells MW-2S and MW-5S, screened over the entire 40-ft thick impacted interval, and pumping at 10 to 20 gpm each, would create capture zones that would encompass the West and Middle parcels of the WOC, and capture groundwater present beneath the parcels. Pumping is anticipated to cause groundwater drawdown of approximately 14 feet below present conditions in the aquifer immediately adjacent to the pumping wells, and between 4 and 14 feet under the rest of the WOC Facility. This simulation was used in conjunction with the Reference and More-Aggressive Remedy scenarios (Figures 6-1, 6-2, and 6-5).

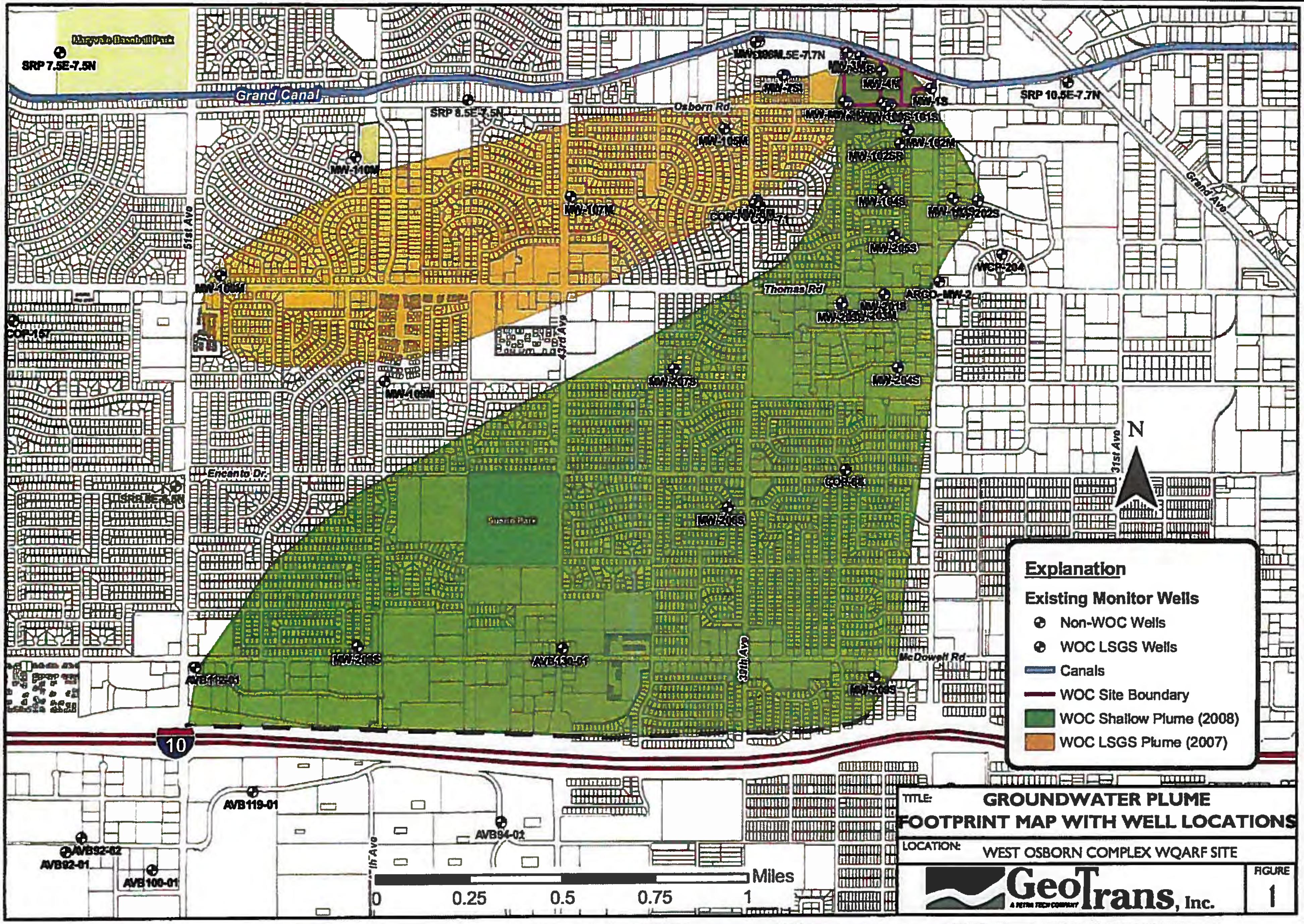
The second simulation, south of Osborn Road, was conducted assuming pumping rates of 100 gpm. This pumping rate is believed to be sustainable based on the results of the initial aquifer test at MW-206S. Extrapolation using pumping rates of 100 gpm for simulation periods of 6 months and 12 months produced less than 4 feet of drawdown at the aquifer-test pumping well (Figures 4 and 5). Simulation of the Reference Remedy, and Less-Aggressive Remedy for three extraction wells are shown in Figures 6-1, and 6-3, respectively. The More-Aggressive Remedy, involving pumping of five extraction wells, is shown in Figure 6-2. A contingency scenario in which COP-68 was pumped at a rate of 225 gpm is shown in Figure 6-4 and combined with the reference remedy scenario in Figure 6-5.

Conclusions

The results of model simulations suggest that down-gradient Reference Remedy pumping will capture the middle of the plume containing the highest concentrations of VOCs. For the More-Aggressive down-gradient remedy pumping simulations suggest that the full width of the plume would be captured. The Less-Aggressive remedy down-gradient pumping is predicted to capture the same middle portion of the plume with the highest VOC concentrations as the Reference Remedy. Finally, if contingency pumping from an extraction well screened in the MFGS at the COP-68 well site occurred, this would enhance remediation of the down-gradient portion of the plume.

References Utilized in Model Development

ADEQ, Various aquifer test results from wells in the general vicinity of the West Osborn Complex
ADWR, Mar 1994. "*A Regional Groundwater Flow Model of the Salt River Valley – Phase II Phoenix Active Management Area Numerical Model, Calibration, and Recommendations*", Modeling Report No. 8
ADWR, Oct 2006. "*Salt River Valley Model Geology Update*" Provisional Report. Modeling Report No. 16.
EPA Office of Research and Development, April 2005. WhAEM2000
Freeze, A., and Cherry, J. "*Groundwater*" Prentice-Hall, Englewood Cliffs, NJ., 1979.
HSI GeoTrans, Inc, Jan 2000. "*A Model of 3-Dimensional Groundwater Flow and TCE Transport at the West Osborn Complex, Phoenix Arizona*". Prepared for United Industrial Corporation.
Locus Technologies, March 2008, "Aquifer Pumping Test Former Southwest Metals Industries Facility" Prepared for ADEQ.
SRP Letter Report, June 2006. Various aquifer test results from wells in the general vicinity of the West Osborn Complex



TITLE: GROUNDWATER PLUME FOOTPRINT MAP WITH WELL LOCATIONS

LOCATION: WEST OSBORN COMPLEX WQARF SITE

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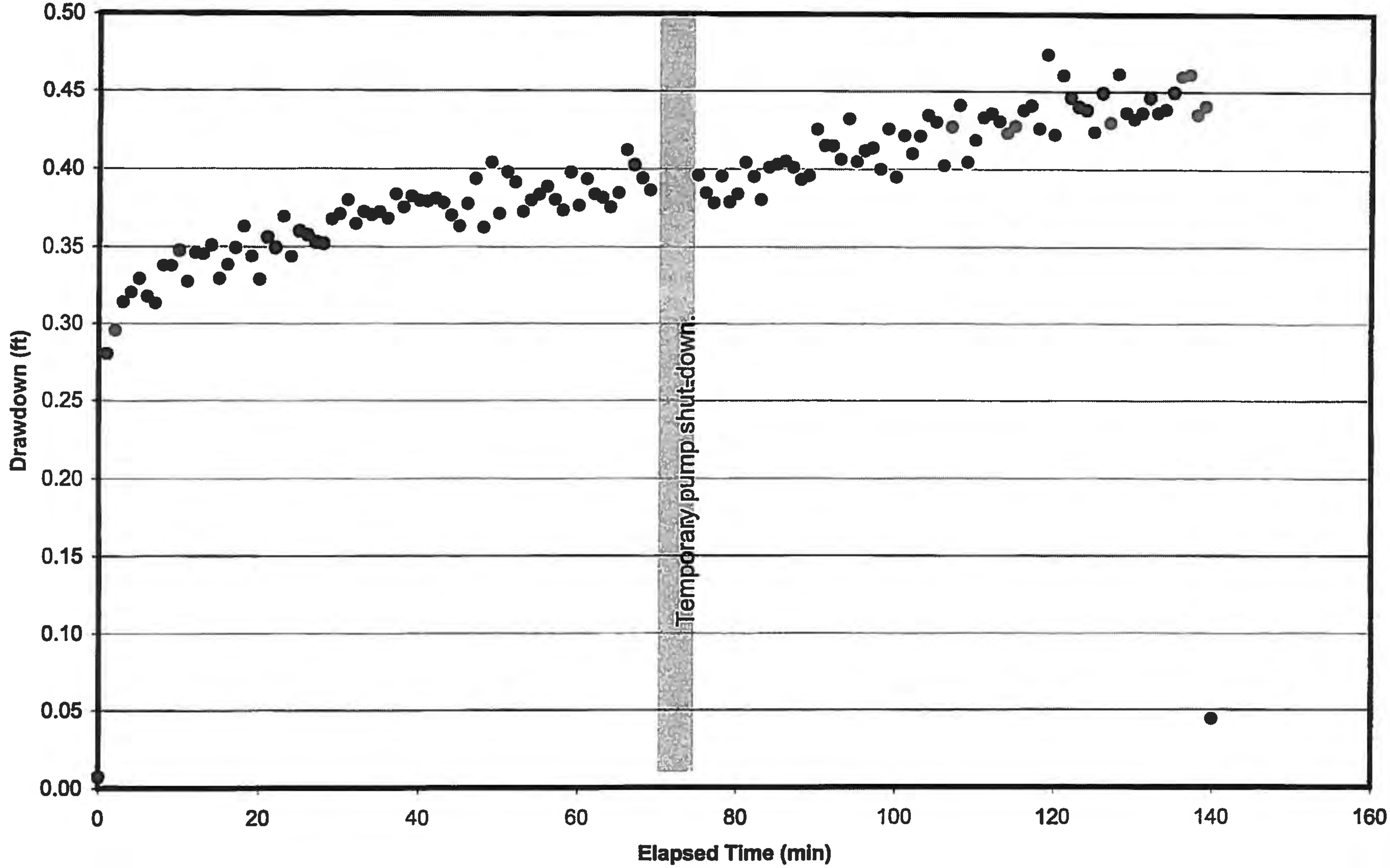
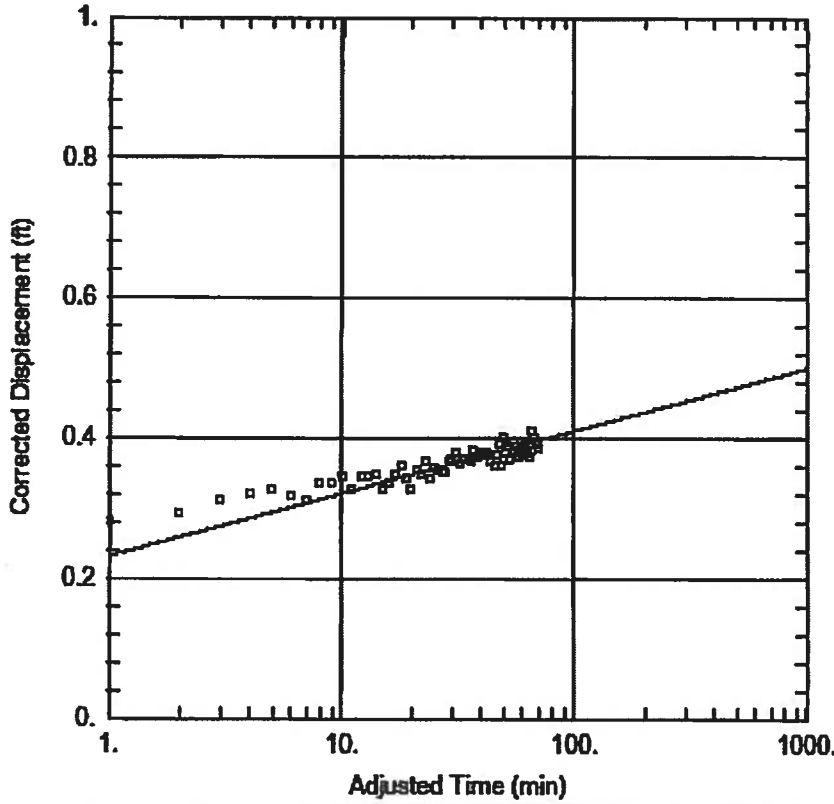
FIGURE 1

Thursday February 14, 2008 3:44:02 PM



Notes:
Data collected using pressure transducer, and baro-corrected in post-processing.
Pumping rate 24 gpm.
Pump shut off for approximately 4 minutes from 70 to 74 minutes.

Figure 2.
MW-206S Drawdown vs Time



WELL TEST ANALYSIS

Data Set: T:\GeoTrans Phoenix\2209.003 - UIC\aqtesolv\Simulated MW-206S 031909a.aqt
Date: 03/25/09 Time: 13:47:32

AQUIFER DATA

Saturated Thickness: 70. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-206S	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MW-206S	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

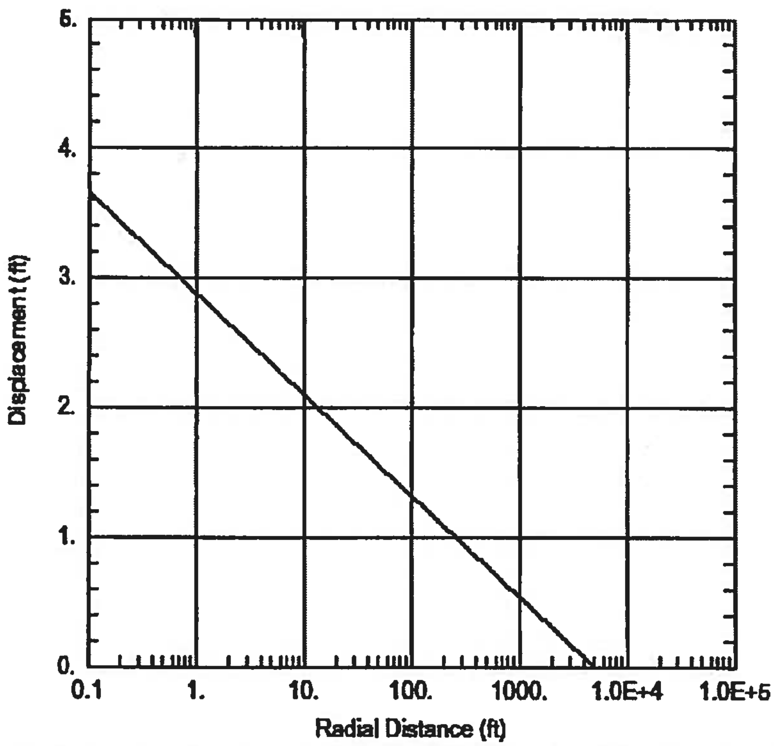
T = 9041.4 ft^2/day S = 0.1497

Cooper-Jacob Pumping Test Analysis

West Osborn Complex WQARF Site

GeoTrans, Inc.

Figure 3



WELL TEST ANALYSIS

Data Set: T:\GeoTrans Phoenix\2209.003 - UIC\aqtesolv\Simulated MW-206S 032509.aqt
Date: 03/25/09 Time: 13:48:34

AQUIFER DATA

Saturated Thickness: 70. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-206S	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MW-206S	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 9041. ft^2/day S = 0.16

Pumping Rate: 100 gpm

Simulated Drawdown from 6-Month Pumping

West Osborn Complex WQARF Site

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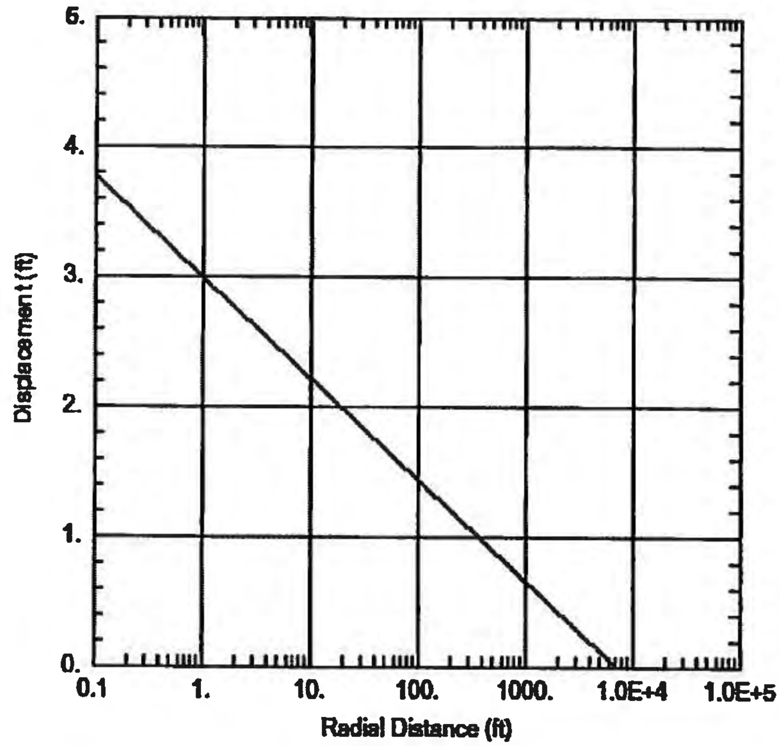
Figure 4



WELL TEST ANALYSIS

Data Set: T:\GeoTrans Phoenix\2209.003 - UIC\aqtesolv\Simulated MW-206S 032509.aqt
Date: 03/25/09 Time: 14:01:47

AQUIFER DATA

Saturated Thickness: 70. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-206S	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MW-206S	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob
$T = 9041.\ ft^2/day$ $S = 0.15$

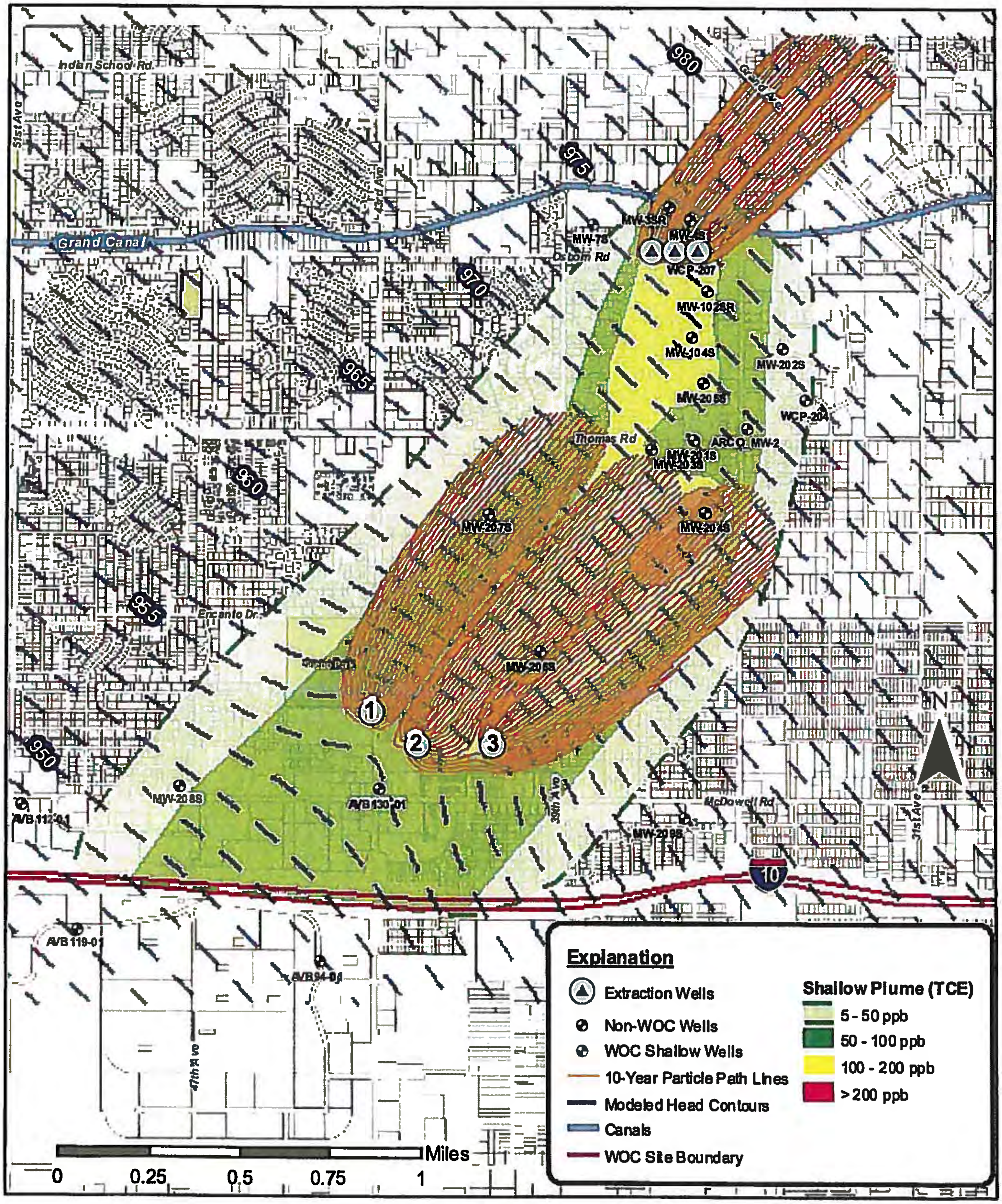
Pumping Rate: 100 gpm

Simulated Drawdown from 1-Year Pumping

West Osborn Complex WQARF Site

GeoTrans, Inc.

Figure 5



Wells 1 - 3 pump at 100 gpm
Treatment Wells at Site Boundary pump at 10 gpm

Model Parameters
Hydraulic Conductivity: 130 feet per day (ft/d)
(WOC Facility path lines reflect simulation of 40 ft/d)
Porosity: 25%
Hydraulic Gradient: 0.0021 feet/foot

TITLE: **Reference Remedy, K = 130 ft/day**

LOCATION: WEST OSBORN COMPLEX

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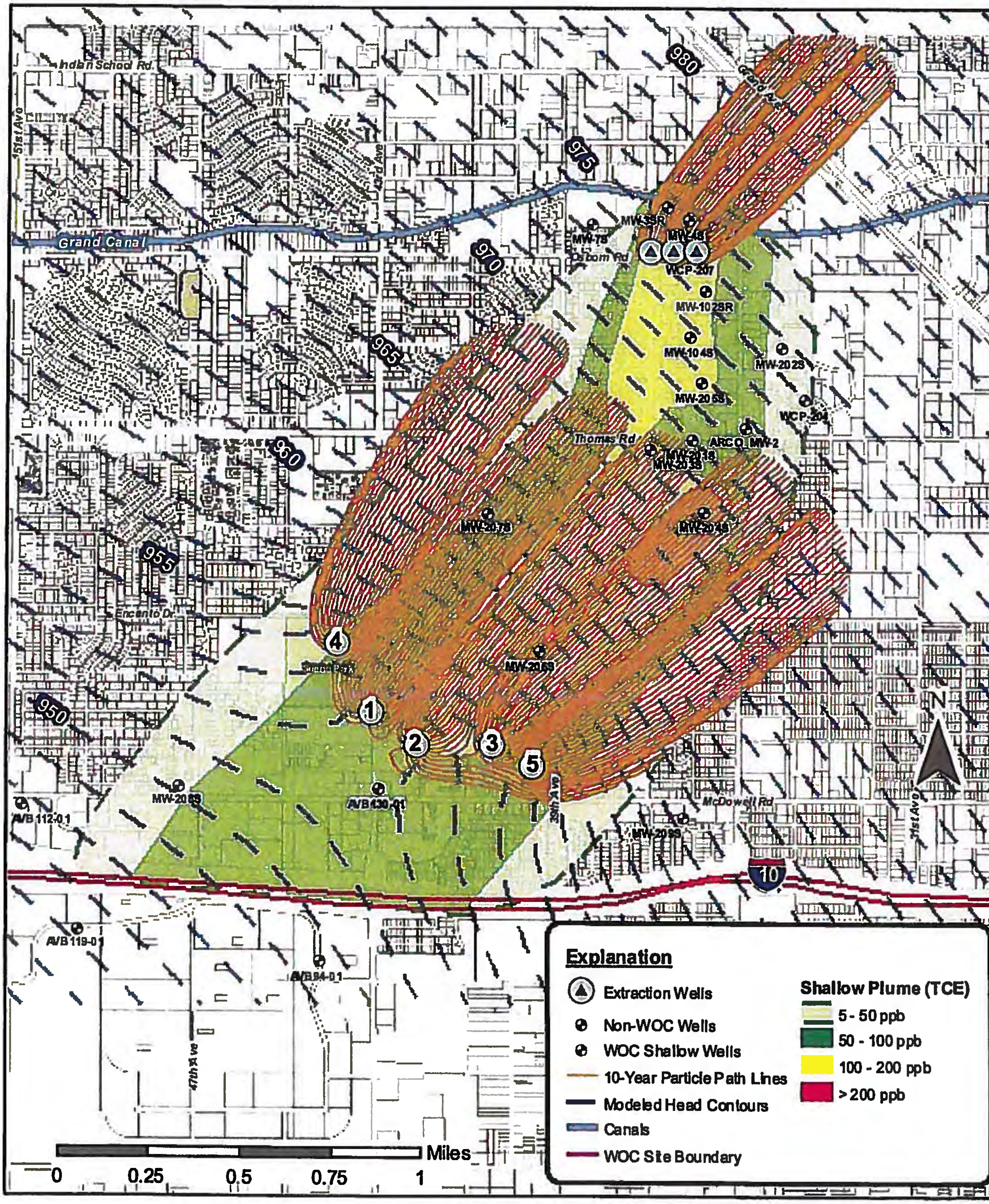
FIGURE 6-1



Wells 1 - 5 pump at 100 gpm
Treatment Wells at Site Boundary pump at 10 gpm

Model Parameters
Hydraulic Conductivity: 130 feet per day (ft/d)
(WOC Facility path lines reflect simulation of 40 ft/d)
Porosity: 25%
Hydraulic Gradient: 0.0021 feet/foot

TITLE: More Aggressive Remedy, K = 130 ft/day

LOCATION: WEST OSBORN COMPLEX

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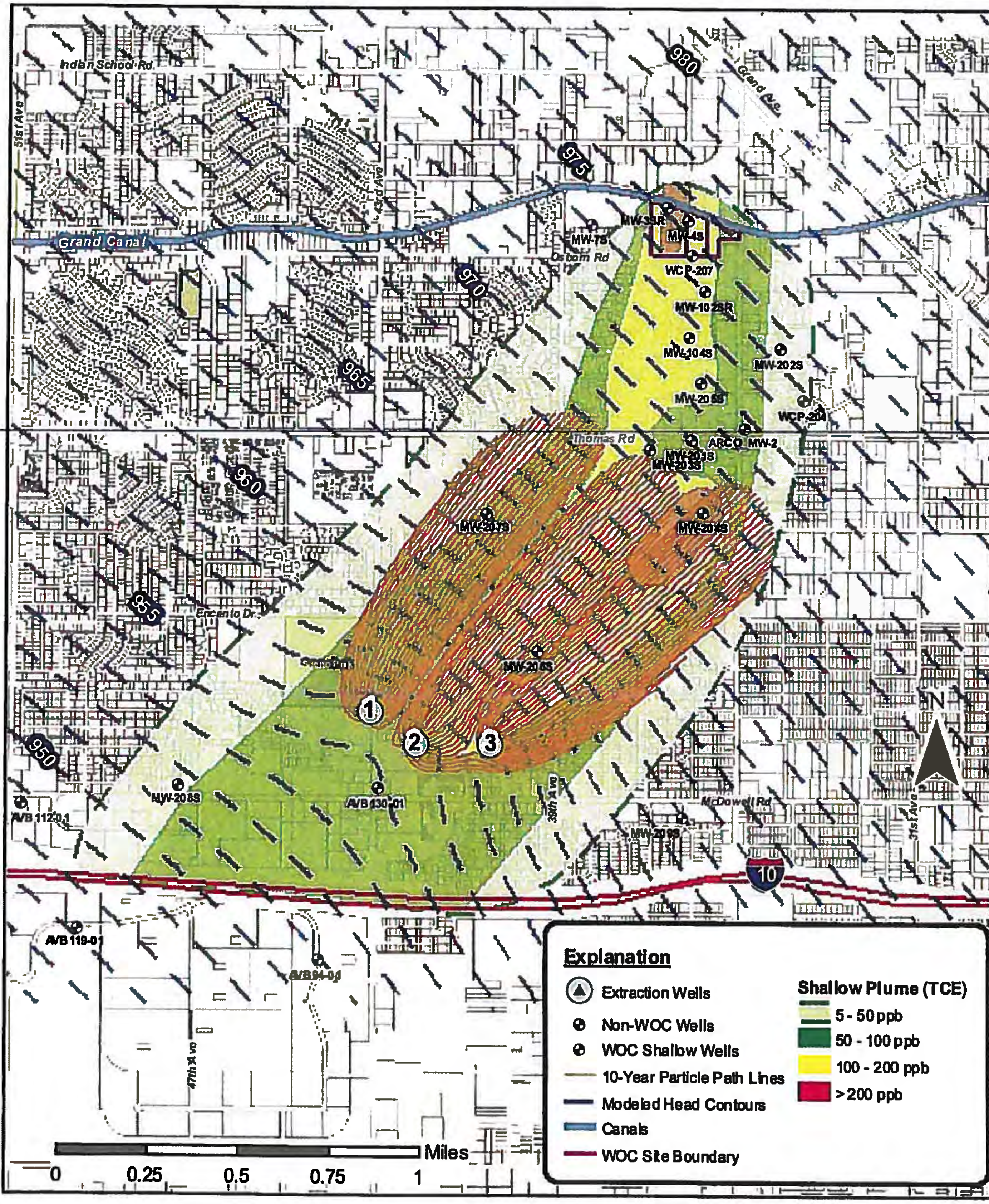
FIGURE 6-2



Wells 1 - 3 pump at 100 gpm

Model Parameters
Hydraulic Conductivity: 130 feet per day (ft/d)
Porosity: 25%
Hydraulic Gradient: 0.0021 feet/foot

TITLE: Less Aggressive Remedy, K = 130 ft/day

LOCATION: WEST OSBORN COMPLEX

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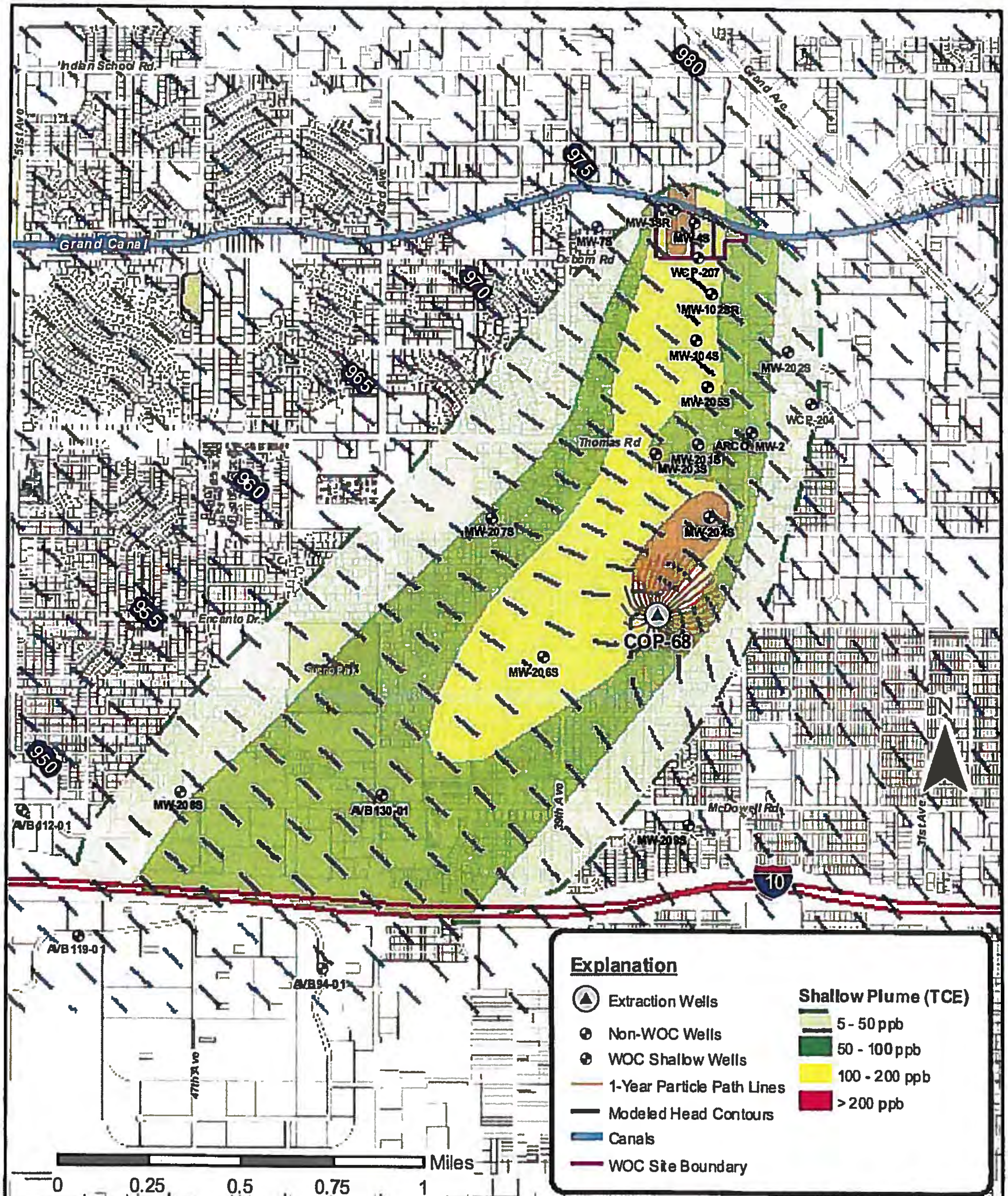
FIGURE 6-3



COP-68 pumps at 225 gpm

Model Parameters
Hydraulic Conductivity: 130 feet per day (ft/d)
(WOC Facility path lines reflect simulation of 40 ft/d)
Porosity: 25%
Hydraulic Gradient: 0.0021 feet/foot

TITLE:	Contingency Pumping at COP-68 K = 130 ft/day
LOCATION:	WEST OSBORN COMPLEX

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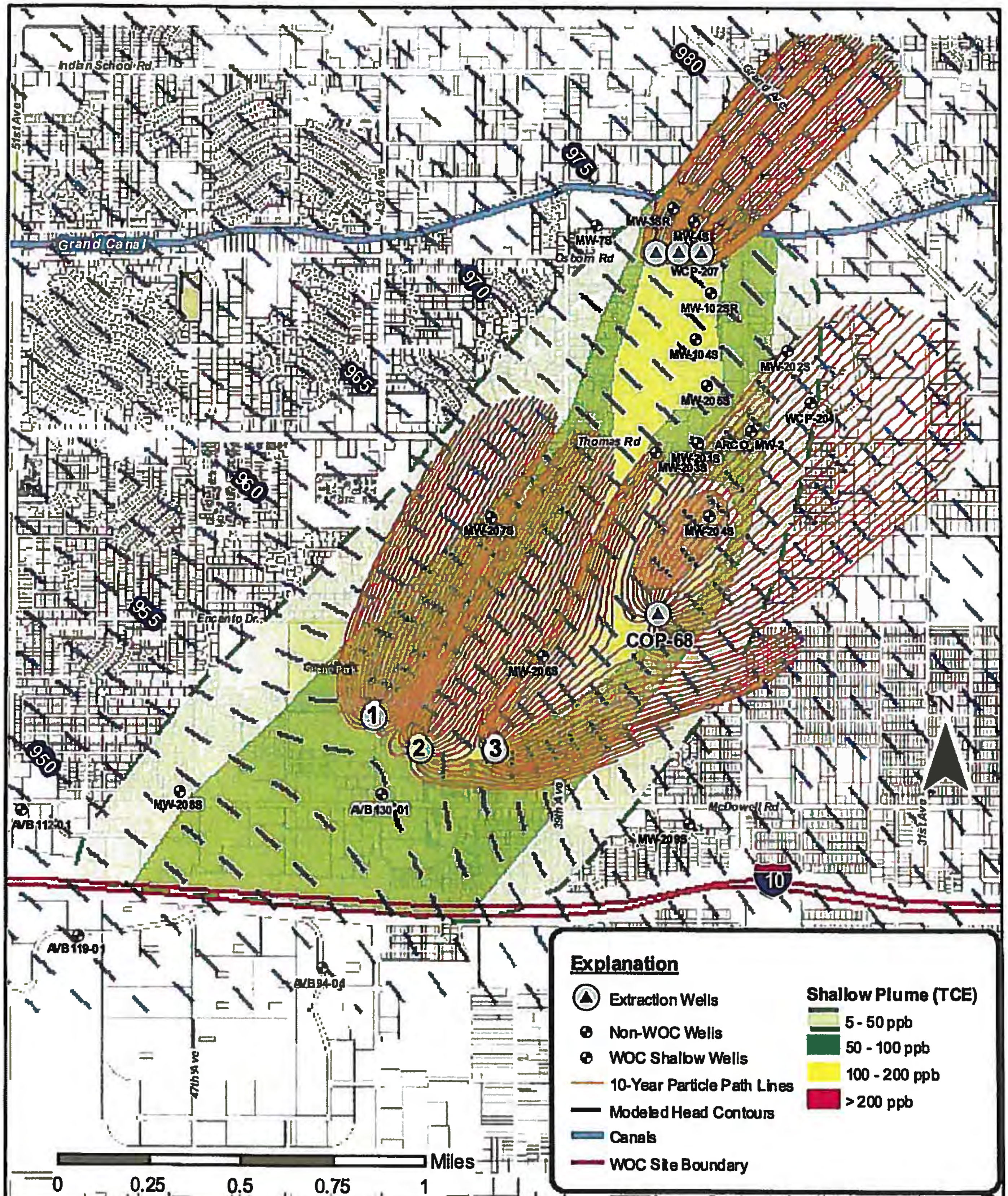
FIGURE 6-4



Wells 1 - 3 pump at 100 gpm
Treatment Wells at Site Boundary pump at 10 gpm
COP-68 Pumps at 225 gpm.

Model Parameters
Hydraulic Conductivity: 130 feet per day (ft/d)
(WOC Facility path lines reflect simulation of 40 ft/d)
Porosity: 25%
Hydraulic Gradient: 0.0021 feet/foot

TITLE: **Reference Remedy with Contingency Pumping at COP-68, K = 130 ft/day**

LOCATION: WEST OSBORN COMPLEX

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FIGURE 6-5