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FEASIBILITY STUDY REPORT

WESTERN AVENUE WQARF SITE
AVONDALE AND GOODYEAR, ARIZONA

PREPARED FOR:
ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY

HARGIS + ASSOCIATES, INC.
HYDROGEOLOGY • ENGINEERING

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ACRONYMS AND ABBREVIATIONS

A.C.C.	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
A.R.S.	Arizona Revised Statues
AWQS	Aquifer Water Quality Standard
bgs	Below ground surface
CAP	Central Arizona Project
COA	City of Avondale
COG	City of Goodyear
COGPW	City of Goodyear Public Works
COG-01	City of Goodyear production well number 1
CSM	Conceptual site model
EPA	U.S. Environmental Protection Agency
ERA	Early response action
ft/ft	Feet per foot
FS	Feasibility study
GeoTrans	GeoTrans, Inc.
gpd/ft	Gallons per day per foot
gpd/ft^2	Gallons per day per square foot
H+A	Hargis + Associates, Inc.
ITSI	Innovative Technical Solutions, Inc.
LAU	Lower alluvial unit
MAU	Middle alluvial unit

ACRONYMS AND ABBREVIATIONS (continued)

MNA	Monitored natural attenuation
PI	Preliminary investigation
PCE	Perchloroethene/tetrachloroethene
PDB	Passive diffusion bag
PGA	Phoenix-Goodyear Airport
PGA-S	Phoenix Goodyear Airport-South Superfund Site
PRAP	Proposed remedial action plan
RI	Remedial investigation
ROs	Remedial objectives
SRP	Salt River Project
the Site	Western Avenue Water Quality Assurance Revolving Fund Site
UAU	Upper alluvial unit
USGS	U.S. Geological Survey
USTs	Underground storage tanks
VOCs	Volatile organic compounds
WQARF	Water Quality Assurance Revolving Fund
WSRV	West Salt River Valley
µg/l	Micrograms per liter

FEASIBILITY STUDY REPORT
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AVONDALE AND GOODYEAR, ARIZONA

EXECUTIVE SUMMARY

This document presents a Feasibility Study (FS) for the Western Avenue Water Quality Assurance Revolving Fund (WQARF) Site (the Site) located in Avondale and Goodyear, Arizona. This FS report has been prepared on behalf of the Arizona Department of Environmental Quality (ADEQ) in accordance with Arizona Administrative Code (A.A.C.) Title 18, Environmental Quality, Chapter 16, Section 407 (R18-16-407) to identify a reference remedy and alternative remedies capable of achieving the remedial objectives (ROs) proposed for the Site.

This FS report evaluates the identified remedies based on prescribed comparison criteria and proposes a preferred remedy that complies with relevant requirements and:

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,
4) Addresses any well that either supplies water for municipal, domestic, industrial, irrigation or agricultural uses or is a part of a public water system, if the well currently, or in the foreseeable future would produce water that would not be fit for its current or reasonably foreseeable end use without treatment.

Tetrachloroethene or perchloroethene (PCE)-impacted groundwater was first discovered in the Site area as part of groundwater monitoring activities conducted at the adjacent Phoenix-Goodyear Airport (PGA)-South Superfund Site (PGA-S) in 1993. PCE was detected in monitor wells located upgradient (east) of PGA-S. Increasing concentrations of PCE over time in these monitor wells indicated a potential upgradient source.

ADEQ conducted a preliminary investigation (PI) in the Site area in 1994. The PI involved limited soil vapor sampling at two suspected source areas: 1) the City of Goodyear Public Works facility leaking underground storage tank site, and 2) the Western Avenue Dry Cleaners (ADEQ, 1995). Soil sampling was also conducted at the two locations in 1995. Two monitor wells were installed in 1995 to assess water quality north and east of PGA-S. PCE was detected in groundwater samples collected from the two monitor wells. The Western Avenue Site was subsequently placed on the WQARF Registry in December 1998.

Subsequently, a systematic series of investigations were performed involving soil gas surveys, monitor well installations, and groundwater monitoring. While these investigations focused on various commercial dry cleaning establishments known to have used PCE, a primary source was not determined. A network presently comprising ten monitor wells has since been established across the Site and groundwater monitoring has been ongoing through the present time. Based on the trends and distribution of groundwater contamination and in the context of the conceptual site model, the primary source area was in the vicinity of monitor well MW-1.

In 2009, ADEQ established remedial objectives (ROs) for the Site. In consideration of the ROs, alternative remedies were identified and evaluated as part of the FS report. The criteria applied for the purposes of the evaluation included:

- Contaminant treatment effectiveness;
- Compatibility with drinking water systems;
- Constructability;
- Flexibility/expandability;
- Operation and maintenance requirements;
- Management of residual waste products;
- Chemical use/operational hazards, and
- Cost/effectiveness.

Site assumptions and requirements were also used for the identification and screening of remedial technologies and alternatives.

Based on the above initial screening criteria, the remedial technologies that were identified for further screening for groundwater remediation at the Site included:

- Enhanced Bioremediation;
- In-situ Chemical Oxidation;
- Air Sparging;
- Pump and Treat Remediation;
- Soil Vapor Extraction, and
- Monitored Natural Attenuation (MNA).

Proceeding through the screening and evaluation resulted in the identification of the following remedial alternatives for the Site:

- Alternative 1: No Action
- Alternative 2: MNA;
- Alternative 3: Alternative Water Supply
- Alternative 4: Wellhead Treatment;
- Alternative 5: Operational Strategies and Monitoring; and
- Alternative 6: Institutional Controls.

Based on the screening, Alternatives 2, 5, and 6 were retained for further evaluation. The study then proceeded to determine implementation strategies with regard to the retained alternatives such that a referenced remedy was selected and more and less aggressive remedy strategies were developed on the basis of the remaining two.

The resulting decision produced MNA as the reference remedy based on the following:

- Site data inferring that there does not appear to be any significant continuing source or sources of PCE within the Site area;
- Concentrations of PCE in Subunit A groundwater have decreased significantly during the last 15 to 20 years;

- The present day extent of PCE contamination in groundwater is decreasing, and
- Present information does not suggest there is any impact on local water supplies.

Based on the combination of remedial effectiveness, practicality, cost, risk, and benefit to achieve the groundwater ROs; MNA was judged to be protective of human health and the environment, compliant with cleanup standards, and state laws. If a further level of control is deemed appropriate, then MNA could be combined with institutional controls.

FEASIBILITY STUDY REPORT
WESTERN AVENUE WQARF SITE
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1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE OF THE FEASIBILITY REPORT

This document presents a Feasibility Study (FS) for the Western Avenue Water Quality Assurance Revolving Fund (WQARF) Site (the Site) located in Avondale and Goodyear, Arizona (Figure 1). This FS report has been prepared on behalf of the Arizona Department of Environmental Quality (ADEQ) in accordance with Arizona Administrative Code (A.A.C.) Title 18, Environmental Quality, Chapter 16, Section 407 (R18-16-407). The purpose of the FS is to identify proposed remedies that may be capable of achieving the remedial objectives (ROs) proposed for the Site (ADEQ, 2009) and to select a preferred remedy from among them 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

4) Addresses any well that either supplies water for municipal, domestic, industrial, irrigation or agricultural uses or is a part of a public water system, if the well currently, or in the foreseeable future would produce water that would not be fit for its current or reasonably foreseeable end use without treatment.

1.2 REPORT ORGANIZATION

This 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 description, physiographic setting, and nature and extent of contamination.

- Section 3.0 – FEASIBILITY STUDY SCOPING: This section presents the regulatory requirements presented in statutes and rules, delineates the area of contamination, and presents the ROs identified by ADEQ (ADEQ, 2009).
- Section 4.0 – IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES AND ALTERNATIVES: This section presents the identification and screening of various remedial technologies and alternatives related to contamination in saturated soil and groundwater and lists the technologies/alternatives that have been retained for evaluation as part of the reference and alternative remedies.
- Section 5.0 – DEVELOPMENT OF REFERENCE REMEDY AND ALTERNATIVE REMEDIES: This section presents the selected reference remedy, a more aggressive remedy, and a less aggressive remedy. Each remedy includes a discussion of its associated strategy and measures.
- Section 6.0 – DETAILED COMPARISON OF THE REFERENCE REMEDY AND THE ALTERNATIVE REMEDIES: The selected remedies are compared to each other based the comparison criteria of practicability, cost, risk and benefit. Uncertainties associated with each remedy or comparison criteria are discussed.
- Section 7.0 – PROPOSED REMEDY: This section presents:
    1) The proposed remedy and discusses how it will achieve the ROs;
    2) How the comparison criteria were considered; and
    3) How the proposed remedy will meet the remedial action criteria as presented in Arizona Revised Statutes (ARS) §49-282.06.
- Section 8.0 – COMMUNITY INVOLVEMENT: This section documents the community involvement activities that will be conducted in association with this FS.
- Section 9.0 – REFERENCES: This section presents the references used to prepare the FS report.

2.0 SITE BACKGROUND

The following descriptions are excerpted from selected reports prepared on behalf of ADEQ for the Site (ADEQ, 1995, 2001; GeoTrans, 2001a, 2001b, 2002a, 2002b, 2002c, 2002d, 2003a, 2003b, 2003c, 2003d, 2005, 2008, 2009a and 2009b; H+A, 2010, 2011a, 2011b, 2012a, 2012c, 2013a, 2013b, 2014a, and 2014b). These reports can be reviewed for more detailed Site information.

2.1 SITE DESCRIPTION

The Site occupies approximately 300 acres situated along Western Avenue in portions of the cities of Avondale and Goodyear, Arizona. From Western Avenue; the Site extends north to San Xavier Boulevard, east to Third Street; south to State Route 85; and west to the Phoenix-Goodyear Airport (PGA)/Litchfield Road (Figure 2)

ADEQ has identified perchloroethene (PCE) or tetrachloroethene as the chemical of concern in groundwater at the Site. Therefore the Site boundaries are generally defined by the historic occurrence of PCE in groundwater. Land use across the Site is a mix of residential, commercial, and industrial properties.

2.2 WQARF REGISTRY

PCE-impacted groundwater was first discovered in the Site area as part of groundwater monitoring activities conducted at the adjacent PGA-South Superfund Site (PGA-S) in 1993. PCE was detected in monitor wells located upgradient (east) of PGA-S. Increasing concentrations of PCE over time in these monitor wells indicated a potential upgradient source.

The ADEQ conducted a preliminary investigation (PI) in 1994 that included limited soil vapor sampling at two potential source areas: 1) the City of Goodyear Public Works (COGPW) facility leaking underground storage tank site, and 2) the Western Avenue Dry Cleaners (ADEQ, 1995). These potential source area locations are illustrated in Figure 3. Two monitor wells were installed in 1995 to assess water quality north and east of PGA-S. PCE was detected in groundwater samples collected from the two monitor wells. The Site was subsequently placed on the WQARF Registry in December 1998 with a score of 51 out of a possible 120.

2.3 CHRONOLOGY OF SITE ACTIVITIES

The following chronology summarizes major events and investigative milestones for the Site:

1993: PCE was detected upgradient of PGA-S. Monitor wells at PGA-S showed increasing trends in PCE concentration in shallow groundwater.

1994: The ADEQ Site Assessment and Hydrology Unit conducted limited soil vapor sampling at the COGPW facility and also at Western Dry Cleaners. The vapor sample results from both facilities did not detect a source for PCE contamination.

1995: Monitor wells MW-1 and MW-2 were installed by ADEQ to characterize the groundwater quality east and north of PGA-S, downgradient of suspected source areas (Figures 2 and 3). PCE was detected in groundwater samples collected from both monitor wells as high as 87 micrograms per liter (µg/l) in samples collected in 1996. No private wells were noted within the Site boundaries. City of Goodyear well COG-01 (COG-01) is located within the Site boundaries.

ADEQ conducted an investigation at the COGPW facility located on the south east corner of Western Avenue and Litchfield Road. Analytical data indicated that PCE and/or other target compounds were not present in soil above the method detection limit.

1998: The Site was placed on the WQARF Registry in December with a score of 51 out of a possible 120.

2000: ADEQ installed five additional monitor wells (MW-3 through MW-7) at the Site as part of an Early Response Action (ERA) evaluation (Figure 2).

2001: ADEQ conducted a soil gas survey at the former Aladdin Dry Cleaners property (ADEQ, 2001). Results of the soil gas survey indicated minor concentrations of PCE.

2003: An Industrial Survey Report was completed as part of the RI to identify properties where PCE may have been used or disposed. Six former dry cleaning facilities were identified in the area. Additional field activities were conducted at two of the dry cleaning facilities, Western Avenue Dry Cleaning and Aladdin Dry Cleaning. The results of the investigations indicated that the facilities did not represent a significant source of PCE contamination in soil or groundwater (GeoTrans, 2003c).

2005: The current and future beneficial land and water use for the Site was evaluated in 2005. Groundwater use within the Site area was expected to remain predominately mixed residential, commercial and industrial. It was believed that mixed land use at the Site would be prevalent into the future. The zoning patterns in the area were long established and there were no foreseeable changes for the future.

2006: The highest concentration of PCE detected in groundwater during the March monitoring event was 3.2 µg/l at COGPW facility monitor well COG-MW3 (Figure 2). The Draft RI Report including the report titled “Current and Future Beneficial Land and Water Use” was submitted for public comment in August (GeoTrans, 2005). One comment was received during the 30-day comment period. This comment did not require a change in the RI.

2007: The highest concentration of PCE detected in groundwater during the August monitoring event was 12 µg/l at monitor well MW-2. Prior to the August sampling results, the last exceedance of the Arizona Aquifer Water Quality Standard (AWQS) for PCE of 5 µg/l in a groundwater sample collected from monitor well MW-2 occurred in April 1999. PCE was detected at concentrations less than the AWQS in subsequent groundwater samples collected from monitor well MW-2.

2008: Monitor well MW-8 was installed by ADEQ north of well COG-01 to provide data to define the northern boundary of PCE-impacted groundwater.

2009: Groundwater samples were collected from Site monitor wells in January. The highest concentration of PCE in groundwater was 4.5 µg/l at monitor well MW-2, less than the AWQS of 5.0 µg/l. The RI was finalized with the issuance of the Proposed ROs report (GeoTrans, 2009b; ADEQ, 2009).

2010: Groundwater samples were collected from Site monitor wells in May and November. The highest concentration of PCE in groundwater in these two events was 6.8 µg/l at monitor well MW-1, a concentration slightly greater than the AWQS.

2011: Innovative Technical Solutions, Inc. (ITSI) initiated an “Area Between the Sites” study. The objectives of the study were to collect data in an effort to further define water level and water quality conditions in the area where the PGA-North Superfund, PGA-S, and Western Avenue sites meet. The results of the study were finalized in March 2013.

Groundwater samples were collected from Site monitor wells in February, May, August, and November. Groundwater samples in February were collected using a portable submersible pump after removing three well casing volumes of groundwater, standard practice to that time. Groundwater samples were collected using passive diffusion bag (PDB) samplers in May, August, and November. In May, PDB samplers were placed vertically across the entire saturated thickness of each monitor well screen to profile PCE concentrations. In August and November, PDBs were placed at the depth in each monitor well where the PCE concentration was the highest based on May vertical profiling. The highest concentration of PCE in groundwater during the four 2011 events was 12.0 µg/l at monitor well MW-1 in November.

2012: Groundwater samples were collected from Site monitor wells in February, May, August, and November using PDB samplers placed at depths determined from the vertical profiling conducted at each well during May 2011. The highest concentration of PCE in groundwater during the 2012 events was 6.59 µg/l at monitor well MW-1 in May. Verification sampling was conducted in June 2012 to verify suspect volatile organic compound (VOC) concentrations at selected wells during the May event. The results of the verification sampling and August 2012 sampling indicated that PCE concentrations were within normal ranges (5.3 µg/l).

A concentration of 6.2 µg/l was reported in November 2012 at MW-1. The Draft FS Work Plan was completed October 25, 2012.

2013: Groundwater samples were collected from Site monitor wells in 2013. The highest concentration of PCE in groundwater during any event was 7.8 µg/l at monitor well MW-1 in May. PCE was not detected at concentrations greater than the AWQS at any of the other monitor wells.

A time-series groundwater test was conducted at well COG-01 during March and April 2013. The purpose of the test was to provide data to determine the source and nature of the PCE detected in samples from well COG-01. The time-series test generated data that supports leakage of PCE-impacted groundwater into the COG-1 wellbore through the well annulus and/or breaches in the casing. A Draft Summary Report was completed on May 15, 2013 and shared with the Cities of Avondale and Goodyear. The Cities submitted comments; ADEQ addressed the Cities' comments in the Final report dated November 1, 2013 (H+A, 2013b).

A draft of the FS report was completed April 4, 2013. The draft FS was shared with the Cities of Avondale and Goodyear. The Cities submitted comments; ADEQ addressed the Cities' comments in a draft FS dated November 4, 2013. The draft FS report was presented at the November 7, 2013 community advisory group quarterly meeting.

2014: ADEQ will issue a notice and hold a public meeting during the comment period to inform the public of the availability of the Proposed Remedial Action Plan (PRAP) and to ensure that the public has an opportunity to comment on the plan. ADEQ will then complete a comprehensive responsiveness summary. Public notice will be provided on the availability of both the responsiveness summary and the Record of Decision (A.A.C. R18-16-404). If significant changes are made to the remedial action plan as a result of the comments received, ADEQ will provide notice to the public.

Groundwater monitoring is continuing during 2014.

3.0 FEASIBILITY STUDY SCOPING

3.1 REGULATORY REQUIREMENTS

The Remedy Selection Rules (A.A.C. Title 18, Chapter 16, Article 4, R-18-16) state 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 them based on the comparison criteria to select a remedy that complies with Arizona Revised Statutes (A.R.S.) § 49-282.06. The remedial actions required by this Article should also be consistent with the requirements of Title 45, Chapter 2, the Groundwater Code, except as provided in amendments. This FS has been conducted in accordance with the Remedial Selection Rule R18-16-407, Sections A, B, E, F, G, H, and I.

3.2 CONCEPTUAL SITE MODEL

A conceptual site model (CSM) was developed to aid in understanding the likely contaminant transport and exposure pathways associated with the Site. The CSM integrates available site data and information including the operational history, geologic and hydrogeologic framework, potential source areas, and groundwater quality dynamics of the Site.

3.2.1 Operational History

The potential sources of PCE contamination in groundwater have been identified as former and existing dry cleaning facilities located within the Site area. However, no specific source area has been identified to date. In 2001, an industrial survey conducted in the vicinity of the Site identified six dry cleaning facilities as potential sources of the PCE contamination:

- Western Avenue Dry Cleaning,
- Aladdin Dry Cleaning,
- Avondale City Cleaners,
- Quinn Cleaners,
- Goodyear Dry Cleaners, and
- A dry cleaning facility of unknown name that historically operated at 1072 South Litchfield Road.

These locations are illustrated in Figure 3. Additional field investigations were focused on the former site of the Western Avenue Dry Cleaning and Aladdin Dry Cleaning based on analytical data observed in monitor wells MW-1 and MW-2.

Former Western Avenue Dry Cleaning

The former Western Avenue Dry Cleaning facility was located at 216/218 West Western Avenue and operated approximately 600 feet east (upgradient) of well MW-1. Presently, Western Dry Cleaners is located at 300 West Western Avenue. The highest concentrations of PCE detected at the Site have been reported in samples obtained from well MW-1 (87 μg/l in 1996). A Chevron gas and service station operated at that location between 1963 and 1985 and historical documents indicate two to three underground storage tanks (USTs) were at one time buried on the southeastern corner of the lot (south of the building) (GeoTrans, 2009b). In 1995, soil vapor sampling conducted in the area near the buried USTs indicated the presence of PCE above the method detection limit in four samples, with the highest concentration reported at 5.4 μg/l. Soil sampling in this area at depths ranging from 10 to 17 feet below ground surface (bgs) indicated that all VOC concentrations were reported below the method detection limit of 4 μg/l (GeoTrans, 2009b).

Former Aladdin Dry Cleaners

The former Aladdin Dry Cleaners was located at 322 East Western Avenue and was located upgradient from well MW-2 where PCE concentrations were reported as high as 76 μg/l in 1996. The facility operated under the name of Aladdin Cleaners from February 5, 1992 to January 1998, and in 1998, the name of the business changed to Estrella Equestrian Laundry. Prior to 1991, a dry cleaning facility by the name of Briteway Cleaners operated at that location (ADEQ, 2001). A fitness spa currently operates at this location.

ADEQ conducted an investigation of soil and soil vapor from 10 sample locations at the former Aladdin Dry Cleaners in March 2001. Samples were collected at depths ranging from 8.5 to 14.5 feet bgs and were analyzed for VOCs. PCE was not detected in any of the soil samples. PCE concentrations in soil vapor (collected at a depth of approximately 8.5 feet) ranged from non-detect to 70 μg/l. The highest concentrations were detected in two soil vapor samples collected approximately 30 feet west of the Aladdin Cleaners building (GeoTrans, 2009b).

Other Identified Dry Cleaning Facilities

In addition to the two facilities listed above, the following facilities were identified during the industrial survey as potential sources of the PCE contamination:

- Avondale City Cleaners operated at 207 East Western Avenue between 1959 and 1972. The facility was located approximately 50 to 100 feet east (upgradient) of well MW-2.
- Quinn Cleaners operated at 404 East Western Avenue between 1957 and 1961. The facility was located approximately 700 feet east (upgradient) of well MW-2.
- Two dry cleaners operated in adjacent suites of a shopping plaza between 1995 and 2002: Goodyear Dry Cleaners operated at 1084 South Litchfield Road between 1995 and 2000, and a dry cleaning facility of unknown name operated at 1072 South Litchfield Road between 2001 and 2002. Both locations are hydraulically downgradient from the Site's monitor wells, but hydraulically upgradient from the PGA-South Superfund Site monitor wells.

All facility locations are illustrated in Figure 3. ADEQ concluded that none of the facilities investigated represented a significant source of PCE to groundwater. Additionally, the geometry and behavior of the impacted groundwater implies a contaminant source may have been present in the vicinity of well MW-1, however, the specific location(s) of which remains undetermined.

3.2.2 Geology

The Site is located in the western portion of the Salt River Valley (WSRV), a broad, relatively level alluvial valley in the Basin and Range physiographic province of central Arizona. The WSRV alluvium comprises an assemblage of sediments derived from the surrounding mountains and fluvial deposits derived from the Salt River. A detailed description of the general alluvial basin geology is documented in (Anderson *et al.,* 1990).

The U.S. Geological Survey (USGS) divides the stratigraphy of the WSRV into Mountain Bedrock, pre-Basin and Range Sediments, Lower Basin-Fill, Upper Basin-Fill, and Stream Alluvium (Anderson, *et al.,* 1990). In upward sequence, the Mountain Bedrock consists of igneous, metamorphic and consolidated sedimentary rocks ranging from Precambrian to Cenozoic in age. The Pre-Basin and Range Sediments consist of moderately to highly consolidated continental deposits of silt, clay gravel and conglomerate, primarily Tertiary in age. Examples of these sediments are the Camelshead Formation and the Tempe Beds, exposed in the Papago Park area of east Phoenix. These sediments generally exceed several thousand feet in thickness.

Above the pre-Basin and Range Sediments lie the Lower Basin-Fill Sediments. The thicknesses, areal extents, and grain sizes of the Lower Basin-Fill Sediments are variable. Generally these sediments consist of weakly to highly consolidated gravel, sand, silt and clay and may include interbedded evaporite deposits and volcanic rocks at certain locations. The Lower Basin-Fill Sediments typically include 2,000 to 7,000 feet of fine-grained facies of silt and clay at the base, in the center of the basins where these deposits are found.

The Upper Basin Fill is generally composed of unconsolidated to moderately consolidated fanglomerates and alluvial deposits laid down during the last stages of the Basin and Range disturbance. This unit also grades into finer grained facies towards the basin interiors, but is generally coarser than the lower unit and with less evaporites.

This unit is generally a very good producer of groundwater. Some fine-grained deposits in this unit impede the vertical migration of groundwater, such that perched or semi-perched conditions exist in much of the area near the Site.

The upper basin fill is composed mainly of silt, sand, and gravel; locally, relatively thin clay layers can be present. Within the WSRV, the unit is predominantly gravel and sand with some thick zones of cobbles near the present channels of the Salt River. Gravel and sand are also found in areas north and south of the present-day channel, where the ancestral channel was located.

The upper-most geologic unit in the WSRV is the Stream Alluvium, which represents stream channel and related sediments, typically up to 1,200 feet thick. This sedimentary unit was deposited after the basins were filled, and during the establishment of the present drainage system. Sediments consist of flood-plain, channel-fill, alluvial-fan, and playa deposits.

The stream alluvium is generally unconsolidated, except where cemented by caliche. Grain size ranges from boulder- and cobble-sized gravel in the alluvial fans to clays in local playa deposits. In general, sand and gravel are found along the stream channels.

3.2.3 Hydrogeology

Hydrogeology at the Site and in its vicinity has been described in an Arizona Department of Water Resources (ADWR) report (Corkhill *et al.,* 1993). Although the hydrogeologic stratigraphy generally corresponds to the geologic unit nomenclature of the USGS, the correlation is not exact and different unit names are used.

The alluvial sediments (lower and upper basin fill) are subdivided into three hydrologic units: the upper, middle, and lower alluvial units (UAU, MAU and LAU, respectively). In the vicinity of the Site, the total thickness of alluvial sediments is estimated to be in excess of 1,200 feet (Corkhill, *et al.,* 1993).

3.2.4 Regional Hydrogeologic Unit Descriptions

Regionally, the hydrogeology of the WSRV is discussed in terms of the LAU, MAU, and UAU. The previously noted bedrock units, including the pre-Basin and Range sedimentary Tempe Beds and Camelshead Formation, and the crystalline bedrock do not produce significant quantities of groundwater except in a few limited areas of the WSRV.

The LAU includes consolidated sands and gravels. The MAU is also consolidated, but with a higher proportion of fine-grained materials. Both the MAU and LAU represent depositional environment within closed basin (lake bed) conditions. Although the hydraulic properties of the MAU are less favorable for water production, the MAU is the most productive basin-wide unit due to its saturated thickness.

The UAU consists of unconsolidated sands and gravels deposited by flowing drainages, and is the most transmissive of the three units. According to the ADWR, the UAU is typically 300 to 400 feet thick in the WSRV (Corkhill, *et al.*, 1993). Where thick saturated sections of the UAU are present, the groundwater production rates are generally very high. At the Site, the UAU extends from ground surface to its contact with the MAU, at approximately 360 feet bgs.

The UAU comprises poorly to well-sorted deposits of clay, silt, sand, and gravel. Based on particle size distribution and data from geophysical logs, the UAU can be subdivided into three subunits referred to as Subunit A, B, and C, in order of increasing depth in the Site area.

Generalized cross-sections through Subunits A and B are provided in Figures 4 and 5. Sediments greater than silt size represent approximately 60 to 70 percent of Subunits A and C and approximately 20 to thirty 30 percent in Subunit B.

3.2.5 Site Hydrogeologic Unit Descriptions - Subunit A

Subunit A is the uppermost subunit of the UAU at the Site extending to a depth of approximately 130 feet bgs. It consists of interbedded deposits of alluvial sediments ranging from silt and clay to varying amounts of sand and gravel. Subunit A is considered an unconfined aquifer. The saturated portion is within the lower one-half to one-third of the subunit. Groundwater from Subunit A may be used for irrigation purposes in some areas.

The transmissivity of Subunit A was estimated to range from 100 to 80,000 gallons per day per foot (gpd/ft) with an average of 20,000 gpd/ft based on aquifer testing conducted as part of the investigation at the adjacent PGA-S. The average hydraulic conductivity was determined to be about 400 gallons per day per square foot (gpd/ft^2) and the specific yield ranges between 0.05 and 0.15 percent (CH2M Hill, 1989).

3.2.6 Subunit B

Subunit B is reported to consist primarily of clay layer situated at depths between approximately 130 feet and 240 feet bgs in the Site area (CH2M Hill, 1989). Subunit B is believed to act as an aquitard hydraulically isolating Subunit A from Subunit C. However, there are no monitor wells completed solely in Subunit B at the Site. Therefore, site-specific data are insufficient to determine the exact nature and thickness of Subunit B or whether Subunit B is continuous or confining beneath the Site; thereby raising uncertainty as to the effectiveness of interaquifer isolation.

The main factors limiting vertical groundwater flow between Subunits A and C are the thickness and grain size of Subunit B. The average transmissivity of Subunit B has been estimated to be 2,000 gpd/ft based on aquifer tests conducted at the PGA-S. The average horizontal hydraulic conductivity has been estimated at 40 gpd/ft^2, and vertical hydraulic conductivity between 0.04 and 4 gpd/ ft^2 (CH2M Hill, 1989).

3.2.7 Subunit C

Subunit C is the lowermost subunit of the UAU and extends from the base of Subunit B to the top of the MAU estimated at a depth of approximately 360 feet bgs. Subunit C is the primary source of groundwater for municipal and agricultural users in the Site area.

Subunit C is reported to consist of interbedded alluvial sediments ranging from clay to poorly-sorted gravel. The upper half of the subunit generally consists of sandy gravel. The lower half of the subunit is generally finer-grained than the upper half of the subunit, and consists primarily of interbedded deposits of sand, clay and gravel. Subunit C is a highly transmissive, leaky confined aquifer based on studies conducted at the adjacent PGA-S. Some aquifer interconnection may take place between Subunit C and thin transmissive sand lenses (where present) within the underlying upper portion of the MAU.

The estimated transmissivity of Subunit C is 120,000 gpd/ft, and the average hydraulic conductivity for the upper and lower halves of the Subunit is estimated at 1,000 gpd/ft^2 and 600 gpd/ft^2, respectively based on aquifer testing conducted at PGA-S.

3.2.8 Groundwater Movement

Results of periodic groundwater level monitoring and sampling performed between November 2000 and November 2013 are documented in a series of reports (GeoTrans, 2001a, 2001b, 2002a, 2002b, 2002c, 2002d, 2003a, 2003b, 2003d, 2008, 2009a and 2009b; and H+A, 2010, 2011a, 2011b, 2012a, 2012c, 2013a, 2014a, and 2014b). The most recent groundwater monitoring event was conducted in February 2014 and results are pending.

Review of water level contour maps prepared from 2008 to the present indicates that the direction of groundwater flow in Subunit A is to the west-northwest at gradients ranging from approximately 0.0020 to 0.0025 feet per foot (ft/ft). These conditions are consistent with those defined prior to 2008. During November 2013, the observed depth to water ranged from approximately 68 to 79 feet bgs (Figure 6). Water levels are approximately ten to 20 feet lower than the highest levels measured in early 2001. Time-series graphs of PCE concentrations and groundwater levels over the entire Site period of record are presented in Appendix A.

Groundwater gradients across the Site are relatively flat. Accordingly, they are quite sensitive to regional influences resulting from a variety of stresses including operation of extraction and recharge wells operating in nearby remedial projects, municipal pumping centers and recharge facilities, agricultural withdrawals, and intermittent flow within the Salt and Agua Fria rivers. This is evident in the historical water level measurements observed at Site wells, which trend with seasonal fluctuations and influence from withdrawals at the City of Goodyear (COG) production wells.

In addition to influencing gradients and directions of flow within the individual hydrogeologic subunits, the regional influences also indicate the potential for creating vertical gradients, which may induce vertical flow of groundwater between or across subunits. The resultant effect(s) of such regional influences on contaminant migration are not fully known. Another consideration is that, if there is significant movement of contaminants within Subunit A, it would appear the plume would move towards the capture zone of adjacent remedial projects. Water level data are insufficient to determine groundwater movement in Subunits B and C in the Site area.

3.3 DELINEATION OF SOURCE AREA(S) – VADOSE ZONE

Investigations performed by ADEQ in 2001 and 2002 were directed toward the identification of potential PCE source areas in Site vadose zone soil. These investigations included soil and soil vapor sampling at selected potential source areas. The results of these investigations were inconclusive as no elevated concentrations of PCE were detected in subsurface soil or soil gas (GeoTrans, 2009b).

The limited presence and decreasing concentrations of PCE in shallow groundwater at the Site suggest that there is no significant, continuing source of PCE in vadose zone soil (Section 3.4.1). Subsequently, an industrial survey report was completed as part of the RI to focus on any potential vadose zone source areas (GeoTrans, 2003c). The data obtained from the survey indicated that additional source investigations would not be required as part of the RI (GeoTrans, 2009b).

3.4 DELINEATION OF GROUNDWATER CONTAMINATION

This section summarizes the available data related to the extent of contamination in Site groundwater.

3.4.1 Subunit A

Concentrations of PCE in Subunit A Site monitor wells during the last five to eight years have remained relatively stable or continued to decrease to concentrations significantly less than those observed during the 1990s and early 2000s. PCE concentrations have remained below the AWQS at most Site wells since the late 1990s and early 2000s (H+A, 2014b).

PCE is still routinely detected at monitor well MW-1 at concentrations greater than the AWQS and sporadically at monitor well MW-2 greater than the AWQS. Based on Site data and using the AWQS to define groundwater contamination, the extent of contamination in Subunit A appears to be consistently limited to a small area of approximately 500 by 500 feet in the vicinity of well MW-1.

PCE concentrations during November 2013 are provided in Figure 7. PCE was detected above the limit of detection in groundwater samples collected from four monitor wells during the November 2013 monitoring event. PCE was detected at concentrations ranging from 1.8 μg/l at monitor well MW-4 to 6.1 μg/l at monitor well MW-1. PCE was only detected at a concentration above the Arizona AWQS at monitor well MW-1. PCE was not detected in groundwater samples collected at monitor wells COG-MW3, MW-5, MW-6, and MW-7 in November 2013.

This is consistent with recent monitoring events. Time-series graphs of PCE concentrations and groundwater levels over the entire Site period of record for all wells are presented in Appendix A. These graphs indicate downward trends in PCE concentrations. A conceptual diagram illustrating the extent of PCE in Subunit A groundwater is presented as Figure 8.

3.4.2 Subunit C

Two wells are screened in Subunit C in the Site area, well COG-1 and monitor well EMW-22LC (Figure 2). Well COG-01 is reported to be screened approximately in the lowermost seven feet of Subunit B and extending into the uppermost 13 feet of Subunit C (COG, 2012). Monitor well EMW-22LC is located at the western boundary of the Site area. Well EMW-22LC is reported to be screened in the lower portion of Subunit C from approximately 280 feet to 310 feet bgs.

PCE has been detected in groundwater samples collected from well COG-01. However, no samples to date have contained PCE at concentrations greater than the AWQS. PCE was detected in the most recent groundwater samples collected from well COG-01 at a concentration of 4.2 µg/l during November 2013. Well COG-01 had not been operated for a period of time by the COG prior to the November 2013 event. Monitor well EMW-22LC is not sampled as part to the Site groundwater monitoring program. However, a groundwater sample was collected during the well COG-01 time-series test from well EMW-22LC and analyzed for VOCs (see below). No VOCs were detected in the sample.

A time-series groundwater test was conducted at well COG-01 during March and April 2013. The purpose of the test was to provide data to determine the source and nature of the PCE detected in samples from well COG-01. The time-series test generated data that supports leakage of PCE-impacted groundwater into the COG-1 wellbore through the well annulus and/or breaches in the casing. A complete summary of the methods and results of the time-series test was prepared on behalf of ADEQ on November 1, 2013 (H+A, 2013b).

3.4.3 Areas of Uncertainty

While no vadose zone source area was identified during the source investigations, the gradient and distribution of PCE in groundwater suggests a source or sources in the area of monitor wells MW-1 and perhaps to a much lesser extent well MW-2. Dry cleaner operations were formerly present in the area of these two monitor wells (GeoTrans, 2009b).

3.5 REMEDIAL OBJECTIVES

ADEQ discussed and proposed ROs for the Site in January 2009 (ADEQ, 2009). Pursuant to A.A.C. R18-16-406 (I)(4), the ROs were chosen with consideration for the current and reasonably foreseeable future uses of land and water of the state that have been or are threatened to be affected by a release of a hazardous substance. PCE was identified as the sole chemical of concern for the Site. Since no potential source areas or areas of significantly PCE-impacted soil or soil vapor were identified at the Site; no ROs for land use were identified (ADEQ, 2009).

The ROs for current and future use of groundwater supply for irrigation and municipal use are as follows:

> *"To protect the supply of groundwater for municipal and irrigation use and for the associated recharge capacity that is threatened by contamination emanating from the Western Avenue WQARF Site. To restore, replace or otherwise provide for the groundwater supply lost due to contamination associated with the Western Avenue WQARF Site. This action will be needed for as long as the need for the water exists, the resource remains available and the contamination associated with the Western Avenue WQARF Site prohibits or limits groundwater use."* (ADEQ, 2009).

4.0 IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES AND ALTERNATIVES

The following criteria were considered for remedial technologies and alternatives for the Site as part of the FS:

- Contaminant treatment effectiveness;
- Compatibility with drinking water systems;
- Constructability;
- Flexibility/expandability;
- Operation and maintenance requirements;
- Management of residual waste products;
- Chemical use/operational hazards, and
- Cost/effectiveness.

The following Site assumptions and requirements were used during the identification and screening of remedial technologies and alternatives:

- Contaminant – PCE concentrations at a maximum of approximately 6 µg/l in one Subunit A groundwater monitor well;
- Remedial Efficiency – Must achieve drinking water standards (AWQS) and groundwater ROs;
- End Use – Domestic consumption;
- Cost – Compared, based on each remedial scenario.

Groundwater and saturated soil were the only matrix/media considered in the FS because no ROs were established for other media. No areas of PCE- or other VOC-impacted unsaturated (vadose zone) soil have been identified at the Site based on previous source area investigation activities (GeoTrans, 2009b). Based on this line of evidence, soil gas and consequently soil vapor intrusion would not be a potential risk to human health or the environment.

4.1 IDENTIFICATION OF TECHNOLOGIES AND ALTERNATIVES

This section identifies the remedial technologies and alternatives considered for groundwater and saturated soil remediation at the Site.

4.1.1 Identified Remedial Technologies

The technologies that have been identified for screening as potentials to remediate groundwater and saturated soil at the Site include the following:

- Enhanced Bioremediation;
- In-situ Chemical Oxidation;
- Air Sparging;
- Pump and Treat Remediation;
- Soil Vapor Extraction, and
- Monitored Natural Attenuation (MNA).

4.1.2 Retained Technology and Identified Remedial Alternatives

Based on the observed natural decrease of PCE concentrations in Subunit A groundwater over time and the limited area of PCE remaining in Subunit A groundwater at concentrations greater than its AWQS, enhanced bioremediation, chemical oxidation, air-sparging, pump and treat, and soil vapor extraction remedial technologies are not considered practical or cost-effective remedies for Site remediation. Nor do these active technologies appear to significantly lower risk to any potential receptors, as the extent of contamination presently is limited. MNA has been retained as a potential technology appropriate for the Site.

The following are remedial alternatives that have been identified as potential Site remedies:

- Alternative 1: No Action
- Alternative 2: MNA;
- Alternative 3: Alternative Water Supply
- Alternative 4: Wellhead Treatment;
- Alternative 5: Operational Strategies and Monitoring; and
- Alternative 6: Institutional Controls.

A summary of these potential alternatives is provided in Table 1. A screening of these potential alternatives is provided in the following sections.

4.2 <u>SCREENING OF ALTERNATIVES</u>

This section defines the assumptions for screening the potential remedial alternatives for groundwater and saturated soil at the Site. The remedial alternatives were screened against the following nine criteria:

Initial threshold criteria:

1) Does the alternative protect human health and the environment?
2) Does the alternative comply with applicable Federal and State regulations?

If the initial threshold criteria are met, the alternatives are evaluated according to the following balancing criteria:

3) Is the alternative an effective long-term solution?
4) Does the alternative use treatment to permanently reduce toxicity, mobility, or volume of the contaminant?
5) Is the alternative protective of workers, the community, and the environment during implementation?
6) Can the alternative be easily constructed and operated with readily available goods and services?
7) Is the alternative cost-effective?

The following modifying criteria are used as a final screening tool:

8) Will state regulatory agencies accept the proposed alternative?
9) Does the affected community accept the proposed alternative?

The preliminary alternatives proposed for evaluation include no action, MNA, alternative water supply, wellhead treatment, operational strategies, and institutional controls. While other methods are potentially applicable, such as large-scale *ex situ* and *in situ* treatments, these methods do not appear to be appropriate based on the CSM and the extent of groundwater contamination. Moreover, PCE concentrations are trending downward (Appendix A).

Physical containment is not considered feasible based on the approximate depth to groundwater at the Site of 70 feet. Source control is likewise eliminated based on the absence of known continuing sources of PCE in Site soils. Specifically, the areal extent and contaminant mass do not appear to warrant these types of remedy.

4.3 DESCRIPTIONS OF ALTERNATIVES

The following subsections describe the alternatives screened for further consideration.

4.3.1 Alternative 1: No Action

The “no action” alternative involves undertaking no active remedial actions.

No measures are implemented to address groundwater contamination or prevent human exposure to groundwater contamination. This alternative is regarded as the baseline for comparison to all other potential remedial alternatives and is listed among the minimum remedial strategies to be considered.

4.3.2 Alternative 2: Monitored Natural Attenuation

MNA involves the passive evaluation of the progress of ongoing natural processes that reduce the volume, toxicity, mobility, and/or concentration of contaminants in groundwater. Source control and long-term monitoring are essential components of MNA. Additionally, it is essential that contaminant dynamics indicate either a relatively static condition or regression in terms of advancement. This is established through a prior monitoring record.

MNA is often evaluated according to various agency guidance manuals (e.g., U.S. Environmental Protection Agency [EPA], 1998). Specifically, MNA involves destructive and/or non-destructive mechanisms that achieve the aforementioned contaminant reduction processes. Nondestructive mechanisms include dilution, dispersion, advection, sorption, and volatilization. Destructive mechanisms, generally involve biodegradation, but may also include various types of chemical reactions, depending on the nature of the contaminant species and ambient conditions in the aquifer. Insofar as PCE is concerned, the biodegradation pathway is well understood under both aerobic and anaerobic conditions (Figure 9). To date, studies have not been performed at the Site to ascertain whether the conditions exist to facilitate biodegradation of groundwater PCE; however, historic water quality data collected at the Site indicate significant decreases in PCE concentration during the last 15 to 20 years.

4.3.3 Alternative 3: Alternative Water Supply

Alternative water supply is a remedial strategy that merits consideration in addition to the aforementioned remedial strategies. The City of Avondale (COA) water supplies are based on a portfolio that includes water allocations from the Central Arizona Project (CAP), Salt River Project (SRP), groundwater produced from COA wells, and reclaimed water that is recharged for supply. The COA has direct access to its SRP allocation and access to its CAP allocation via the SRP system. The COA does not have a surface water treatment facility. Therefore, the entire COA drinking water system is based on recharge and recovery of its surface water rights. There are no COA production wells at the Site.

The majority of the COG groundwater is supplied by its ten wells. All of these wells, with the exception of one (well COG-01) are located outside of the Site and within the WSRV Sub-basin. Presently, COG does not supply surface water to residents, so groundwater is the only potable water supply source. Three irrigation districts hold surface water rights, but deliver water only to agricultural users. The ability of COG to expand its boundaries south of the Gila River provides another possible alternative groundwater supply.

4.3.4 Alternative 4: Wellhead Treatment

Wellhead treatment is an *ex situ* method that involves conventional extraction of groundwater from wells and post-extraction treatment by appropriate methods that will remove or reduce the contaminant concentrations to permissible levels prior to end use. For PCE, various potential treatment methods are available, including small-scale air stripping and granular activated carbon filtering. Depending on the water distribution system, treatment could either be done at multiple wellheads or the water could be routed to a central facility for treatment.

4.3.5 Alternative 5: Operational Strategies and Monitoring

Various operational strategies can be implemented to avoid capture of contaminated groundwater. Specifically, operational strategies may involve pumping from other supply wells, and with close monitoring of water quality and contaminant dynamics. Additionally, consideration should be given to the possibility of well modifications and/or maintenance for the purpose of insuring against cross-contamination and induced vertical movement of contaminants.

4.3.6 Alternative 6: Institutional Controls

Institutional controls are non-engineered instruments, such as administrative and legal controls, that help minimize the potential for human exposure to contamination and/or protect the integrity of the remedy. For example, one control might be a ban on the use of groundwater within an area defined by the extent of the plume. Use of institutional controls requires that an authority has legal jurisdiction to control or regulate in the matter or to impose the essential requirements. Institutional controls are generally not a stand-alone remedy but a component of a broader remedial strategy.

4.4 RETAINED ALTERNATIVES

Table 1 summarizes the results of the screening analysis. The following alternatives have been retained for further consideration:

- Alternative 2: MNA,
- Alternative 5: Operational Strategies and Monitoring, and
- Alternative 6: Institutional Controls.

These alternatives are anticipated to achieve groundwater ROs and meet the nine screening criteria (Section 4.2). Alternative 1: No Action, was not retained because this alternative would not necessarily achieve groundwater ROs. Alternatives 3 and 4: Alternative Water Supply and Wellhead Treatment, respectively, were not retained because current information indicates there is no evidence of impact to COG or COA water supply from the Site.

Wellhead treatment could be considered if the COG water supply becomes impacted by Site contamination or if one of the retained alternatives proves to be ineffective over time. However, based on the results of the well COG-01 time-series test; pumping of well COG-01 appears to be effective in removing PCE that enters the wellbore by leakage and to date the AWQS of 5 µg/l has not been exceeded (H+A, 2013b).

The subsequent sections provide an evaluation of achieving the groundwater ROs, their compatibility with applicable state and federal regulations, their effectiveness at treating the target contaminants, their operational and maintenance requirements, and their overall costs. The retained alternatives have been used to develop the reference remedy and alternative remedies as discussed below.

5.0 DEVELOPMENT OF A REFERENCE REMEDY AND ALTERNATIVE REMEDIES

This section develops a reference remedy for groundwater and saturated soil along with two alternative remedies: 1) more aggressive remedy, and 2) less aggressive remedy. These three remedies are based on retained remedial alternatives and evaluation of remedial measures, strategies, and discharge considerations to achieve ROs for the Site as discussed in the sections above.

Remedial measures necessary for each alternative remedy were developed for the Site ROs and identified with consideration of the needs of the water providers in the region (COA and COG) 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 modification, water treatment, provision of replacement water supplies, and engineering controls, if deemed necessary and/or appropriate. 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. The reference remedy and the alternative remedies are described below.

5.1 REFERENCE REMEDY: STRATEGY AND MEASURES

A reference remedy is defined as a combination of remedial strategies and remedial measures which, as a whole, is capable of achieving ROs. The Alternative 2: MNA is proposed as the reference remedy for groundwater. This conclusion is based on:

- Site data inferring that there does not appear to be any significant continuing source or sources of PCE within the Site area;
- Site data indicating that concentrations of PCE in Subunit A groundwater have decreased significantly during the last 15 to 20 years;

- Site data that indicates that the present day extent of PCE contamination in groundwater is minimal, and
- Present information that does not suggest there is any impact on local water supplies. This is based on the fact that the AWQS for PCE in well COG-01 has not been exceeded to date. However, PCE concentrations have approached the AWQS in the recent past. ADEQ anticipates that the continued decrease of PCE in monitor well MW-1, a possible source of PCE to well COG-01, will reduce any potential risk to well COG-01 in the future. ADEQ will continue to monitor PCE at both wells COG-01 and MW-1 in the future (Section 5.1.2).

If this remedy were implemented and if future groundwater conditions were to indicate potential risks to Subunit C, specifically well COG-01, as a contingency, well COG-01 will be abandoned and destroyed pursuant to ADWR regulations. Indications of potential risks to Subunit C will be defined as two consecutive groundwater sampling events where PCE is detected in groundwater samples from well COG-01 at concentrations greater than the AWQS of 5 µg/l. The details of potentially abandoning and destroying well COG-01 will be summarized in the future, if necessary.

5.1.1 Requirements of the Reference Remedy

The requirements for a reference remedy are to meet the saturated soil and groundwater ROs. The proposed reference remedy of MNA will accomplish this requirement by:

1) Allowing for the continued definition and monitoring of Subunit A groundwater by the current monitor well network;
2) Provide for the ability of the COG to utilize groundwater at the Site, if and when necessary, and
3) Provide for remediation of PCE and any potential daughter products.

MNA is capable of meeting each of these requirements and achieving the groundwater ROs.

5.1.2 Remedial Strategy and Measures of the Reference Remedy

The remedial strategy and measures for the reference remedy at the Site is: remediation of the Subunit A groundwater within an acceptable timeframe by MNA. Based on the current trend of PCE concentrations at well MW-1, it is projected that PCE will decrease to concentrations less than the AWQS in less than ten years (Appendix A). As previously discussed, no continuing PCE source or sources have been identified within the Site area. Therefore, source control is not included in the reference remedy.

The evaluation of groundwater data collected from Site monitor wells over the past 15 to 20 years indicates a decreasing trend of PCE concentrations in nearly all wells (Section 3.0; Appendix A). Thus, it is reasonable to conclude that PCE concentrations will continue to decline due to the natural physical, geochemical, and/or biological processes that are present in the aquifer system.

MNA would include both measuring water levels in Site Subunit A monitor wells to confirm the direction and magnitude of the hydraulic gradient and collecting groundwater samples to confirm PCE concentrations are stable or continuing to decrease. This FS report recommends that the entire Site monitoring network be retained for the implementation of the MNA program. This network currently consists of ten Subunit A monitor wells (Figure 2). Two of these 10 monitor wells, GMW-4 and GMW-5, are currently monitored for water levels only. All other monitor wells are monitored for water levels and water quality. Additionally, water level and water quality would be measured in well COG-01 during MNA to assess the nature of potential vertical migration from Subunit A to Subunit C.

Groundwater samples from these wells would be collected utilizing PDB samplers for VOC and HydraSleeve® samplers for MNA parameter analyses on a semi-annual basis. The existing pumping equipment would be used to collect samples from well COG-01. Technical reporting of results would also be completed on a semi-annual basis. MNA data would be reviewed after a period of one year to evaluate contaminant attenuation and based on this review, sample frequency may be modified.

A detailed scope of MNA activities will be presented in the PRAP developed for the Site. The costs for MNA as the reference remedy will be compared and evaluated against the two other selected alternatives in Section 6.0.

5.2 MORE AGGRESSIVE ALTERNATIVE REMEDY: STRATEGY AND MEASURES

Pursuant to A.A.C. R18-16-407 (E)(3), a more aggressive strategy is a strategy that requires additional remedial measures to achieve ROs, a strategy that achieves ROs in a shorter period of time, or a strategy that is more certain in the long term and requires fewer contingencies. Alternative 5: Operational Strategies is proposed as the more aggressive alternative remedy for the Site.

5.2.1 Requirements of the More Aggressive Alternative Remedy

The requirements for a more aggressive alternative remedy are the same as the reference remedy. Operational strategies and monitoring are potentially capable of meeting each of the ROs in a shorter timeframe compared to the reference remedy MNA.

5.2.2 Remedial Strategy and Measures of the More Aggressive Alternative Remedy

Implementation and use of operational strategies would be used to avoid capture of contaminated groundwater from domestic use wells in the vicinity of the Site. Specifically, operational strategies may involve pumping other COG wells to meet demand and the close monitoring of water quality and plume dynamics. However, the results of the well COG-01 time-series test indicates that pumping well COG-01 is effective in removing PCE that enters the well through breaches in the casing and/or annulus after periods of inactivity (H+A, 2013b).

If this remedy were implemented and if future groundwater conditions were to indicate potential risks to Subunit C; as a contingency, a new Subunit C monitor well may be drilled and completed at the Site in an appropriate location to monitor groundwater conditions. Potential risks to Subunit C will be defined as two consecutive groundwater sampling events where PCE is detected in groundwater samples from well COG-01 at concentrations greater than the AWQS of 5 µg/l. The details of potential new Subunit C monitor well installation will be summarized in the future, if necessary.

A detailed scope of operational strategies may be presented in the PRAP developed for the Site. The costs for operational strategies as the more aggressive remedy will be compared and evaluated against the two other selected alternatives in Section 6.0.

5.3 LESS AGGRESSIVE ALTERNATIVE REMEDY: STRATEGY AND MEASURES

Pusuant to A.A.C. R18-16-407 (E)(3), at least one of the alternative remedies must employ a remedial strategy or combination of strategies that is less aggressive than the reference remedy. This alternative will still be capable of achieving the defined ROs, but may use less intensive or fewer remedial measures than the reference remedy. Alternative 6: Institutional Controls is proposed as the less aggressive alternative remedy for the Site.

5.3.1 Requirements of the Less Aggressive Alternative Remedy

The requirements for a less aggressive alternative remedy are the same as the reference remedy. Institutional controls are capable of meeting each of these requirements using fewer remedial measures than the reference remedy.

5.3.2 Remedial Strategy and Measures of the Less Aggressive Alternative Remedy

Institutional controls would consist of non-engineered instruments, such as administrative and legal controls, that would help to minimize the potential for human exposure to contamination.

Specific institutional controls may include: state and local government land use controls, (such as zoning restrictions, statutes, well-drilling permits, and building permits); proprietary or property-law based controls, (such as environmental covenants, restrictive covenants, reversionary interests, easements, servitudes, and requirements of notices in deeds and other property conveyance documents); governmental controls (such as No Further Action letters, consent decrees, and certificates of completion), and informational devices (such as notifications of residual contamination, state registries of hazardous waste sites, advisories, signs, and warnings) (Pendergrass and Probst, 2005). Arizona Department of Water Resources and ADEQ would be the legal authorities to control or regulate in the matter or to impose the essential requirements for the water use restriction and permitting. The primary uncertainties and contingencies are considered to be whether or not the less aggressive remedy would be responsive to the COG's need to utilize the Site groundwater in a timely manner, consistent with its possible future needs.

A detailed scope of institutional controls may be presented in the PRAP developed for the Site. The costs for institutional controls as the less aggressive remedy will be compared and evaluated against the two other selected alternatives in Section 6.0.

6.0 DETAILED COMPARISON OF THE REFERENCE REMEDY AND ALTERNATIVE REMEDIES

The reference remedy and the alternative remedies have been evaluated based on the comparison criteria to select a remedy that complies with A.R.S. § 49-282.06 and in accordance with A.A.C. R18-16-407. Each remedy is capable of achieving the groundwater ROs and therefore would be consistent with the local water management plans and general use plans (ADEQ, 2009). The following sections discuss additional comparison criteria for each of the selected alternatives.

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

Each remedy was also evaluated based on the following criteria: practicability, cost, risk, and benefit. The evaluations are presented below.

6.1.1 Reference Remedy – MNA

Practicability

MNA is a practicable and feasible remedy for the Site. MNA is essentially already in place in the Site area and has been proven to be effective in the long-term based on the decreasing PCE concentrations from the 1990s to the present. The only consistently remaining area of groundwater contamination at the Site is near monitor well MW-1. It is anticipated that PCE concentrations will continue to decrease at their current rate. As such, MNA will be effective in the short-term as PCE is anticipated to continue to decrease in concentration in the well MW-1 area to below the AWQS in less than ten years. MNA would achieve the groundwater ROs because groundwater quality would then be restored to concentrations at or below the AWQS. If MNA were implemented and if future conditions were to indicate potential risks to Subunit C downgradient of the Site, as a contingency, well COG-01 will be abandoned and destroyed pursuant to ADWR regulations. Indications of potential risks to Subunit C will be defined as two consecutive groundwater sampling events where PCE is detected in groundwater samples from well COG-01 at concentrations greater than the AWQS of 5 µg/l. The details of potentially abandoning and destroying well COG-01 will be summarized in the future, if necessary (Section 5.1).

Cost

The estimated cost to implement MNA is approximately $425,000 for a period of 15 years (Table 2). Although it is anticipated that concentrations of PCE at well MW-1 will be less than the AWQS in approximately 10 years by MNA, costs are estimated for 15 years as a contingency.

This timeframe is anticipated to be more than adequate for natural processes to reduce PCE concentrations to less than its AWQS and for MNA to confirm that PCE concentrations have not rebounded. Costs were estimated assuming that eight of the ten existing Subunit A monitor wells and well COG-01 would be sampled for VOCs and other selected MNA parameters on a semiannual basis for 15 years. The cost estimate also includes semi-annual reporting, a one-year review, and project administrative review every five years.

Risk

MNA will be protective of public health by confirming that PCE is reduced in all monitor wells to concentrations less than its AWQS and meeting Site groundwater ROs. The fate and transport of contaminates over the life of the remedy is not anticipated to be significant since there is only one limited area above the AWQS and this condition has been present since the early 2000s.

However, reduced PCE concentrations in Subunit A will decrease the potential risk to the COG water supply in Subunit C. There are no potential exposure pathways for human or terrestrial biota since Subunit A groundwater is not used as a source of groundwater for domestic or municipal use. There are no surface water bodies present at the Site so there is no potential exposure pathway for aquatic biota. The residual risk at the conclusion of remediation will be minimal as groundwater ROs will be met and PCE will not be present in Subunit A groundwater at concentrations greater than the AWQS.

Benefit

Natural attenuation appears to be effective in reducing PCE concentrations at the Site. MNA will therefore confirm that reduced PCE concentrations will present a lower risk to potential receptors, reduce the volume of impacted groundwater, and decrease the liability of the state. Reduced PCE concentrations in Subunit A will decrease the potential risk to the COG water supply in Subunit C. By achieving groundwater ROs, MNA will also provide benefit for exiting and future uses in the community; potentially improving the local economy.

6.1.2 More Aggressive Remedy – Operational Strategies and Monitoring

Practicability

Operational strategies and monitoring is a practicable remedy for the Site. The implementation of this remedy may require initial coordination and planning between ADEQ and the COG. Coordination may be required to develop a plan for groundwater extraction at well COG-01.

This plan may require a change in the cycling of pumps in conjunction with monitoring of water quality by both COG and ADEQ. However, ADEQ recognizes that the COG requires flexibility to be able to use well COG-01 on an as-needed basis.

If this remedy were implemented and if future groundwater conditions were to indicate potential risks to Subunit C, as a contingency, a new Subunit C monitor well may be drilled and completed at the Site in an appropriate location to monitor groundwater conditions. Potential risks to Subunit C will be defined as two consecutive groundwater sampling events where PCE is detected in groundwater samples from well COG-01 at concentrations greater than the AWQS of 5 µg/l. The details of potential new Subunit C monitor well installation will be summarized in the future, if necessary (Section 5.2.2).

Cost

The estimated cost to implement operational strategies and monitoring is approximately $450,000 for a period of 15 years (Table 2). The cost of operational strategies and monitoring was estimated assuming that eight groundwater monitoring wells and well COG-01 would be sampled on a semi-annual basis for 15 years, contingent upon a review of data after the first year of implementation.

It is also assumed that a project administrative review will occur every five years and after 15 years, groundwater data results will indicate the remedy changing the operational COG strategies for pumping has effectively achieved the ROs for the Site. The cost includes a breakdown of the estimated annual monitoring. Optional costs described above have not been included in these costs.

Risk

Operational strategies and monitoring has less risk than the reference remedy because modification(s) would be implemented in the operational strategies to help protect the COG water supply. It would; however, not include any active remediation other than removing the PCE that has entered the well during down-time. Current data do not suggest there is presently any impact on local water supplies; monitoring of Site monitor wells and well COG-01 will continue to ensure that continues to be the case. Should monitoring indicate a change in water quality impacting the water supply, contingent measures may be taken.

Therefore, operational strategies and monitoring will be protective of public health by further decreasing the potential that PCE-impacted groundwater is not used for municipal use. Similar to the reference remedy, the fate and transport of contaminates over the life of this remedy is not anticipated to be significant since there is only one limited area above the AWQS. Reduced PCE concentrations in Subunit A through MNA will also decrease the potential risk to well COG-01.

There are no potential exposure pathways for human or terrestrial biota under this remedy. There are no surface water bodies present at the Site so there is no potential exposure pathway for aquatic biota. The residual risk at the conclusion of remediation will be minimal as groundwater ROs will be met and PCE will not be present in Subunit A groundwater at concentrations greater than the AWQS (through MNA).

Benefit

Operational strategies and monitoring will allow for the continued use of well COG-01 for municipal use at the Site and present a lower risk to potential receptors. Ongoing natural attenuation processes will continue to reduce PCE concentrations and the volume of impacted groundwater.

Reduced PCE concentrations will also decrease the potential risk to well COG-01, achieving groundwater ROs. This will provide benefit for exiting and future uses in the community and potentially improving the local economy.

6.1.3 Less Aggressive Remedy – Institutional Controls

Practicability

Institutional controls are a less practicable remedy. The implementation of this remedy would also require a substantial amount of coordination and planning between ADEQ, the COG, and other governmental entities to establish non-engineered instruments. Use of institutional controls requires that an authority has legal jurisdiction to control or regulate in the matter or to impose the essential requirements including a ban on groundwater use and other administrative and legal controls.

Cost

The estimated cost to implement institutional controls is approximately $200,000 for a period of 15 years (Table 2). The cost of institutional controls for the Site was estimated assuming permitting and correspondence would be required, as well as annual site inspections.

Risk

Institutional controls have the least risk of all the remedies because institutional controls would be implemented to restrict land and groundwater use in the Site area and require alternative water supplies for the COG. It would; however, not include any active remediation. As discussed above, current data does not suggest there is presently any impact on local water supplies; monitoring of well COG-01 will continue to ensure that continues to be the case.

Benefit

The institutional control remedy would prevent the continued use of wells in the Site area by installing restrictions and other non-engineered instruments. This would present the lowest risk to potential receptors. However, these restrictions may negatively impact exiting and future uses in the community, potentially damaging the local economy.

6.2 COMPARISON OF REMEDIES

The remedial alternatives developed for the Site were compared to one another based on the above listed comparison criteria.

Practicability

All three retained remedies are considered protective of human health and the environment within a reasonable time frame. Water quality data indicates MNA is occurring at the Site.

The operational strategies and monitoring remedy of changing COG operational controls and continued monitoring has an uncertainty in the protectiveness because it is moderately practicable because extensive changes would need to be made to the COG operational strategies which might be difficult in a reasonable timeframe. Institutional controls would support the protection of human health and the environment, but the implementation is at best moderately practicable for the COG in a reasonable timeframe.

Of the three retained remedies, MNA, the reference remedy, is the most practicable strategy. As discussed above, current data does not suggest any present impact on local water supplies; and thus no need for an active remedy. MNA would fulfill the groundwater ROs because groundwater quality would be restored to concentrations below the AWQS.

Cost

Estimated order of magnitude costs for the retained remedies are as follows:

Remedy	Estimated Annual Costs	Estimated Costs after 15 Years
Reference Remedy – *MNA*	$28,000	$425,000
More Aggressive Remedy *Operational Strategies and Monitoring*	$30,000	$450,000
Less Aggressive Remedy *Institutional Controls*	$13,000	$200,000

Risk

MNA has an increased risk compared to operational strategies and monitoring because there is no modification of COG operations for water supply. However, natural attenuation is anticipated to decrease PCE in groundwater to the AWQS over time and PCE concentrations remain consistently low (Appendix A). Current data does not suggest there is presently any impact on local water supplies; monitoring of well COG-01 will continue to ensure that continues to be the case. Should monitoring indicate a change in water quality impacting the water supply, contingent measures may be taken.

The institutional controls remedy has the least risk of all the remedies because institutional controls would be implemented to restriction land and groundwater use in the Site area and require alternative water supplies for the COG. It would; however, not include any active remediation.

Benefit

MNA would provide the most benefit for the Site of the three retained remedies. MNA would be most beneficial to the Site and Site areas existing and future use and be of most potential benefit to the local economy.

6.3 UNCERTAINTIES

The primary uncertainties/difficulty in implementing the more and less aggressive remedies is the coordination between ADEQ and COG to implement modifications and other administrative instruments and/or changes in operational strategies. As noted above, ADEQ recognizes that the COG requires flexibility to be able to use well COG-01 on an as-needed basis.

The time-frame required for negotiations for the more and less aggressive remedies is unknown at this time, as well as the willingness for the COG to incorporate the necessary changes. Impacts on city and state budgets for such water supply alterations are also currently unknown.

7.0 PROPOSED REMEDY

The ROs for the Site is:

> *"To protect the supply of groundwater for municipal and irrigation use and for the associated recharge capacity that is threatened by contamination emanating from the Western Avenue WQARF Site. To restore, replace or otherwise provide for the groundwater supply lost due to contamination associated with the Western Avenue WQARF Site. This action will be needed for as long as the need for the water exists, the resource remains available and the contamination associated with the Western Avenue WQARF Site prohibits or limits groundwater use."* (ADEQ, 2009).

Based upon the evaluation and comparison of the reference remedy and the other alternative remedies developed by this FS report, MNA, the reference remedy, is the proposed remedy for the Site. This recommendation is based on the combination of remedial effectiveness, practicality, cost, risk, and benefit to achieve the groundwater ROs. MNA has been judged to be protective of human health and the environment, compliant with cleanup standards, and state laws. MNA also allows for the maximum beneficial use of the waters of the State and also general land use of mixed business, residential, and industrial. If a further level of control is deemed appropriate, then MNA could be combined with institutional controls.

8.0 COMMUNITY INVOLVEMENT

Public concerns and comments are considered throughout the entire WQARF process. This helps ADEQ to complete its mission of protecting public health, welfare and the environment in Arizona. The public is invited to attend the quarterly Community Advisory Group meetings and receive Western Avenue Site updates, as well as updates for the neighboring PGA Superfund sites. Site meeting agendas and meeting minutes can be found at: http://www.azdeq.gov/environ/waste/sps/reg.html. The latest Site information, documents, and notices can be found at: http://www.azdeq.gov/environ/waste/sps/phxsites.html#westavea.

A notice of the availability for the FS work plan was mailed to the Site mailing list, the CAG, and other interested parties. The FS work plan was also discussed during the November 8, 2012 CAG meeting. However, because of the close working relationship with the cities of Goodyear and Avondale; ADEQ submitted the Draft FS report and the Draft Time-Series Groundwater Sampling of City of Goodyear Well COG-01 report, which contributed to the FS report, to the cities for review. The cities' comments have been addressed in the FS report. The draft FS and draft and final Well COG-01 reports were also discussed at the February 7, 2013, May 2, 2013, August 8, 2013, and November 7, 2013 CAG meetings.

The PRAP is the next phase of the WQARF process. The PRAP will be based on the RI and FS reports and will describe the proposed Site remedy and its estimated cost. ADEQ will be issuing a notice of the availability of the PRAP as well as when the public comment period will be conducted.

9.0 REFERENCES

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TABLES

TABLE 1
SUMMARY OF REMEDIAL ALTERNATIVES SCREENING

Alternatives		Likelihood to Achieve Current Remedial Objectives	Implementability	Rough Order of Magniture Costs	Retained for Further Consideration
1	No Action	Low	Easy	Low	No
2	Monitored Natural Attenuation	High	Easy	Low to Moderate	Yes
3	Alternative Water Supply	High	Moderate to Difficult	High	No
4	Wellhead Treatment	Moderate to High	Moderate	Moderate	No
5	Operational Strategies and Monitoring	High	Moderate	Low to Moderate	Yes
6	Institutional Controls	High	Difficult	Low	Yes

FOOTNOTES

WQARF= Water Quality Assurance Revolving Fund

TABLE 2
COST ESTIMATE FOR RETAINED REMEDIES

Reference Remedy - MNA

Description	Quantity	Unit	Unit Cost	Amount
Groundwater sampling and gauging labor	50	HR	$100	$5,000
Equipment (materials and rental)	2	LS	$2,000	$4,000
Project Management	20	HR	$120	$2,400
Reporting	60	HR	$120	$7,200
Hydrasleeves	9	EA	$25	$225
Laboratory Analysis – VOCs	9	EA	$130	$1,170
Laboratory Analysis – MNA	9	EA	$300	$2,700
Quality Control	$3,870		20%	$774
Waste Disposal	1,000	GAL	$0.20	$200
Annual Monitoring Cost (2014 to 2029) – Subtotal				$23,669
Contingency	$23,669		20%	$4,734
Annual Monitoring Cost – Total				$28,403
TOTAL (15 Years, 2014 to 2029)				**$426,042**

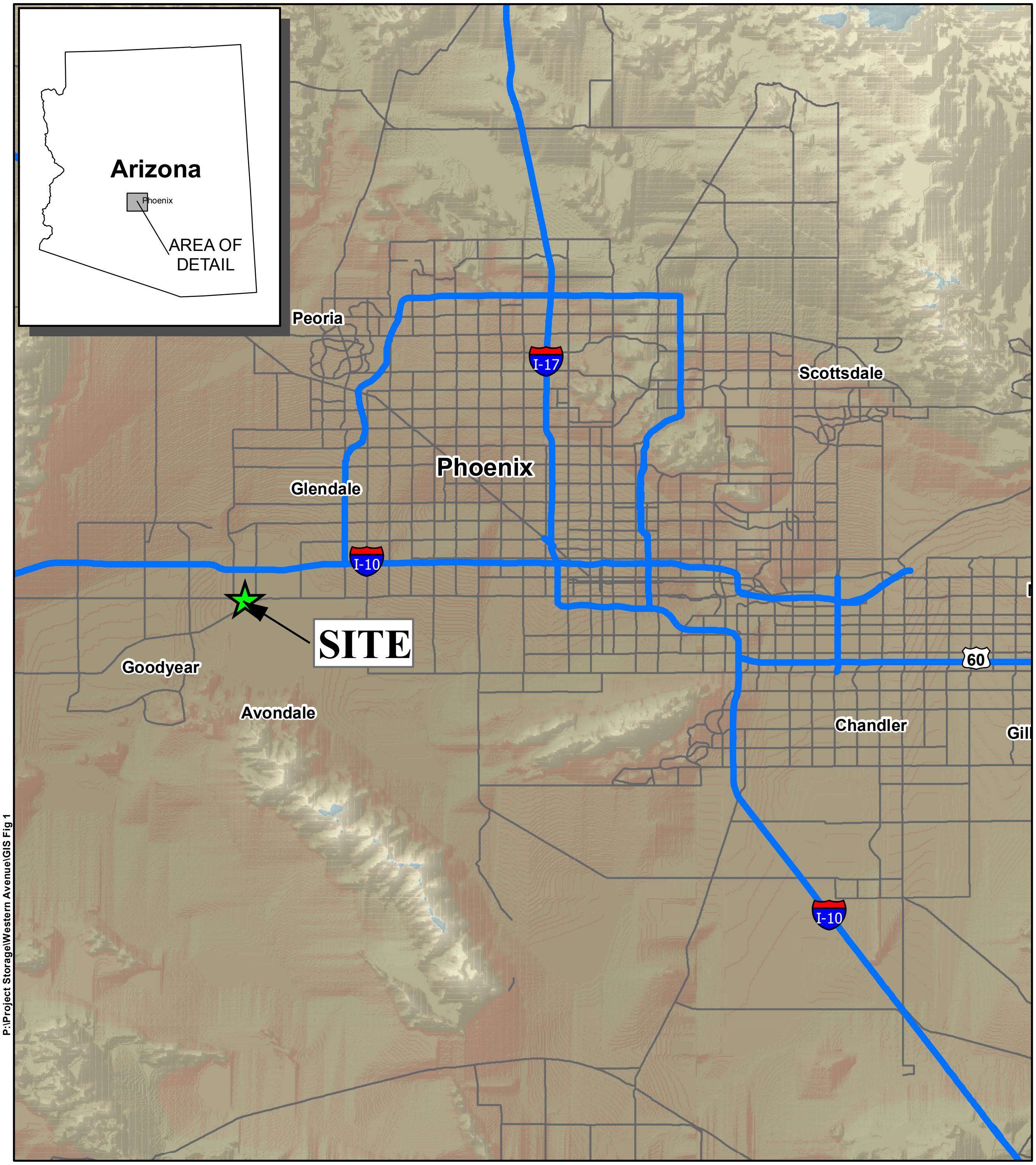
More Aggressive Remedy - Operational Strategies and Monitoring

Description	Quantity	Unit	Unit Cost	Amount
Groundwater sampling and gauging labor	50	HR	$100	$5,000
Equipment (materials and rental)	2	LS	$2,000	$4,000
Project Management	40	HR	$120	$4,800
Reporting/Correspondence	80	HR	$120	$9,600
PDBs	9	EA	$25	$225
Laboratory Analysis – VOCs	9	EA	$130	$1,170
Quality Control	$1,170		20%	$234
Waste Disposal	500	GAL	$0.20	$100
Annual Cost (2014 to 2029) – Subtotal				$25,129
Contingency	$25,129		20%	$5,026
Annual Monitoring Cost – Total				$30,155
TOTAL (15 Years, 2014 to 2029)				**$452,322.00**

Less Aggressive Remedy - Institutional Controls

Description	Quantity	Unit	Unit Cost	Amount
Annual Site inspections labor	8	HR	$100	$800
Annual Fees	1	LS	$1,000	$1,000
Project Management	40	HR	$155	$6,200
Reporting	20	HR	$155	$3,100
Annual Cost (2014 to 2029) – Subtotal				$11,100
Contingency	$11,100		20%	$2,220
Permitting Initial Costs	1	LS	$2,000	$2,000
Annual Monitoring Cost – Total				$13,320
TOTAL (15 Years, 2014 to 2029)				**$201,800.00**

FIGURES



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0 4 8 Miles

P:\Project Storage\Western Avenue\GIS Fig 1

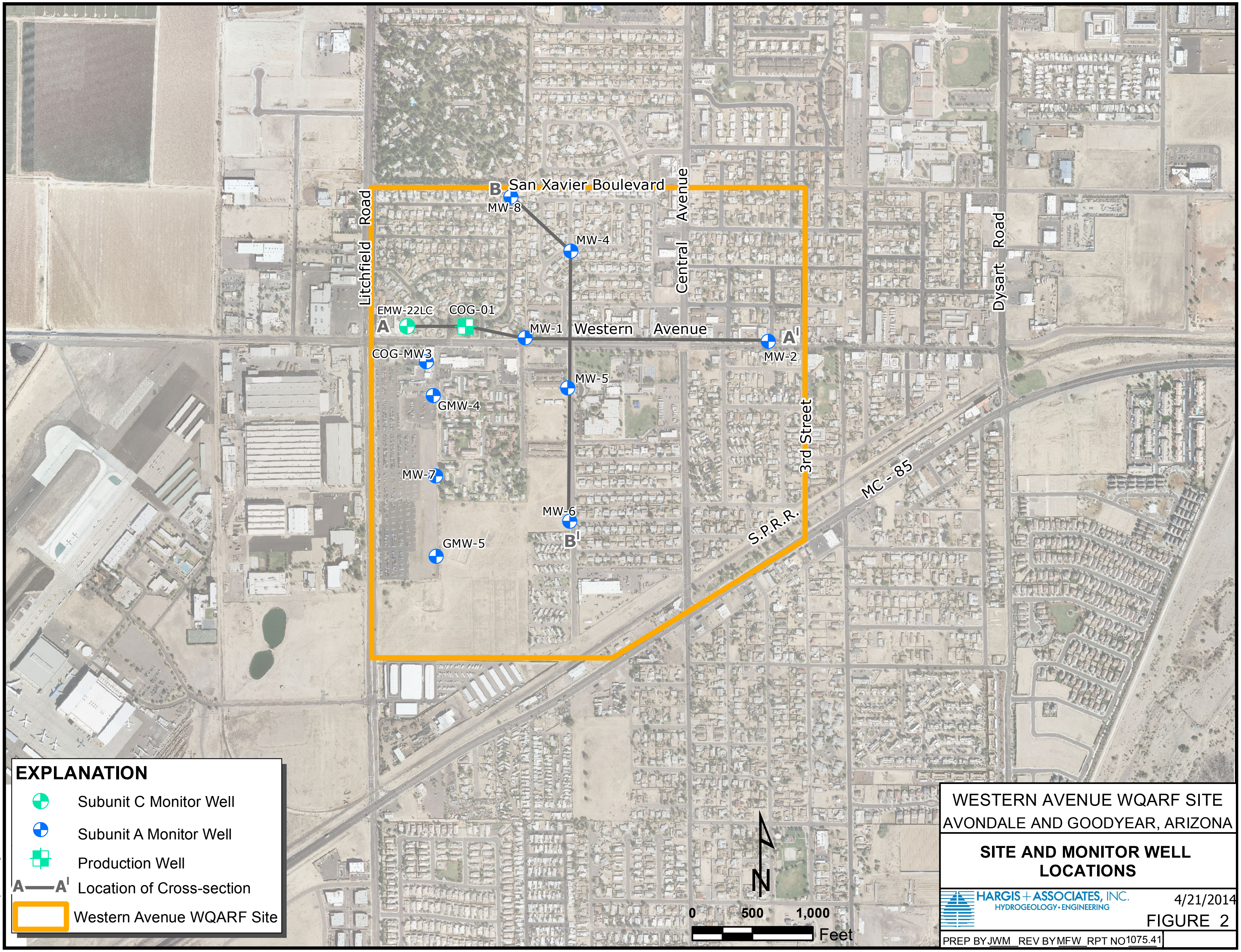
WESTERN AVENUE WQARF SITE
AVONDALE AND GOODYEAR, ARIZONA

SITE LOCATION

HARGIS + ASSOCIATES, INC.
HYDROGEOLOGY • ENGINEERING

FIGURE 1

PREP BY: JWM REV BY: MFW	DATE: 6/21/2010 FILE: Fig 1.mxd	PROJECT: 1075.41



WESTERN AVENUE WQARF SITE
AVONDALE AND GOODYEAR, ARIZONA

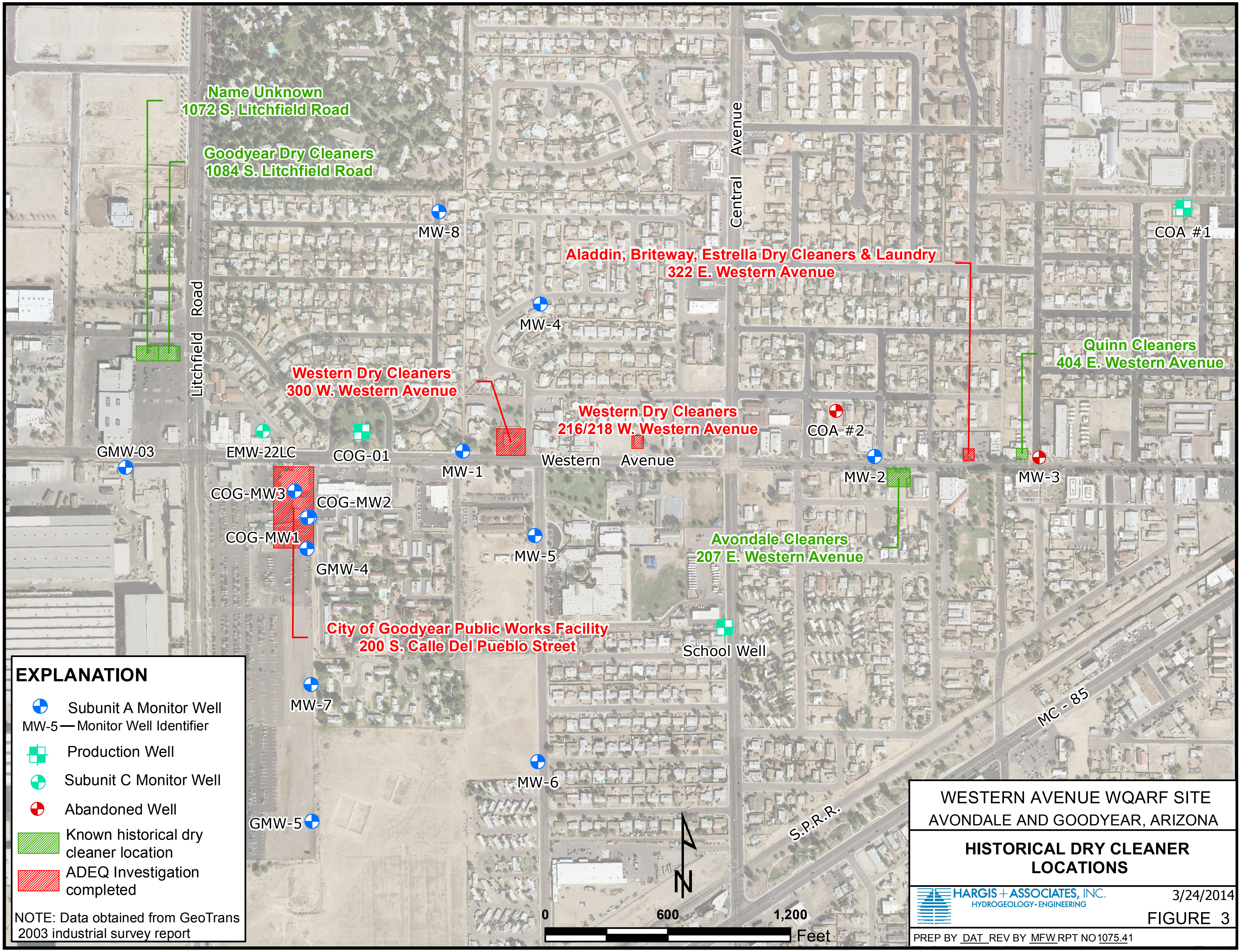
SITE AND MONITOR WELL LOCATIONS

HARGIS + ASSOCIATES, INC.
HYDROGEOLOGY • ENGINEERING

4/21/2014

FIGURE 2

PREP BY JWM REV BY MFW RPT NO 1075.41



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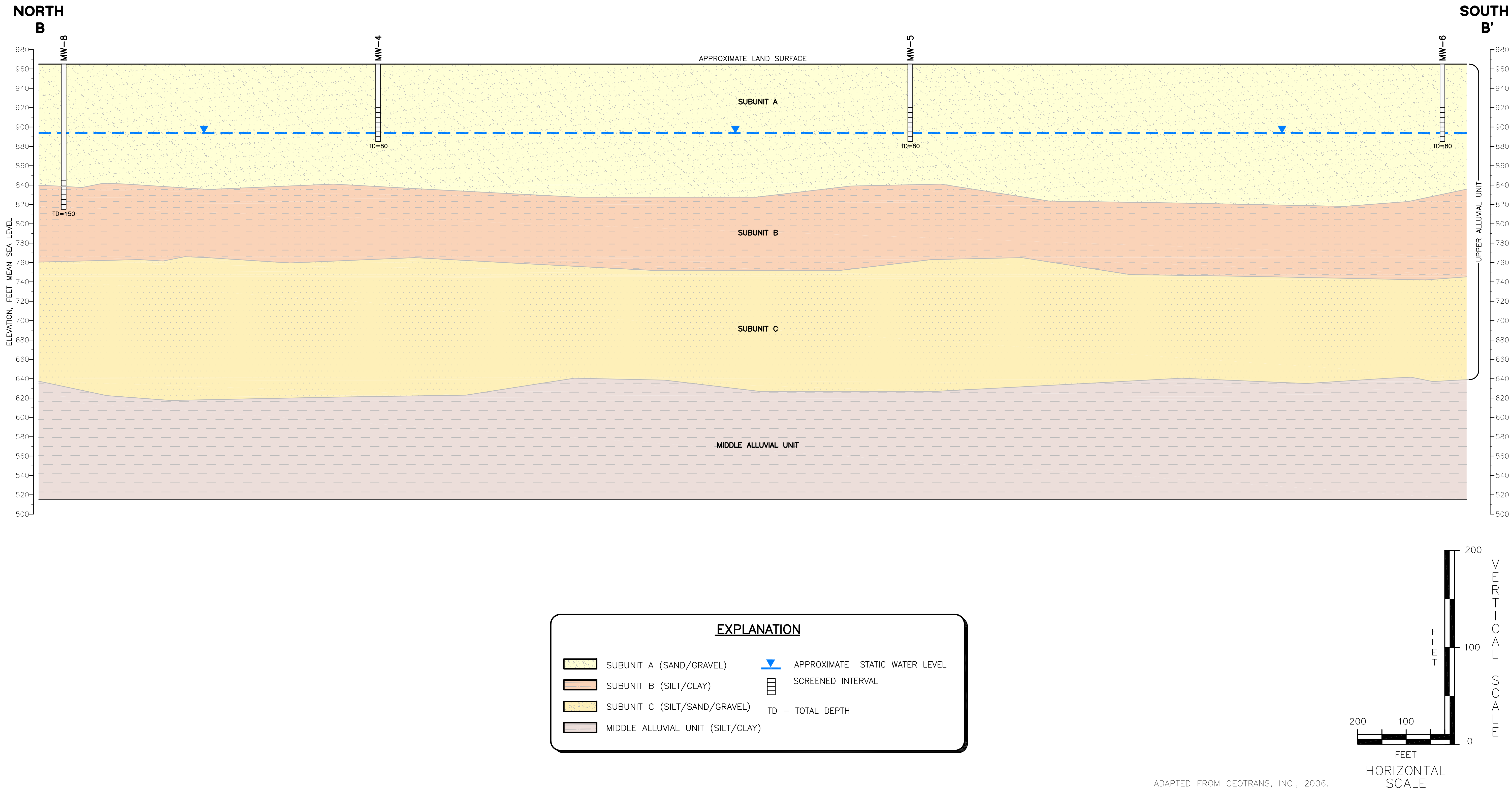

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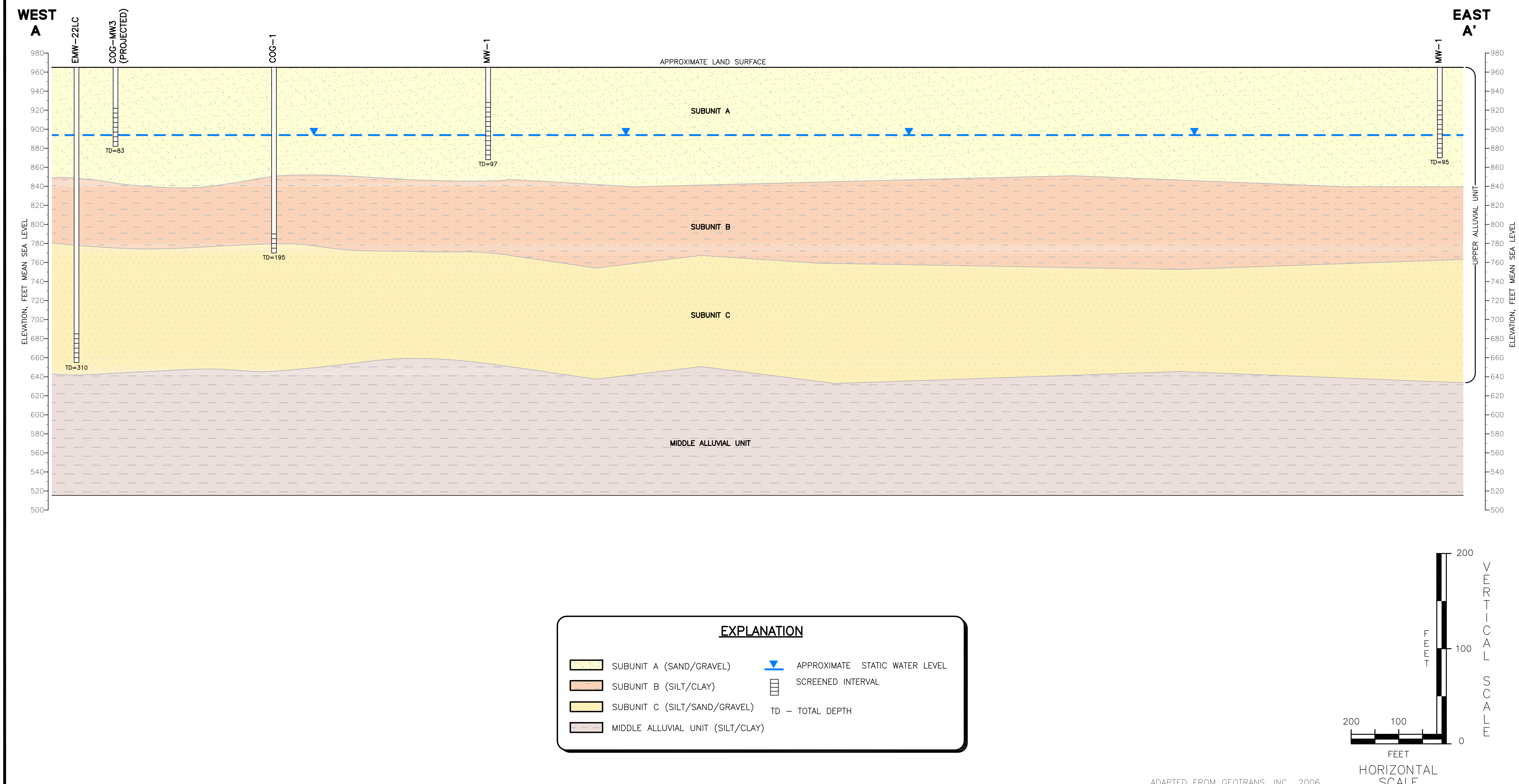
HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

FIGURE 4.
NORTH – SOUTH HYDROGEOLOGIC CROSS SECTION



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HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

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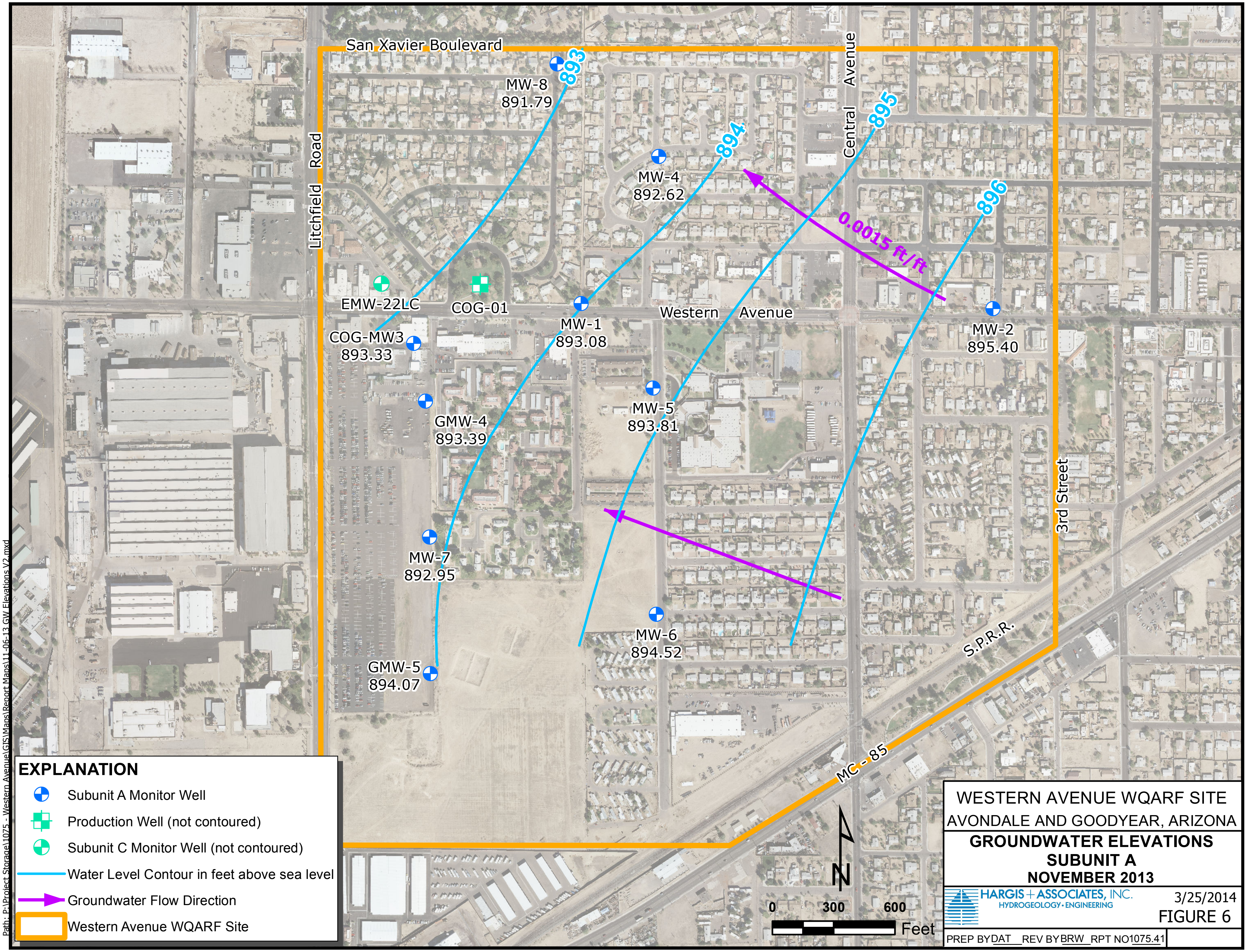
FIGURE 5.
EAST – WEST HYDROGEOLOGIC CROSS SECTION



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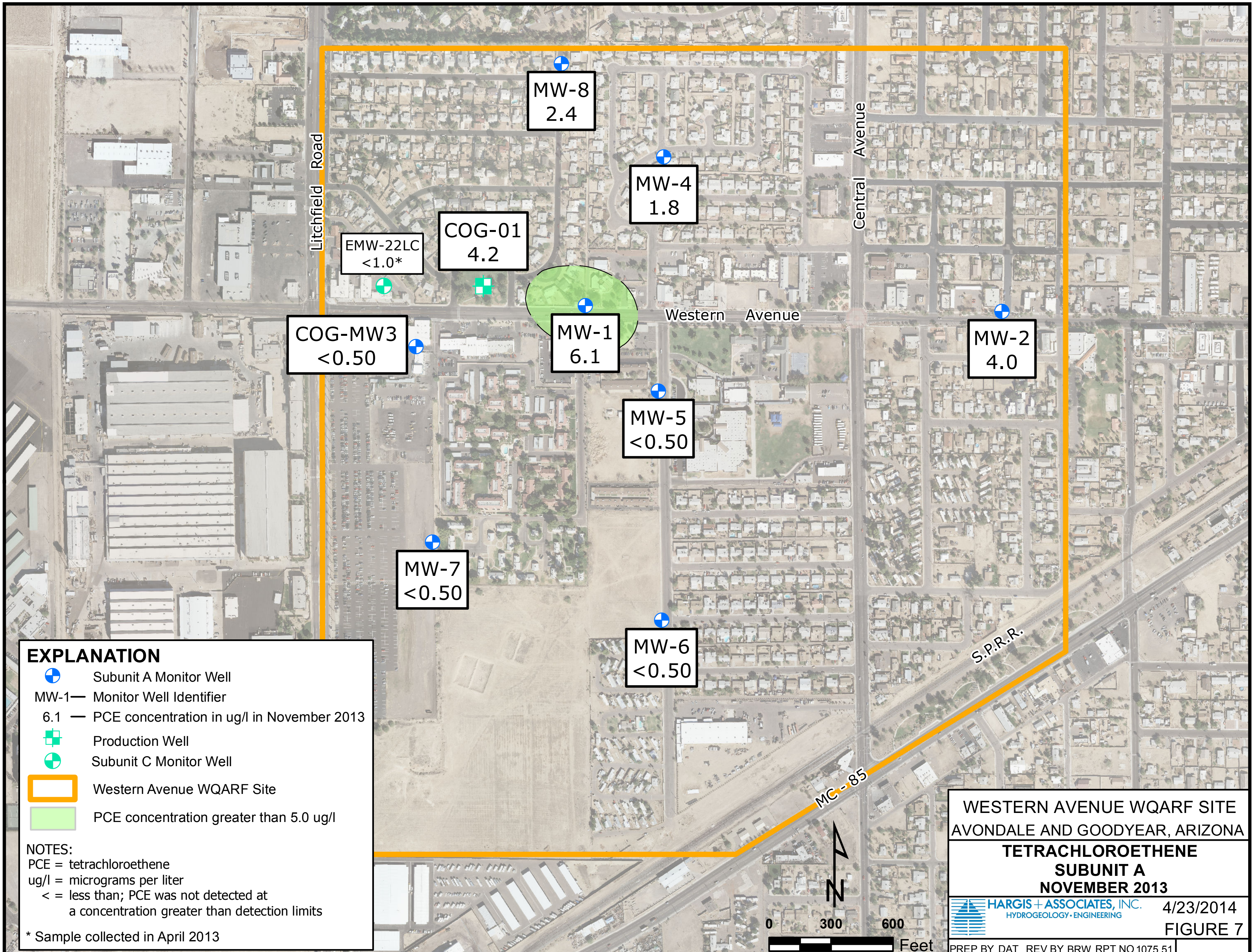

EXPLANATION

- Subunit A Monitor Well
- MW-1 — Monitor Well Identifier
- 6.1 — PCE concentration in ug/l in November 2013
- Production Well
- Subunit C Monitor Well
- Western Avenue WQARF Site
- PCE concentration greater than 5.0 ug/l

NOTES:
PCE = tetrachloroethene
ug/l = micrograms per liter
< = less than; PCE was not detected at a concentration greater than detection limits

* Sample collected in April 2013

WESTERN AVENUE WQARF SITE
AVONDALE AND GOODYEAR, ARIZONA

TETRACHLOROETHENE
SUBUNIT A
NOVEMBER 2013

HARGIS + ASSOCIATES, INC.
HYDROGEOLOGY • ENGINEERING

4/23/2014
FIGURE 7

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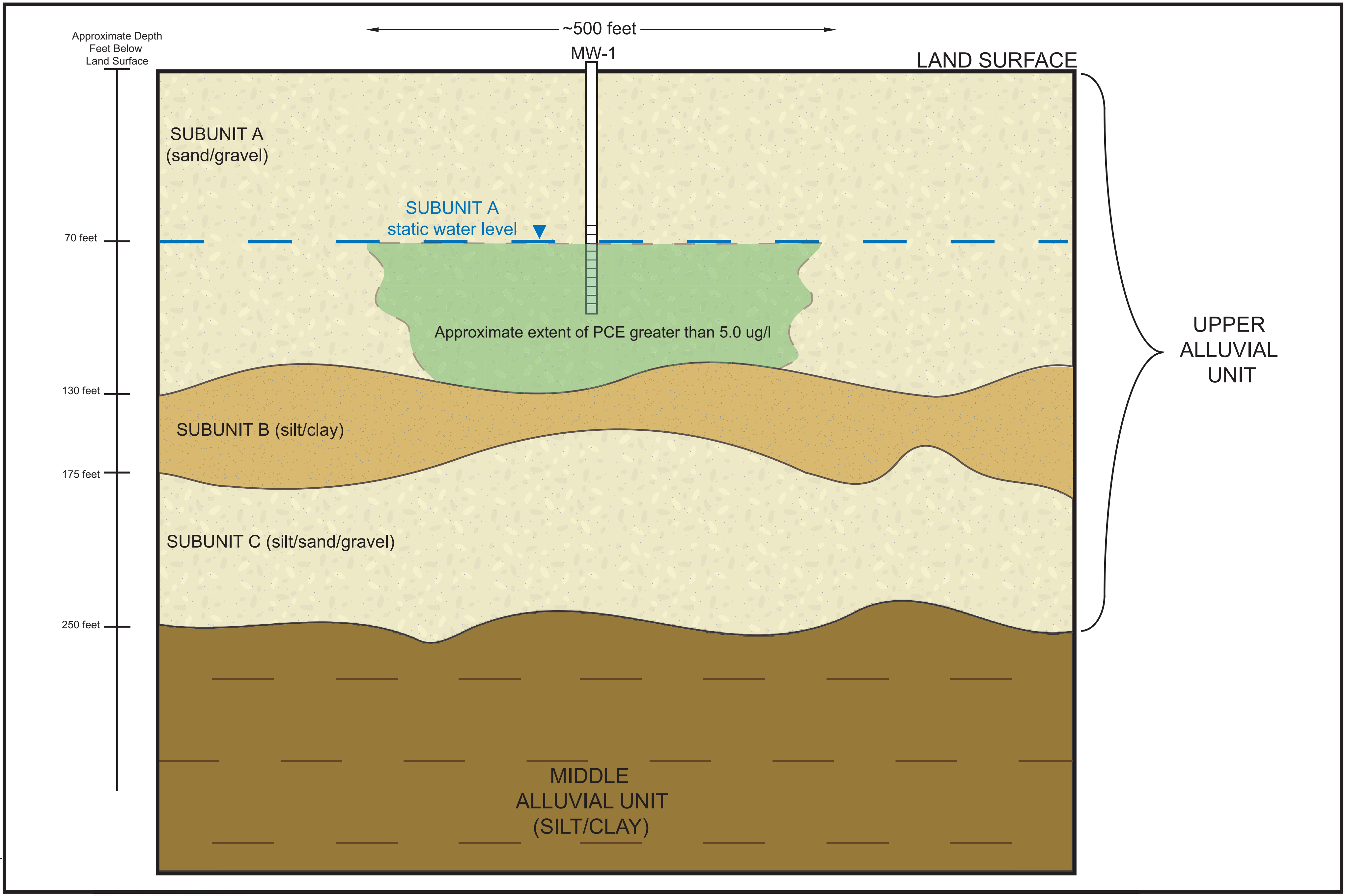

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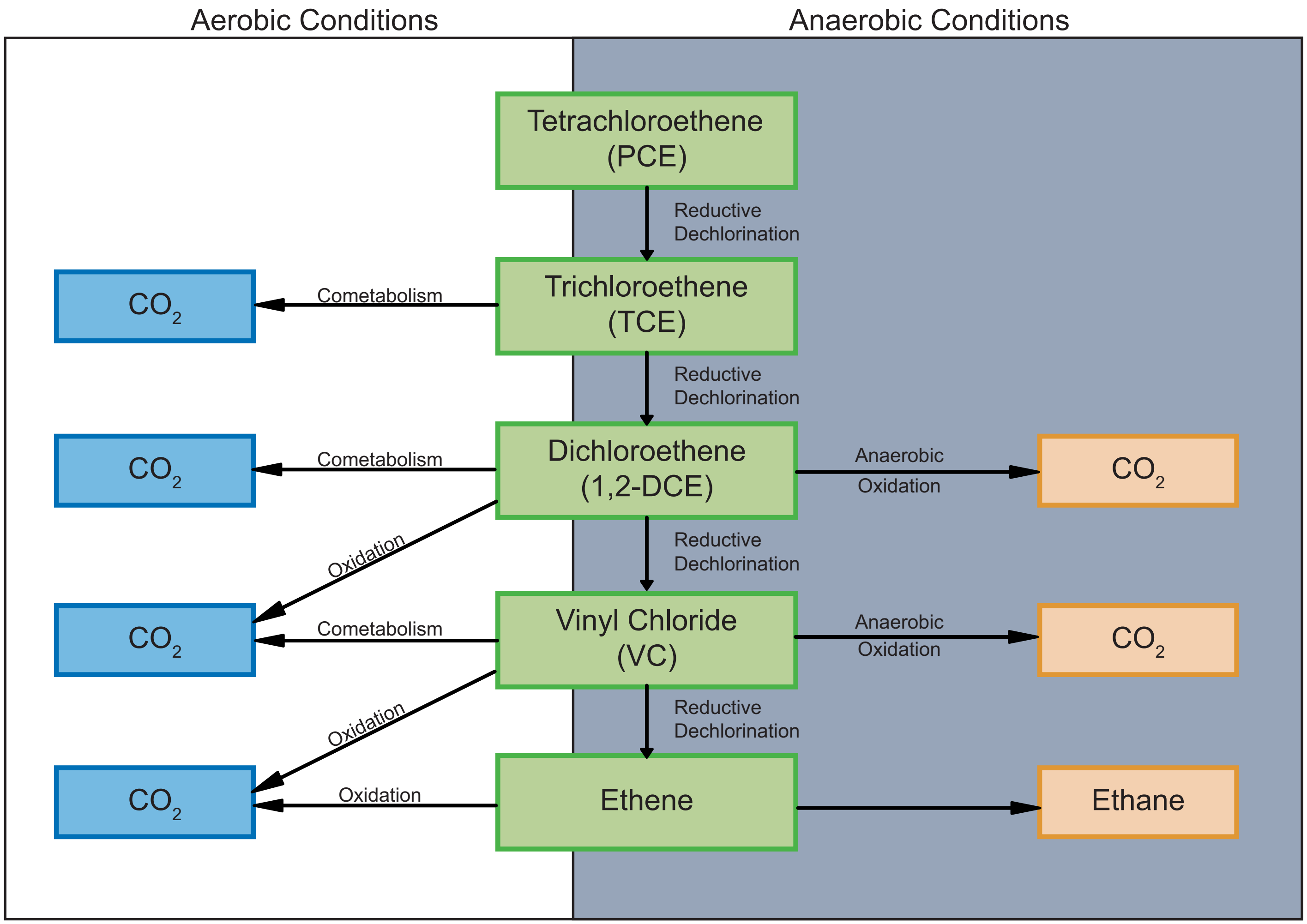
NOT TO SCALE

FIGURE 8.
CONCEPTUAL DIAGRAM
EXTENT OF TETRACHLOROETHENE IN GROUNDWATER
WESTERN AVENUE WQARF SITE



Note: Adopted from Hazardous Substance Research Centers (2005) www.hsrc.org/prague/major

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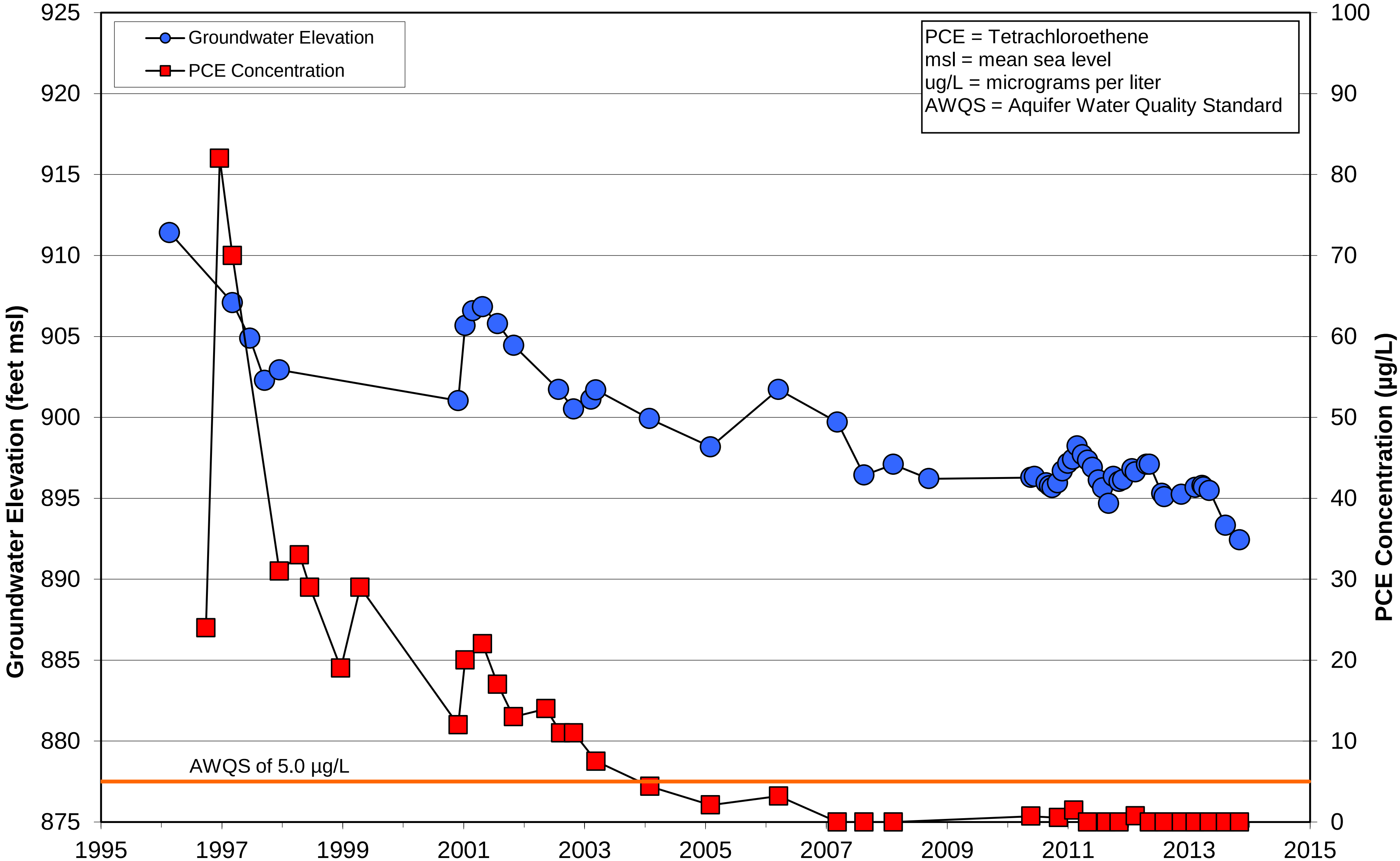
FIGURE 9.
TETRACHLOROETHENE DEGRADATION MECHANISMS AND PATHWAYS

APPENDIX A

GROUNDWATER ELEVATION
AND
PCE CONCENTRATION GRAPHS



WESTERN AVENUE WQARF SITE

FIGURE A-1

GROUNDWATER ELEVATION AND TETRACHLOROETHENE CONCENTRATIONS

MONITOR WELL COG-MW3

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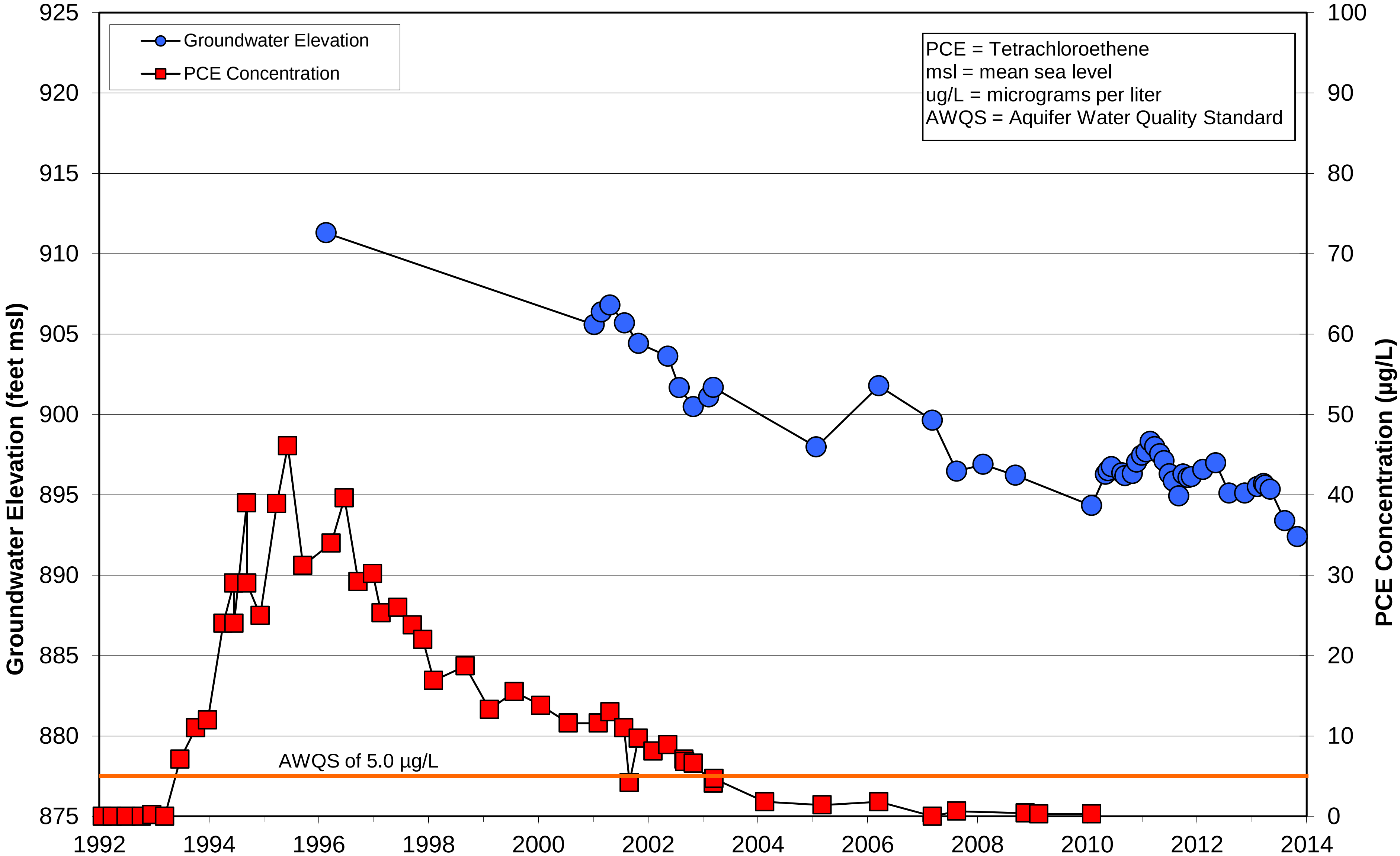
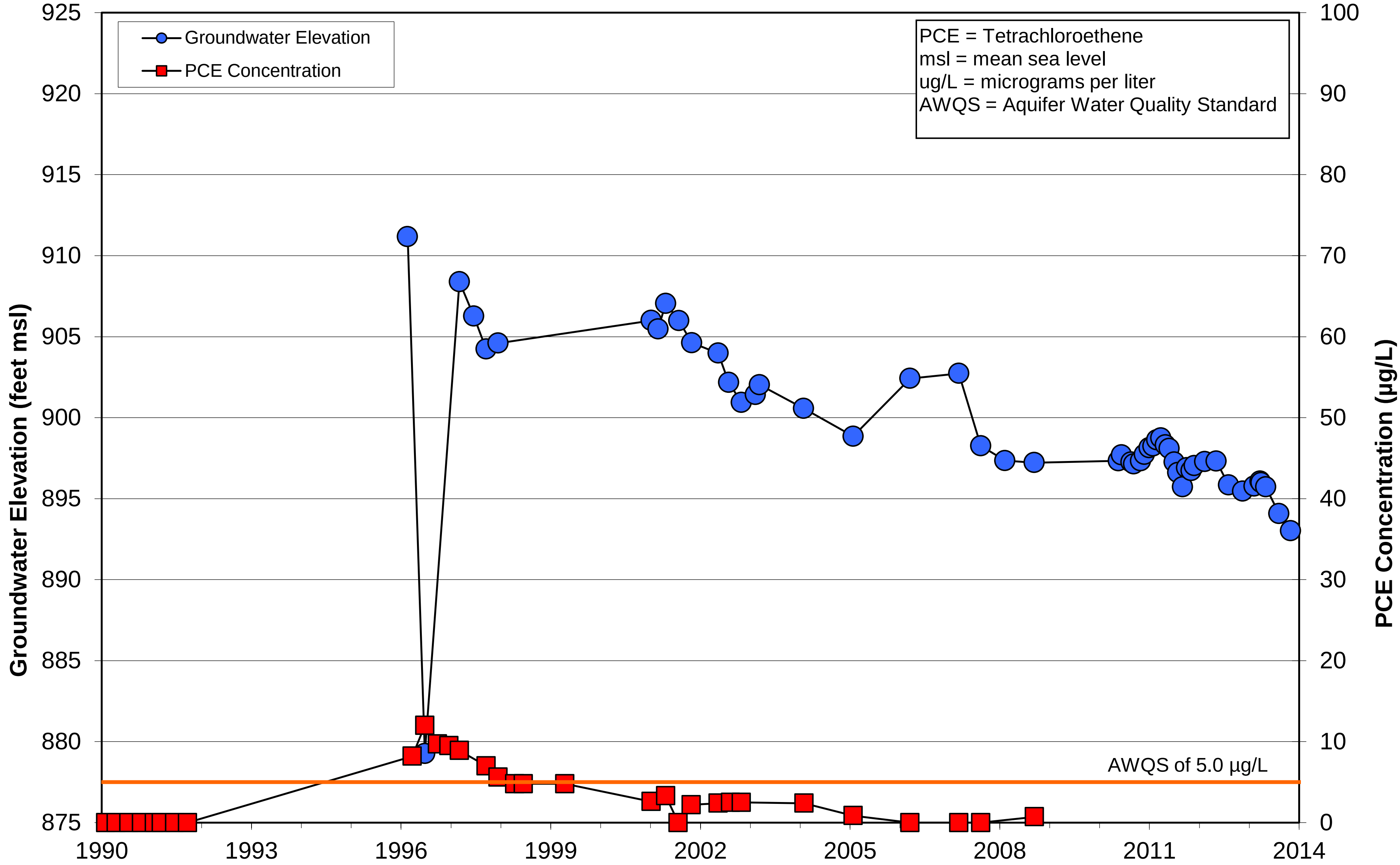
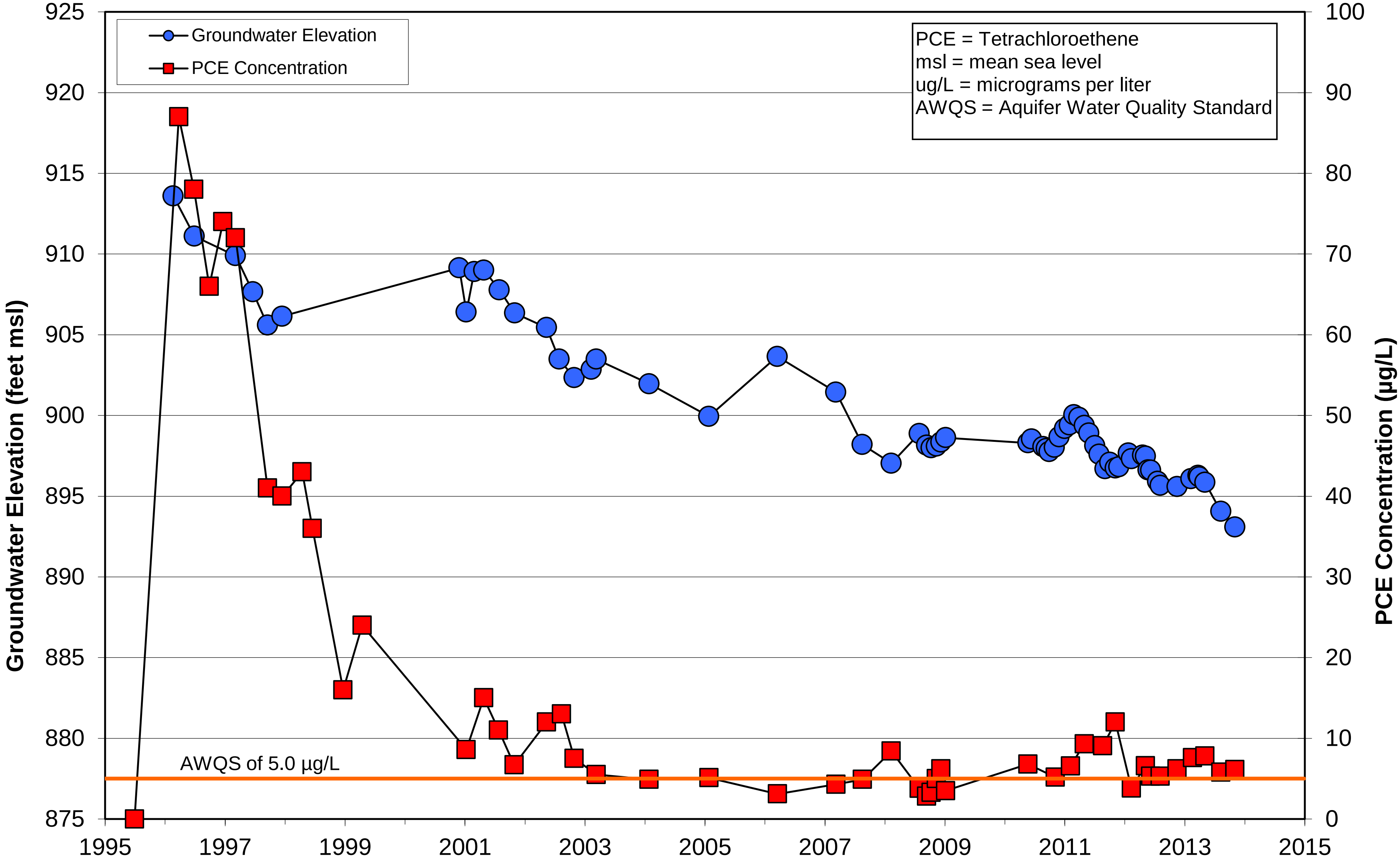


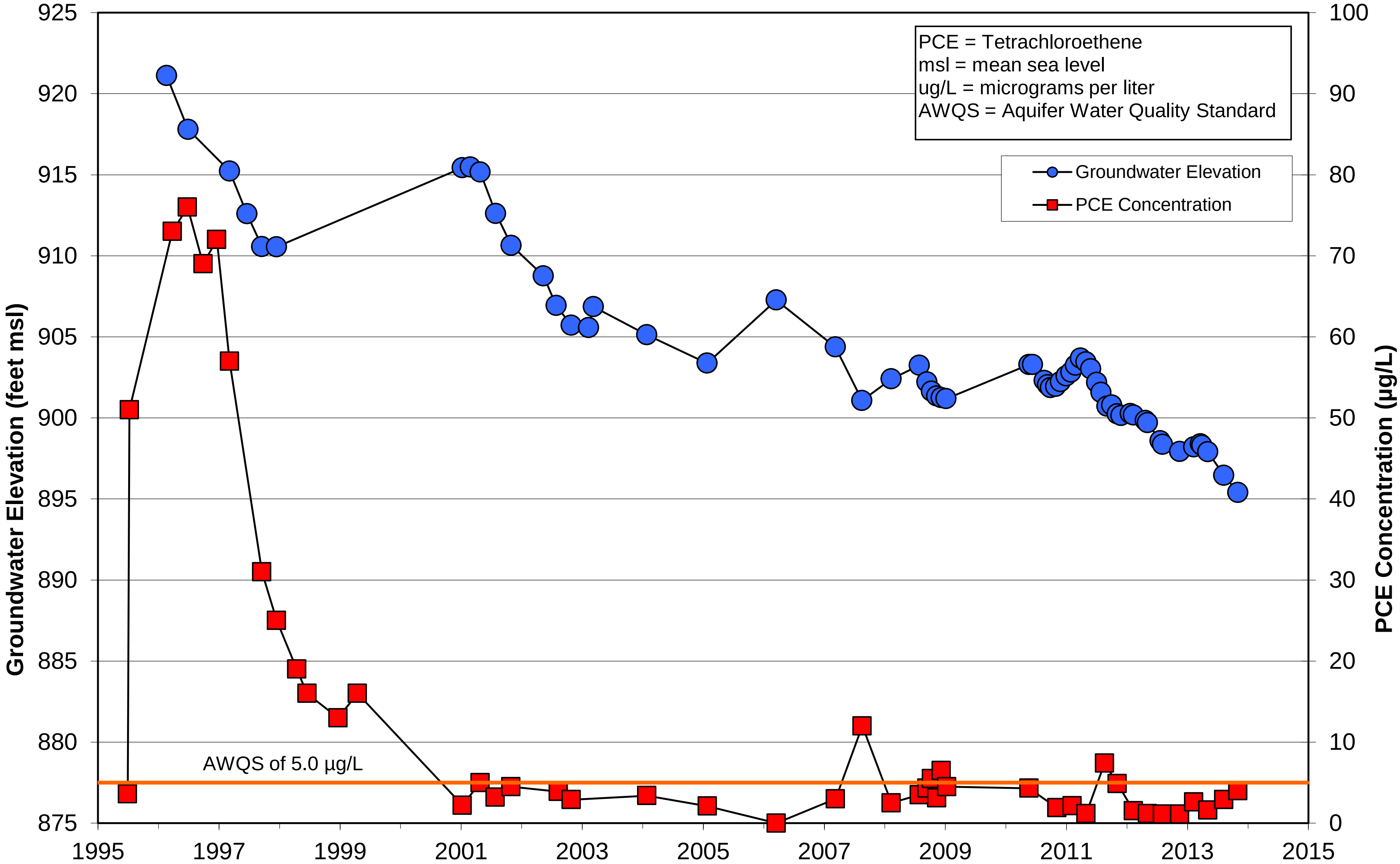
WESTERN AVENUE WQARF SITE
FIGURE A-2
GROUNDWATER ELEVATION AND TETRACHLOROETHENE CONCENTRATIONS
MONITOR WELL GMW-4



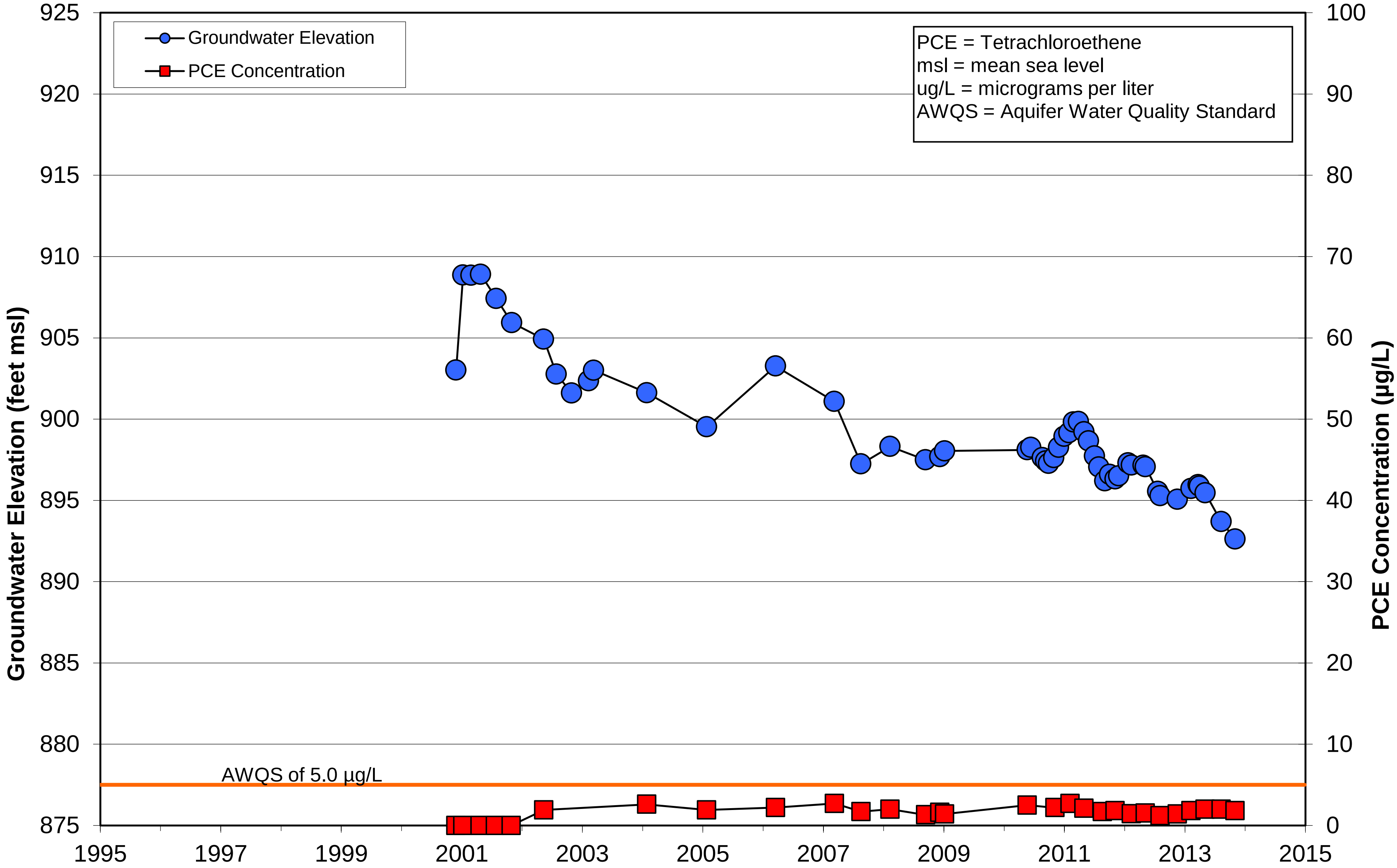
WESTERN AVENUE WQARF SITE
FIGURE A-3
GROUNDWATER ELEVATION AND TETRACHLOROETHENE CONCENTRATIONS
MONITOR WELL GMW-5



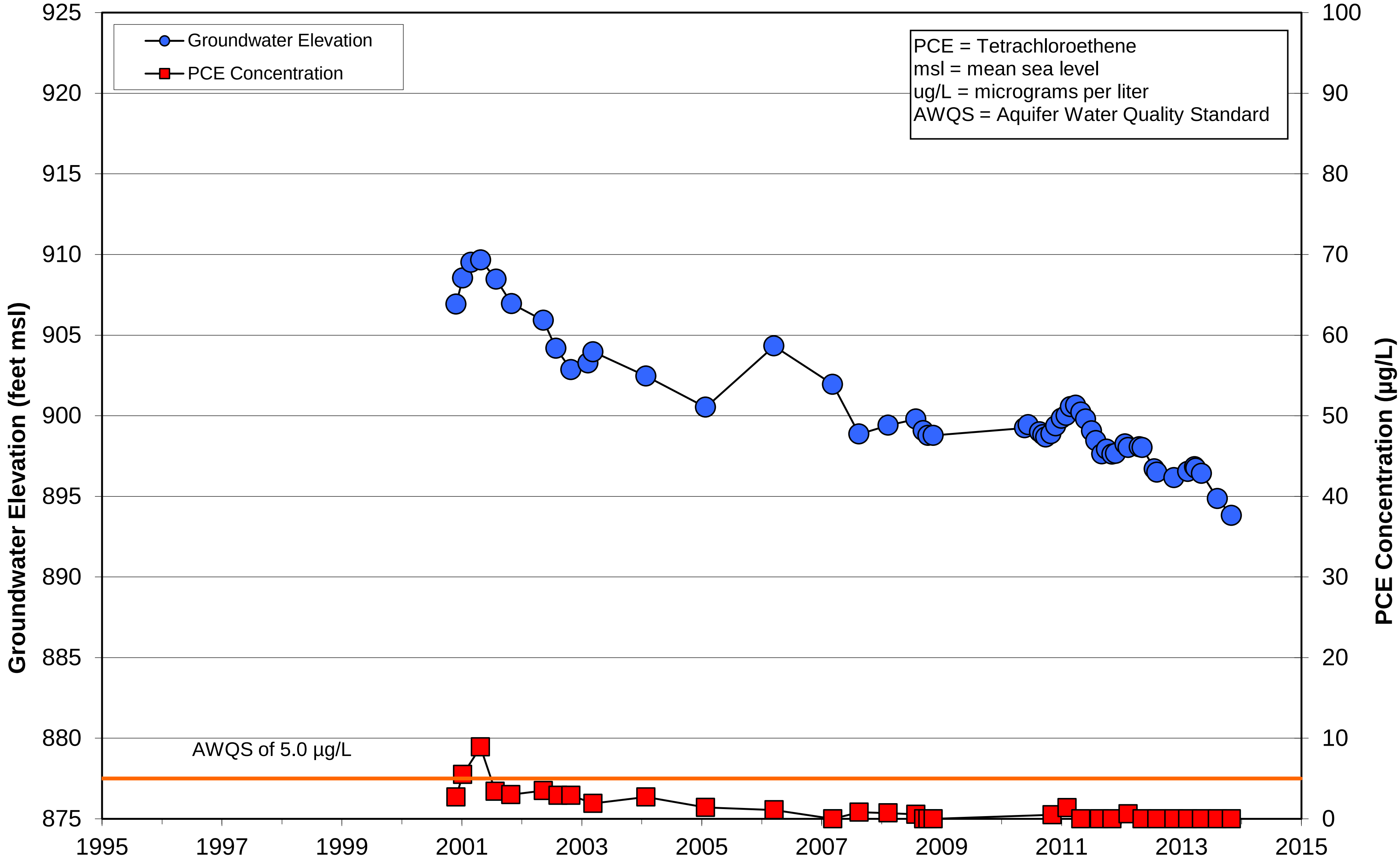
WESTERN AVENUE WQARF SITE
FIGURE A-4
GROUNDWATER ELEVATION AND TETRACHLOROETHENE CONCENTRATIONS
MONITOR WELL MW-1



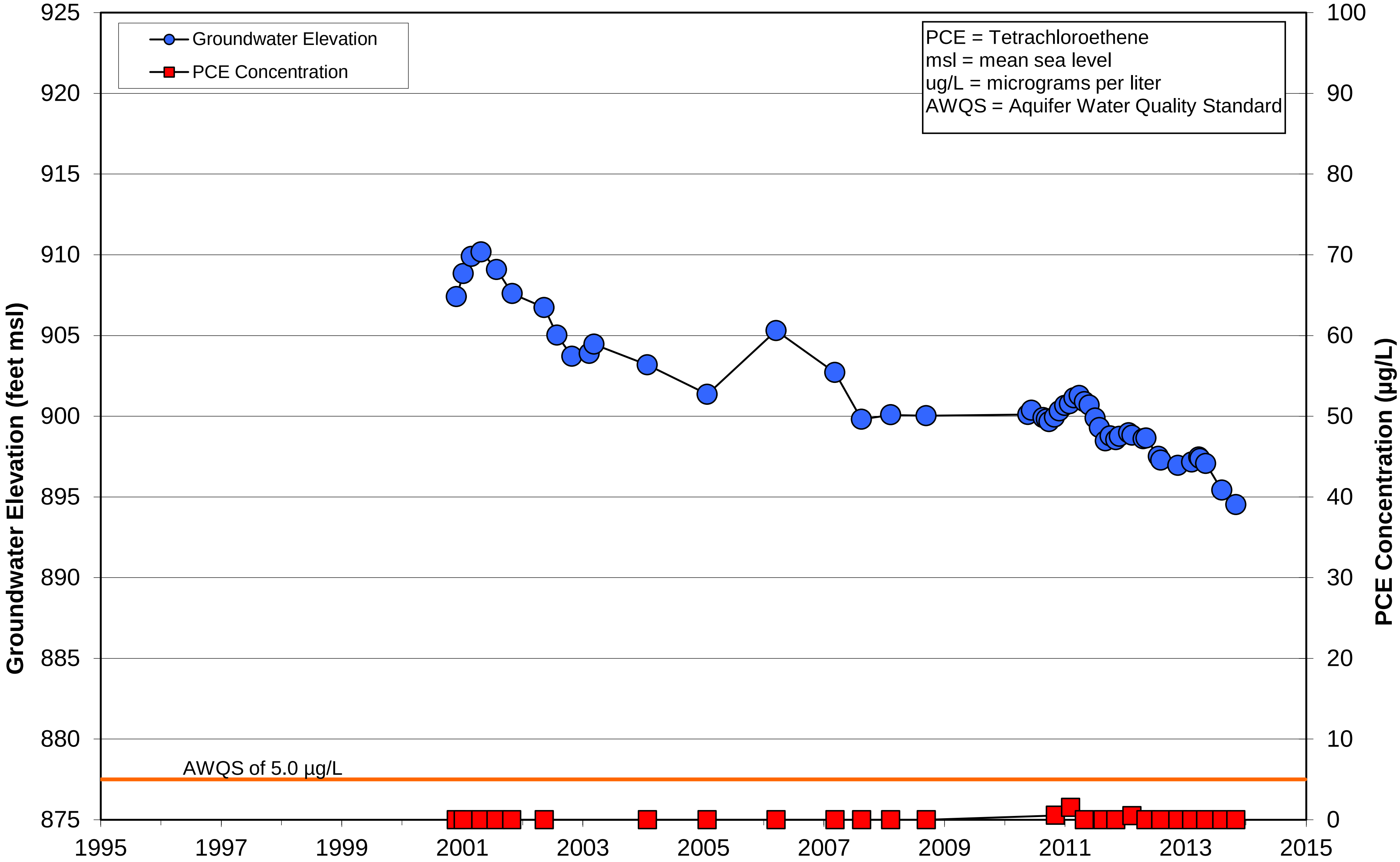
WESTERN AVENUE WQARF SITE
FIGURE A-5
GROUNDWATER ELEVATION AND TETRACHLOROETHENE CONCENTRATION0S
MONITOR WELL MW-2



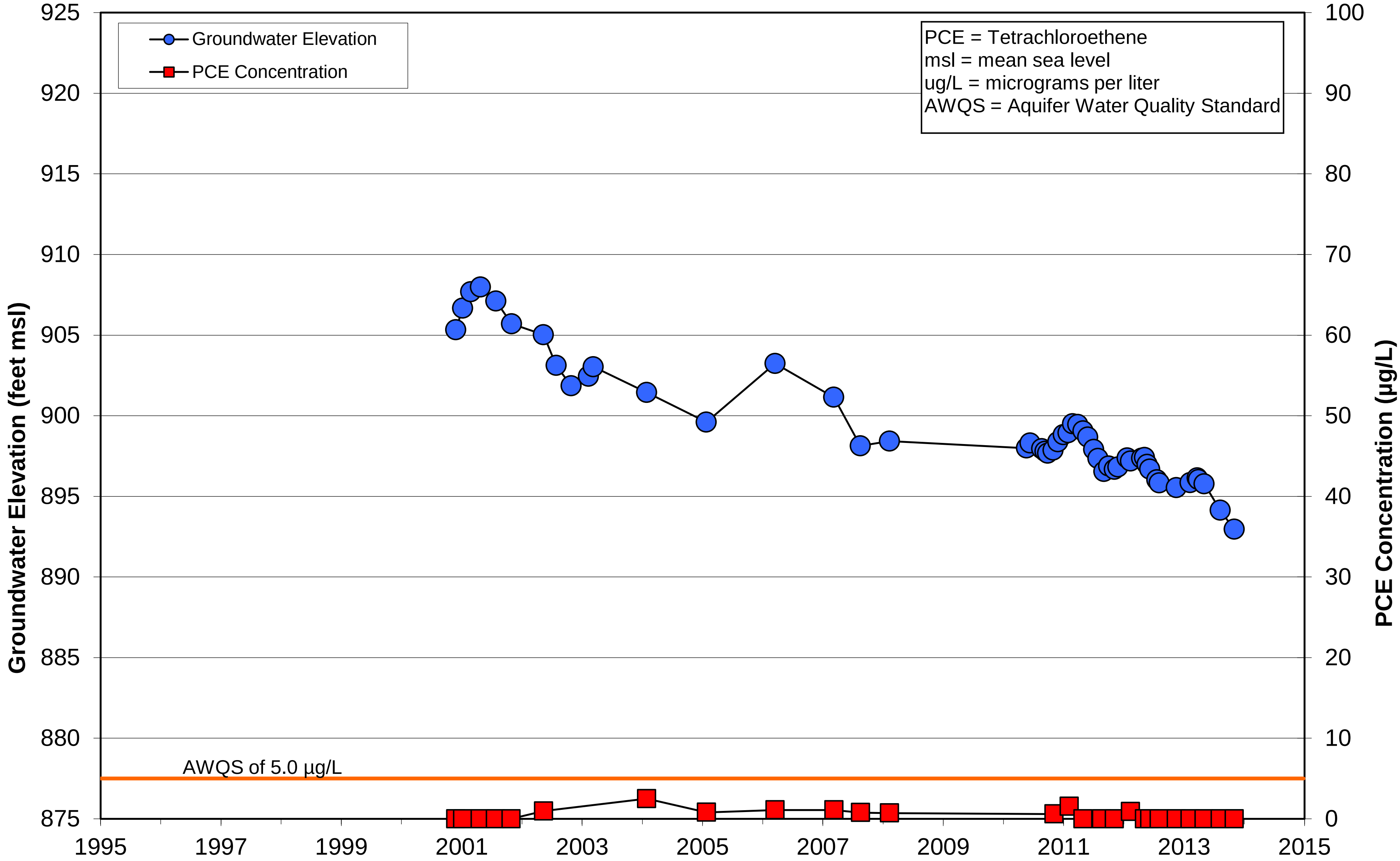
WESTERN AVENUE WQARF SITE
FIGURE A-6
GROUNDWATER ELEVATION AND TETRACHLOROETHENE CONCENTRATIONS
MONITOR WELL MW-4



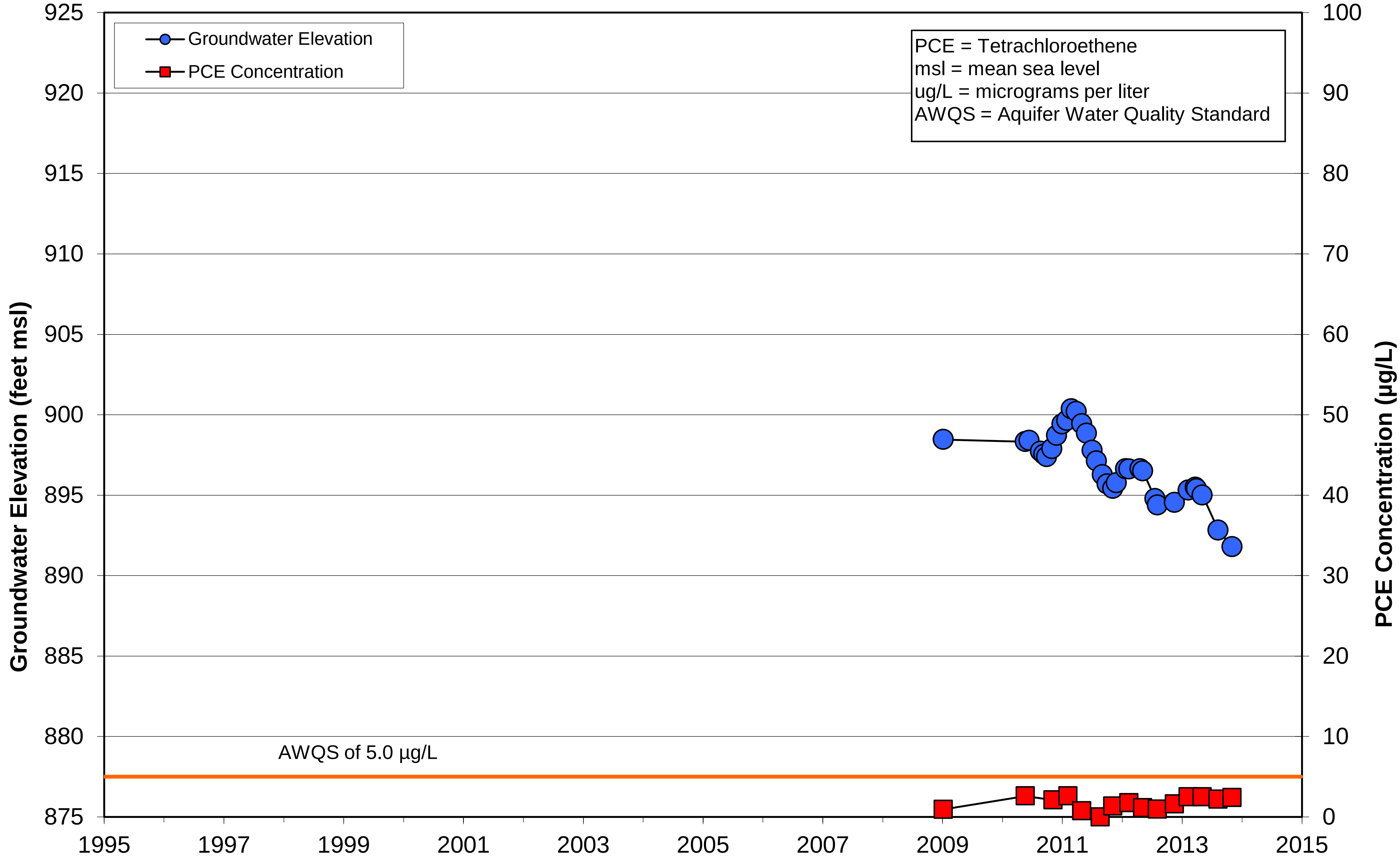
WESTERN AVENUE WQARF SITE
FIGURE A-7
GROUNDWATER ELEVATION AND TETRACHLOROETHENE CONCENTRATIONS
MONITOR WELLL MW-5



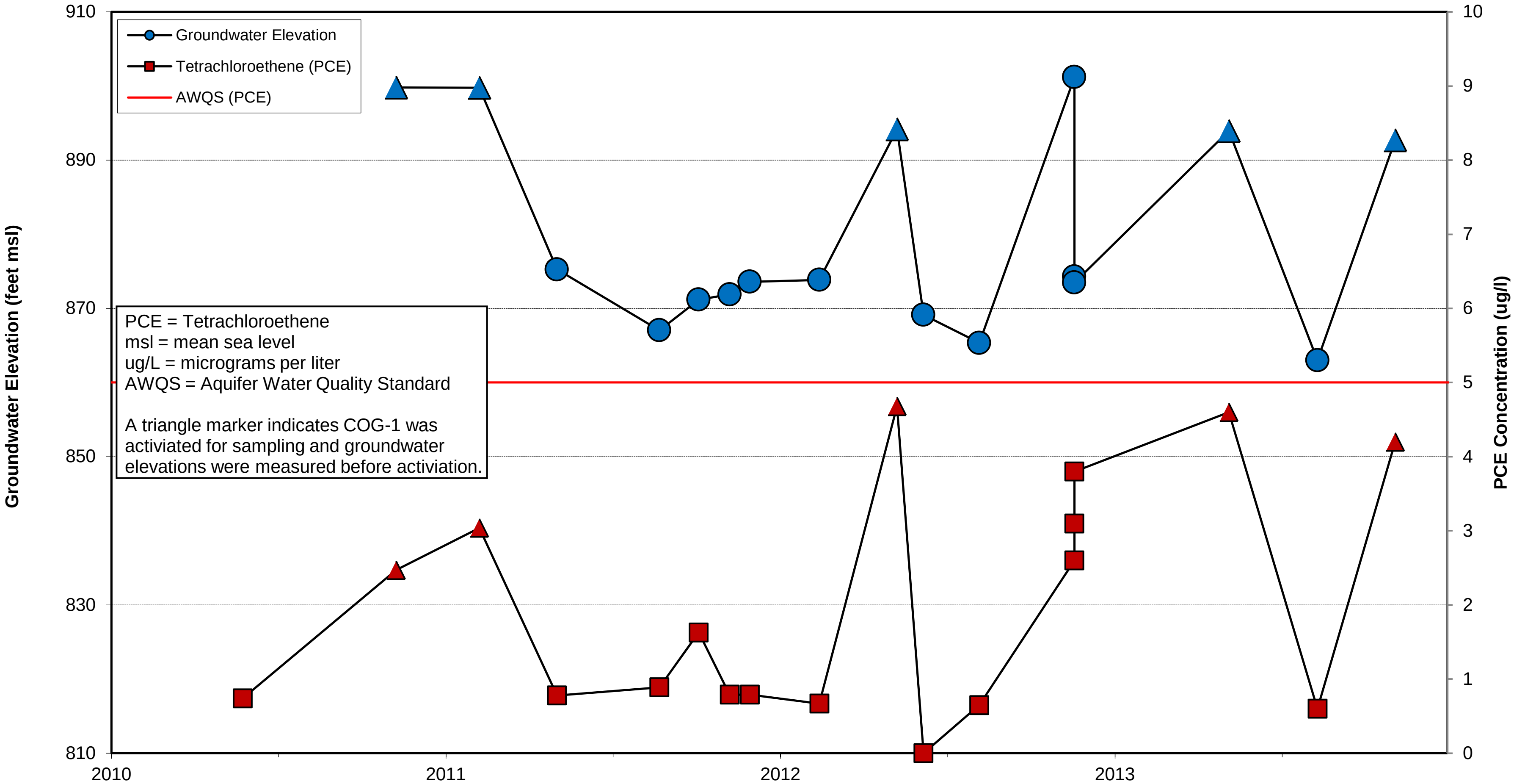
WESTERN AVENUE WQARF SITE
FIGURE A-8
GROUNDWATER ELEVATION AND TETRACHLOROETHENE CONCENTRATIONS
MONITOR WELL MW-6



WESTERN AVENUE WQARF SITE
FIGURE A-9
GROUNDWATER ELEVATION AND TETRACHLOROETHENE CONCENTRATIONS
MONITOR WELL MW-7



WESTERN AVENUE WQARF SITE
FIGURE A-10
GROUNDWATER ELEVATION AND TETRACHLOROETHENE CONCENTRATIONS
MONITOR WELL MW-8



WESTERN AVENUE WQARF SITE
FIGURE A-11
GROUNDWATER ELEVATION AND TETRACHLOROETHENE CONCENTRATIONS
PRODUCTION WELL COG-1

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