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REMEDIAL INVESTIGATION REPORT

EAST CENTRAL PHOENIX
24TH STREET AND GRAND CANAL
WATER QUALITY ASSURANCE
REVOLVING FUND SITE
PHOENIX ARIZONA

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EAST CENTRAL PHOENIX
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PHOENIX, ARIZONA

We certify that this document and attachments presented in this report are accurate and complete. This report was prepared by the staff of Geosyntec Consultants under our supervision to ensure that qualified personnel properly gather and evaluate the information submitted. Based on our inquiry of the person or persons who are directly responsible for gathering the information, the information submitted is, to the best of our knowledge and belief, true, accurate and complete.

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EXECUTIVE SUMMARY

This report summarizes the findings of remedial investigation (RI) activities conducted by the Arizona Department of Environmental Quality (ADEQ) at the 24th Street and Grand Canal Water Quality Assurance Revolving Fund (WQARF) site (herein referred to as the WQARF site or the site; Figure 1) of the East Central Phoenix (ECP) WQARF study area located in the City of Phoenix, Arizona. The WQARF site is defined by the estimated tetrachloroethene (PCE) Arizona Aquifer Water Quality Standard (AWQS) concentration contour (the plume), which begins in the vicinity of the intersection of 24th Street and Thomas Road and extends to the southwest. The plume is approximately bounded by Thomas Road to the north, 24th Street to the east, East Sheridan Street to the south, and North 17th Street to the west (Figure 2).

The WQARF site has been assessed to a total depth of 250 feet (ft) below ground surface (bgs) in the northeast portion and 408 ft bgs towards the southwest extent. The Arizona Department of Water Resources (ADWR) defined three hydrogeologic units in the Basin and Range physiographic province fill. These include from the shallowest to deepest: the Upper Alluvial Unit (UAU), the Middle Alluvial Unit (MAU), and the Lower Alluvial Unit (LAU) (Corkhill et al., 1993). The groundwater surface within the WQARF site lies within the UAU (Lluria, 2011).

Groundwater elevations in the UAU at the 24th Street and Grand Canal site have been monitored since May 2014 (Table 1 and Appendix B). Monitoring wells installed at the WQARF site are screened across both shallow (water table) and deeper intervals within the UAU. During the period of record for monitoring wells installed to investigate the Former Carnation 1-Hour Cleaners (Former Carnation) and the Former McKean's Model Laundry and Dry Cleaning (Former McKean's) property, groundwater elevations have generally been consistent. Depth to water has ranged from approximately 83 ft below top of casing (btoc) in 24MW-08B in 2015 to approximately 102 ft btoc in -24MW-01A in 2015. The direction of groundwater flow within the WQARF site is to the west-southwest with gradients between approximately flat and 0.007 ft per foot. Historical groundwater elevations are shown in Table 1.

The 24th Street and Grand Canal WQARF site has historically contained dry-cleaning facilities, a service station, and printing shops, with some of the dry-cleaners operating since the 1950s. After investigations in the vicinity of the property, the source areas of the PCE were determined to be located at two dry-cleaning facilities. The facilities, the Former Carnation and the former McKean's (Figure 4), historically operated northeast of

the intersection of 24th Street and Thomas Road, herein referred to as "the property." The contaminants of concern at the 24th Street and Grand Canal WQARF site are PCE, trichloroethene, cis-1,2-dichloroethene, trans-1,2-dichloroethene, and vinyl chloride.

In 2001, Terracon conducted a Phase II Environmental Site Assessment (ESA) at the Former Carnation/Former McKean's property. This work suggested that the Former Carnation and Former McKean's facilities were the likely sources of COC impacts within the 24th Street and Grand Canal WQARF site. This was followed by historical site characterization associated with the RI, as well as Preliminary Investigations (PIs), Preliminary Assessments (PAs), ESAs, and an early response action (ERA).

Soil vapor extraction (SVE) was successfully implemented at the Former Carnation/ Former McKean's property in 2016 to address residual vadose zone volatile organic compound (VOC) impacts, and formal system decommissioning is planned.

In October 2018, Geosyntec performed a human health risk assessment (HHRA) for the Former Carnation/Former McKean's property. The HHRA evaluated the results from the December 2017 soil vapor rebound monitoring event for potential vapor intrusion risk under a commercial/industrial exposure scenario, and also under a conservative potential future site redevelopment residential exposure scenario. The results of the vapor intrusion HHRA indicate that concentrations of contaminants of concern (COCs) still present in soil vapor do not pose an unacceptable risk to site receptors with a calculated cumulative cancer development risk that is less than the point of departure of "one in a million" (10^{-6}). The results support a conclusion that no further action is required to address residual vadose zone soil vapor COCs concentrations, and as such, the SVE ERA is no longer warranted.

Historical site characterization associated with the RI, as well as PIs, PAs, and ESAs, have demonstrated that the vadose zone was significantly impacted at the Former Carnation/Former McKean's property. Soil and soil vapor volatile organic compound (VOC) impacts, primarily from PCE, have been observed. However, the vadose zone is considered to be fully characterized for the site COCs.

Approximately two years of SVE remediation have effectively performed vadose zone cleanup, reducing soil vapor concentrations to below the site-specific cleanup goals, including during a rebound evaluation performed three months after final shutdown of the SVE system. Residual VOC concentrations do not pose unacceptable vapor intrusion risk under a residential site redevelopment scenario, which is significantly more conservative than the current commercial site use and exposure scenario.

Groundwater COCs originating from the Former Carnation/Former McKean's property historically migrated vertically through the vadose zone through relatively low permeability geology until they reached approximately 75 ft bgs. The COCs then migrated through sandy silt, and silty gravel until they reached groundwater at approximately 80 ft bgs, and then migrated in a southwesterly direction while vertically migrating downward until contacting a relatively consistent lean clay layer at approximately 103 ft bgs. The lean clay layer appears to have restricted vertical migration of COC impacts allowing the groundwater plume to stay relatively shallow as it continued to migrate. The resulting plume is approximately 5000 ft long with most of its mass at a depth of less than approximately 120 ft bgs.

When examining the extent of PCE impacts two-dimensionally in plan view, as shown by the PCE groundwater isoconcentration map (**Figure 9**), there appears to be an interaction (overlap) of the PCE plumes associated with the WQARF site and the PCE impacts to groundwater associated with the 32nd Street and Indian School Road WQARF site. The two plumes, however, are discrete, separate plumes traveling alongside each other and at different vertical elevations, with the plume associated with the 24th Street and Grand Canal WQARF site being shallower and located to the south. The independence of these plumes is shown in Geologic Cross Section B-B' (**Figure 13**) and in the three-dimensional EVS visualization of PCE impacts (**Figure 14)**.

Petroleum hydrocarbon impacts that were identified at the Site, although not considered COCs, should be delineated and associated source area(s) identified. It should be noted that these impacts are not associated with the Former McKean's and Former Carnation dry-cleaning facilities.

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LIST OF ACRONYMS AND ABBREVIATIONS

°F	degrees Fahrenheit
µg/L	micrograms per liter
µg/m^3	micrograms per cubic meter
1,2,4-TMB	1,2,4-trimethylbenzene
1,2-DCA	1,2 dichloroethane
A.A.C.	Arizona Administrative Code
A.R.S.	Arizona Revised Statutes
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
ADWR	Arizona Department of Water Resources
amsl	above mean sea level
ASRAC	Arizona Superfund Response Action Contract
AWQS	Aquifer Water Quality Standard
bgs	below ground surface
bmp	below measuring point
BTEX	benzene, toluene, ethene, and total xylenes
btoc	below top of casing
CAP	Central Arizona Project
cis-1,2-DCE	cis-1,2- dichloroethene
COC	contaminant of concern
COP	City of Phoenix
COPC	contaminant of potential concern
CVOC	chlorinated volatile organic compound
DNAPL	dense non-aqueous phase liquid
ECP	East Central Phoenix
ERA	early response action
ESA	Environmental Site Assessment
Former McKean's	McKean's Model Laundry and Dry Cleaning
FS	feasibility study
ft	feet
GAC	granular activated carbon
GPL	groundwater protection limit
gpm	gallons per minute
HHRA	human health risk assessment
HI	hazard index
IARSL	indoor air Regional Screening Level
IIARSL	industrial indoor air Regional Screening Level
IPaC	Information, Planning and Conservation
J&E	Johnson & Ettinger
LAU	Lower Alluvial Unit

LUST	leaking underground storage tank
MAU	middle alluvial unit
MEK	methyl ethyl ketone
mg/kg	milligrams per kilogram
O&M	operations and maintenance
PA	preliminary assessment
PCE	tetrachloroethene
PDB	passive diffusion bag
PI	preliminary investigation
PID	photoionization detector
RBSL	Risk-Based Screening Levels
RI	remedial investigation
RIARSL	residential indoor air Regional Screening Level
RL	reporting limit
ROs	remedial objectives
RSL	Regional Screening Levels
RSRL	Residential Soil Remediation Level
SRL	soil remediation level
SRP	Salt River Project
SVE	soil vapor extraction
SVP	soil vapor probe
TCE	trichloroethene
trans-1,2-DCE	trans-1,2-dichloroethene
TSCA	Toxic Substances Control Act
UAU	upper alluvial unit
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Society
VC	vinyl chloride
VOCs	volatile organic compounds
WQARF	Water Quality Assurance Revolving Fund
WSRV	western portion of the Salt River Valley

1. INTRODUCTION

Geosyntec Consultants, Inc. (Geosyntec) has prepared this final *Remedial Investigation (RI) Report* for the East Central Phoenix (ECP) 24th Street and Grand Canal Water Quality Assurance Revolving Fund (WQARF) site (herein referred to as the WQARF site or the site) located in Phoenix, Arizona (**Figure 1**). Geosyntec was contracted by Arizona Department of Environmental Quality (ADEQ) to prepare this report under an Arizona Superfund Response Action Contract (ASRAC).

A Salt River Project (SRP) water supply well is located near the intersection of 24th Street and Grand Canal (SRP Well 16E-6.8N). A detection of tetrachloroethene (PCE) in a sample from this supply well, recorded in January 1995, initiated investigations to locate a potential source. The vicinity surrounding the well was investigated to develop information on the presence of chlorinated solvent impacts in groundwater. According to a 2018 *Land and Water Use Report* (Hargis + Associates, Inc. [H+A], 2018), PCE impacts in SRP Well 16E-6.8N were suspected to have come from two historical dry-cleaning facilities that were located at the northeastern corner of 24th Street and Thomas Road and two historical service stations that were located at the northwestern and northeastern corners of 24th Street and Thomas Road.

The current boundary of the WQARF site is defined by the approximate limits of the PCE plume; it is approximately bounded by Thomas Road to the north, 24th Street to the east, East Sheridan Street to the south, and North 17th Street to the west. The PCE plume boundary depicted on the Site Plan (**Figure 2**) represents ADEQ's interpretation of the data available at this time. The map is intended to provide the public with basic information as to the estimated extent of known PCE impacts to groundwater.

In June 2007, ADEQ sent out notices in accordance with Arizona Revised Statute (A.R.S.) §49-287.03 initiating the RI for the 24th Street and Grand Canal site. The 24th Street and Grand Canal site was placed on the WQARF Registry List in May 2009 with an Eligibility and Evaluation Score of 29 out of 120. The most recent RI activity was a comprehensive site-wide groundwater sampling event in August 2018, and the most recent ERA activity was the Human Health Risk Assessment (HHRA) in October 2018.

This report describes the results of RI activities conducted from 2001 through October 2018. Historical information presented herein is a summary of investigations conducted

by previous consultants and is summarized as necessary to meet the RI objectives described below.

1.1 Remedial Investigation Objectives

This RI report was prepared in accordance with A.R.S. §49-287.03 and Arizona Administrative Code (A.A.C.) R18-16-406(A). This RI summarizes field investigations in accordance with A.A.C. R18-16-406(C). Additionally, a site-specific risk evaluation to characterize the current risks to public health and the environment was conducted pursuant to A.A.C. R18-16-406(E).

1.2 Report Organization

This RI report summarizes the following information and data pertaining to the WQARF site:

- Physical setting of the site, including topography, climate, geology, and hydrogeologic setting;
- Site plans showing sampling locations;
- Analytical results for soil, soil vapor, and groundwater samples, including comparisons to appropriate regulatory standards, criteria, and guidance;
- Soil vapor extraction (SVE) system operations, maintenance, and monitoring;
- Groundwater flow direction, concentrations of groundwater contaminants of concern (COCs), and vertical profiling;
- An exposure route pathways model figure (depicted in **Figure 3** and discussed in **Sections 6.5.2, 6.5.3, and 6.5.4**);
- A discussion of the physical and analytical results;
- A land and water use study;
- A human health risk evaluation; and
- Gaps in data for the completion of the RI.

1.3 Site History

The WQARF site is located in an area of mixed commercial and residential development. In 1997, ADEQ established the WQARF Registry, replacing the WQARF Priority List. In 1998, the ECP Study Area (of which this site was a part) was divided into six individual WQARF Registry sites:

- 24th Street and Grand Canal;
- 32nd Street and Indian School Road;
- 38th Street and Indian School Road;
- 40th Street and Osborn Road;
- 40th Street and Indian School Road; and
- 48th Street and Indian School Road.

The facilities initially investigated as potential source areas are located on properties in the vicinity of the intersection of 24th Street and Thomas Road. A parcel on the northeastern corner of this intersection has historically been occupied by dry-cleaning facilities since at least 1950 (HydroGeoLogic, Inc. [HGL], 2014). A general chronology of site history, facility ownership, and operations for the properties at the 24th Street and Grand Canal WQARF site is described below.

1.3.1 Former Carnation Facility

The facility located at 2402 East Thomas Road (herein referred to as the Former Carnation facility) operated as a dry-cleaner and laundry from approximately 1985 or 1986 (Terracon, 2001a; Shaw Environmental, Inc. [Shaw], 2005) to at least 2008. According to information provided in a 2001 Terracon *Phase I Environmental Site Assessment* (ESA) report, the facility contained a 200-gallon aboveground storage tank (AST) containing virgin PCE, a 55-gallon drum of PCE, and a smaller container of spent PCE inside the building (Terracon, 2001a; Stantec Consulting Services, Inc. [Stantec], 2008). This address housed the following businesses:

- Carnation 1-Hour Cleaners from 1986 to 1997;
- Arizona's Best 1-Hour Cleaners from 1998 to 2001; and
- ABC Cleaners from 2002 to 2008.

From approximately 1985 to 1997, Carnation 1-Hour Cleaners operated a dry-cleaning service and was assigned United States Environmental Protection Agency (USEPA) Resource Conservation and Recovery Act (RCRA) identification (ID) number AZD981395031. On 8 February 1985, M and N Cleaners, Inc., doing business as Carnation, entered into a lease agreement for operation as a dry-cleaning and laundry plant for clothing and related fabrics. The lease period began on 1 March 1985.

Carnation filed its initial Notification of Hazardous Waste form with USEPA on 18 April 1986. The company was listed as a small quantity generator (SQG) of hazardous waste (USEPA hazardous waste codes F001 and F002). The owner of the company was listed as "M&N Cleaners, Inc." From 1992 to 1994, approximately 6,700 pounds of hazardous waste was generated by Carnation.

A USEPA Notification of Hazardous Waste form dated 27 November 1995 lists Carnation as an SQG of hazardous waste (USEPA hazardous waste codes D039 and F002). The form notes that a change in ownership occurred on 20 November 1995. The owner of Carnation was listed as Karishma Investments Corporation. A USEPA notification form filed on 18 February 1996 lists Carnation as an SQG of hazardous waste (USEPA hazardous waste codes D009 and F002). According to handwritten notes on an account maintenance document collected from ADEQ RCRA files, ADEQ was notified on 25 February 1997, to note that the name on the account should be changed from Carnation to Arizona Best. ADEQ issued a confirmation letter on 27 February 1997, noting that the change had been made. From 1998 to 2007, Arizona Best was listed in Phoenix city directories as being located at 2402 East Thomas Road and operated under USEPA RCRA ID AZD981395031.

A 13 June 2001 Terracon Phase I ESA of the northeast corner of 24th Street and Thomas Road notes that a Union L760-U2000 dry-cleaning machine used at the time of the assessment had been installed in 2000. The site reconnaissance reported a 200-gallon AST containing virgin PCE. Reportedly, PCE was supplied by Laundry & Cleaning Supply on an as-needed basis. One 55-gallon drum and a smaller plastic container containing waste dry-cleaning fluid were temporarily stored on-site, and the contents of the containers were reportedly collected regularly by Pacific Waste Disposal Services. The Phase I ESA report notes that a plaster wall behind the dry-cleaning machine showed damage that may have occurred from solvent spillage. The report also notes that concrete near a floor drain in the northern part of the suite had been eroded, but that the drain did not appear to be receiving fluid from the dry-cleaning machine (Terracon, 2001a).

From 1999 to 2003, Arizona's Best generated approximately 4,528 pounds of hazardous waste. Arizona's Best filed a hazardous waste annual facility registration form with USEPA on 16 June 2006, indicating that the company was an SQG of hazardous waste and that approximately 1,280 pounds of hazardous waste had been disposed of off-site in 2005. On 7 February 2008, Arizona's Best filed another hazardous waste annual facility registration form; however, according to the form, the facility closed on 31 December 2006 (HGL, 2014).

1.3.2 Former McKean's Facility

The facility located at 2915 North 24th Street (herein referred to as the Former McKean's facility) operated as a dry-cleaner and laundry from at least 1950 to 1963, according to Terracon's review of City of Phoenix (COP) directories and Stantec's Preliminary Draft Workplan for RI (Terracon, 2001a; Stantec, 2008) and a letter report by HGL (2014). This address contained McKean's Model Laundry and Dry Cleaning (Former McKean's) from 1950 to 1960 and Thriftway Laundry and Cleaners from 1961 to 1963.Other Potential Source Areas

Several facilities were identified in previous investigations (Terracon, 2001a; Stantec, 2008; HGL, 2013) as potential sources of subsurface impacts due to their reported historical solvent use. These facilities are located within an approximately 1/3-mile radius of the Former Carnation/Former McKean's property boundary. They are generally categorized as service stations, printing facilities, dry-cleaning and laundry facilities, and other commercial/industrial facilities, and are listed in chronological order of reported operational years.

Service Stations

- Former service station, located at 2348 East Thomas Road, operated from approximately 1950 to the early 1980s (Terracon, 2001a); Former 7-11/Shell Service Station, located at 2843 North 24th Street, operated from approximately 1960 to 1991 (Terracon, 2001a); and
- Former Arco Facility No. 1523, located at 2322 East Thomas Road, operated from 1975 to 1995, and was Prestige Station No. 628 from 1976 to 1977 (HGL, 2013).

Printing Facilities

- Peter L. Amico Printing, southeast of the intersection of 24th Street and Thomas Road (at an unreported address), operated from 1970 to 1975 (Stantec, 2008).
- Phoenix Fine Printing, southeast of the intersection of 24th Street and Thomas Road (at an unreported address), operated from 1970 to 2008 (Stantec, 2008).
- Metro Printing and Type, northwest of the intersection of 24th Street and Thomas Road (at an unreported address), operated from 1981 to 1983 (Stantec, 2008);
- Flash Printing, northeast of the intersection of 24th Street and Thomas Road (at an unreported address), operated from 1989 to 1993 (Stantec, 2008); and
- Phoenix Fine Printing, southeast of the intersection of 24th Street and Thomas Road (at an unreported address), operated from 1970 to 2008 (Stantec, 2008).

Dry Cleaning and Laundry Facilities

- Fisher Cleaners, located at 3037 North 24th Street, operated from 1956 to 1973 (HGL, 2013);
- Spic-N-Span Launderette and Dry Cleaning, located at 2441 East Thomas Road, operated from 1958 to 1962 (Stantec, 2008);
- Western Cleaners, located at 3012 North 24th Street, operated in 1963 (HGL, 2013);
- Coin-Op Laundromat Western Cleaners, located at 3008 North 24th Street, operated from 1964 to 1966 (HGL, 2013);
- Colonial Wash and Dry Cleaning, southeast of the intersection of 24th Street and Thomas Road (at an unreported address), operated in 1974 (Stantec, 2008);
- Maytag Town Coin-Op Laundry & Dry Cleaners, located at 2833 North 24th Street, operated from 1975 to 1982 (HGL, 2013);
- Just-Rite Cleaners, located at 3037 North 24th Street, operated from 1976 to 1979 (HGL, 2013);

- Spencer's Chem-Dry, located at 2720 East Thomas Road, operated from 1987 to 1989 (HGL, 2013); and
- 3023 North 24th Street: Arizona Best One Hour Cleaners operated from 2010 to 2013 (HGL, 2013).

Other Commercial/Industrial Facilities

- Kaman Industrial Technologies, located at 2601 North 24th Street, operated from 1993 to 2001 (HGL, 2013); and
- Flash Printing was formerly located on the property (on the eastern portion of the parcel). The other facilities located in the general vicinity may be potential contributors to groundwater impacts but are considered nonviable so were not further investigated in this RI.

1.4 Contaminants of Concern

The following contaminants have been detected in samples collected from soil borings, soil vapor probes (SVPs), SVE wells, and temporary and/or permanent groundwater monitoring wells installed to investigate and/or remediate the area around the Former Carnation/Former McKean's property.

Soil

- PCE.

Soil vapor

- PCE;
- Trichloroethene (TCE);
- 1,2,4-Trimethylbenzene (1,2,4-TMB);
- 2,2,4-Trimethylpentane;
- 2-Butanone / methyl ethyl ketone (MEK);
- Benzene, toluene, ethylbenzene, m/p-xylenes and o-xylene (BTEX);
- Methylcyclohexane, cyclohexane, and n-hexane;

- Ethanol;
- n-Heptane and n-octane;
- Methylene chloride;
- Chloroform and bromodichloromethane;
- Tetrahydrofuran; and
- Acetone.

Groundwater

- PCE;
- TCE;
- cis-1,2-Dichloroethene (cis-1,2-DCE);
- 1,2-Dichloroethane (1,2-DCA);
- Chloroform;
- MEK;
- Benzene;
- Toluene; and
- Acetone.

Based on the nature of the potential release from the two dry-cleaning establishments (the Former Carnation and Former McKean's facilities), and the potential degradation compounds of the substances released, the COCs at the 24th Street and Grand Canal WQARF site include the following:

- PCE;
- TCE;
- cis-1,2-DCE;
- trans-1,2-Dichloroethene (trans-1,2-DCE); and
- Vinyl chloride (VC).

The BTEX, methylcyclohexane, cyclohexane, n-hexane, n-heptane, n-octane, acetone, 1,2,4-TMB, 1,2-DCA and MEK detections are likely associated with leaking underground storage tank (LUST) releases from the former gasoline service stations (former gas station), including the former 7-11 gas station located directly southeast of the intersection of 24th Street and Thomas Road, immediately across the street to the south of the Former Carnation/Former McKean's property, and/or the former unnamed gas station located directly northwest of the intersection of 24th Street and Thomas Road, immediately across the street to the west of the Former Carnation/Former McKean's property.

Chloroform is likely associated with drinking water chemicals, potentially released to the subsurface as part of landscape irrigation activities, and not associated with the Former Carnation and Former McKean's facilities' operations; thus, is not considered a site COC.

The RI is focused on the distribution and the fate and transport of the identified COCs; however, analytical results for additional contaminants analyzed are presented in the corresponding appendices.

The chemical and biological transformation of the COCs is a relatively common occurrence. These transformation processes are discussed below.

Biological Transformation: The predominant degradation mechanism for natural attenuation of chlorinated ethenes is anaerobic reductive dechlorination, which involves the sequential replacement of chlorine atoms on the alkene molecule with hydrogen atoms. Under anaerobic conditions, PCE and TCE are dechlorinated through cis-/trans-1,2-DCE and VC to ethene. Hydrogen typically produced during bacterial metabolism of simple organic carbon compounds such as alcohols (e.g., methanol) or organic acids (e.g., acetate), serves as the electron donor in the dechlorination reactions. Aerobic and anaerobic oxidation of lesser chlorinated ethenes (e.g., VC) can also occur. **Figure 5** shows the common biodegradation pathways for chlorinated ethenes.

Abiotic Transformation: Abiotic transformation of organic contaminants can occur naturally, without being mediated by microorganisms, and results in partial or complete contaminant degradation. Such processes include hydrolysis and, for select volatile organic compounds (VOCs), dehydrochlorination (elimination of hydrogen and chlorine). Abiotic transformation is dependent on contaminant properties and groundwater geochemistry.

Abiotic transformation can also be facilitated by reactive minerals that are either present naturally (i.e., as part of the native geology/mineralogy) or produced/regenerated by biological processes (Brown *et al*., 2007; Parsons Infrastructure & Technology Group, Inc. [Parsons], 2008; Naval Facilities Engineering Command [NAVFAC], 2014). Reactive minerals that promote abiotic transformation processes include iron sulfides (e.g., mackinawite, pyrite, greigite) and additional reduced iron minerals such as magnetite, green rust, and phyllosilicate clays (e.g., biotite and vermiculite). Abiotic transformation via reactive minerals has been documented for chlorinated solvents and is generally promoted in environments where both sulfate and iron are present under reducing conditions (NAVFAC, 2014). Rates of abiotic transformation are typically much slower than for biodegradation.

Other Abiotic Mechanisms for Attenuation:

Sorption: Dissolved organic contaminants can sorb to aquifer materials (i.e., organic carbon, clay minerals). This process tends to reduce apparent contaminant transport velocity (i.e., retards transport relative to groundwater flow).

Dilution: Dilution is primarily the result of groundwater recharge (e.g., from precipitation), leading to reduced contaminant concentrations. This process is dependent on aquifer matrix properties, depth to groundwater, surface water interactions, and climate.

Dispersion: Dispersion is the result of fluid mixing due to groundwater movement and aquifer heterogeneities (causing tortious migration pathways), leading to longitudinal, transverse, and vertical spreading of groundwater impacts. This process, which reduces contaminant concentrations, is dependent on aquifer properties and scale of observation, but not contaminant properties.

Diffusion: Molecular diffusion results in the spreading and dilution of contaminants in groundwater. This process is dependent on COC properties and concentration gradients, as described by Fick's Laws. At most groundwater velocities, diffusion is less significant than dispersion.

Volatilization: Volatilization is the transfer of dissolved groundwater contaminants into the vapor phase (soil gas), resulting in lower contaminant concentrations in groundwater. This process is dependent on contaminant vapor pressure and Henry's Law constant.

These abiotic mechanisms are expected to reduce the concentrations of PCE and its daughter products as they migrate in groundwater downgradient of source area(s) through non-transformative processes.

2. PHYSICAL SETTING

The following subsections provide the physical setting of the WQARF site, including topography, climate, and surface water.

2.1 Topography

Arizona is primarily divided into two main physiographic provinces: the Colorado Plateau and the Basin and Range (United States Geological Society [USGS], 1996). The site is situated within the Basin and Range physiographic province. The Basin and Range physiographic province consists of broad alluvial basins dissected by northwest-southeast trending block-faulted Precambrian through Tertiary igneous, sedimentary, and metamorphic highlands. These basins are filled with Holocene age alluvial sediments that are primarily derived from the weathering of these adjacent highlands, and consist primarily of fine-grained, well-sorted sediments, but also include coarse to gravelly channel, terrace, and alluvial fan deposits at depth (Rascona, 2005).

The site is located within the USGS Topo 7.5 Minute Phoenix map, which has a general topographic trend of decreasing elevations from the northeast to southwest. Monitoring well elevations in the central portion of the site range from 1,187 ft above mean sea level (amsl) in the northeast portion of the site (at monitoring wells MMW-04 and MMW-06) to 1,090 ft amsl in the southwest portion (at monitoring well VCMW-24; **Figure 2**).

2.2 Climate

The site is located within the semiarid climate of the northern Sonoran Desert. The region experiences hot summers and mild winters. Daytime high temperatures in July, typically the hottest month, are generally between 100 degrees Fahrenheit (°F) and 110°F, with overnight lows usually between 75°F and 85°F. January, usually the coolest month, typically experiences daytime highs between 60°F and 70°F and nighttime lows from 35°F to 45°F.

Annual precipitation is low, averaging from 7 to 8 inches for the greater Phoenix area. There are two distinct but erratic precipitation periods during the year: the monsoon season and the winter rains. The monsoon season occurs primarily in July and August, and in the winter months there are less intense but more widespread and longer-lasting rainfall events (Schmidli, 1996).

Prolonged droughts are common and shorter periods of drought even more so. Spring runoff from snow melt in the Salt, Gila, and Verde River watersheds provides most of the surface water stored by the reservoirs that serve portions of the metropolitan area's population. During years of winter drought, reduced surface water availability can result in elevated groundwater pumping (Schmidli, 1996).

2.3 Surface Water

The nearest man-made surface water body is the Grand Canal, located approximately 800 ft to the southwest of the Former Carnation/Former McKean's property. The closest natural surface water body to the is the Salt River, located approximately 4 miles south of the Former Carnation/Former McKean's property.

Surface water usage within the site is for residential irrigation. The surface water source generally comes from the Salt River via the Arizona Canal, Grand Canal, associated laterals and various groundwater pumping wells (H+A, 2018a).

2.4 Geology

2.4.1 Regional Geology

The site is located within the West Salt River Valley (WSRV) sub-basin, a broad, relatively level alluvial valley. The alluvium represents a combination of deposits from the surrounding mountains and fluvial deposits from the Salt River (HydroGeoChem, Inc., 2017).

2.4.2 Surficial Soil

Surficial soil in the area consists primarily of the Gilman loam, with up to one percent slopes, according to H+A's review of 2017 data from the National Resources Conservation Service (NRCS) (United States Department of Agriculture [USDA], 2018). The Gilman loam is described as a loam to a depth of 37 inches where a very fine sandy loam is present to a depth of 64 inches.

2.4.3 Site Geology

Generally, the top approximately 90 to 100 ft of subsurface is comprised of sandy or clayey silt and silty sand, followed by silty gravel with sand to approximately 100 to 110 ft bgs, followed by intermittent layers of sand, gravel, and silt to approximately

200 ft bgs, as evidenced in boring logs from 24AS-01, 24MW-06B, and 24SV-01 (Appendix A). The Arizona Department of Water Resources (ADWR) imaged well records for the SRP well located nearest to the property, SRP Well 16E-6.8N (ADWR 55-607726; **Figure 2**), were reviewed; the registration forms indicate the well was drilled to 620 ft below ground surface (bgs) and water was encountered at 66 ft bgs. A boring log was not included in the records so lithologic information below approximately 200 ft bgs (the deepest boring log acquired by Geosyntec) is unknown.

In the vicinity of the two former dry-cleaners, lithology has been investigated to a maximum depth of 200 ft bgs in 24MW-06B (**Figure 4**). The lithology encountered in 24MW-06B was primarily sandy-silt and silty-sand with clay layers and gravel seams occurring at various depths. The 24MW-06B boring and construction log is included in **Appendix A**.

2.5 Hydrogeologic Setting

2.5.1 Regional Groundwater Conditions

The site lies within the WSRV Sub-basin of the Phoenix Active Management Area (AMA), which includes the communities of Phoenix, Buckeye, Surprise, Glendale, Peoria, Goodyear, Tolleson, and Avondale. The WSRV is one of seven sub-basins located in the Phoenix AMA. The AMA was established due to concerns of over-draft conditions, resulting in the passage of the 1980 Arizona Groundwater Management Act. Although conditions and circumstances vary across the Phoenix AMA, groundwater is generally pumped from the deeper portions of the Upper Alluvial Unit (UAU). Furthermore, groundwater conditions change and develop over time due to both natural and human-induced fluctuations in the amount of water being added or removed. Natural groundwater recharge occurs along stream channels and from mountain-front recharge. Groundwater also enters the sub-basin from the Lake Pleasant, northern Hassayampa, and East Salt River Valley sub-basins, and from the Maricopa-Stanfield Sub-basin in the Phoenix AMA. Agricultural irrigation water and effluent discharged from the COP 23rd and 91st Avenue wastewater treatment plants also contributes to recharging the aquifer (NV5 Environmental Services, 2015).

2.5.2 Site Hydrostratigraphy

In 1993, ADWR released the results of its modeling study of the Salt River Valley (Corkhill *et al*., 1993). For modeling purposes, the ADWR defined three hydrogeologic

units in the basin-fill by differences in grain size that occur throughout most of the Phoenix Basin and are generally correlative with the hydrostratigraphic units defined by the United States Bureau of Reclamation in 1976. These include from the shallowest to deepest: the UAU, the Middle Alluvial Unit (MAU), and the Lower Alluvial Unit (LAU).

2.5.2.1 Upper Alluvial Unit

The UAU consists of unconsolidated sands and gravels deposited by flowing drainages and is the most permeable unit. According to the ADWR, the UAU is typically 300 to 400 ft thick in the WSRV. Where thick saturated sections of the UAU are present, the groundwater production rates are the highest in the region.

2.5.2.2 Middle Alluvial Unit

The MAU is composed primarily of silt, clay, mudstone, and gypsiferous mudstone, interbedded with silty sand and gravel. As is the case with the UAU and LAU, coarser-grained sediments predominate near the Basin margins, where the MAU is indistinguishable from the overlying or underlying units.

2.5.2.3 Lower Alluvial Unit

The LAU consists mainly of conglomerate and gravel near the margins of the Salt River Valley. It grades into finer grained mudstone, gypsiferous and anhydritic mudstone, and anhydrite toward the center of the basin. Parts of the Western Salt River Valley also contain some interbedded lava flows. The LAU overlies crystalline and volcanic bedrock (HydroGeoChem, Inc., 2017).

2.6 Site Hydrogeology

The hydrostratigraphic units have been defined based on review and evaluation of data generated during groundwater assessments at the ECP WQARF sites. The hydrogeology has been investigated to a maximum depth of approximately 407 ft bgs within the UAU. The base of the UAU has not been encountered during drilling activities to date; however, the UAU ranges in thickness from approximately 125 to more than 300 ft in the ECP WQARF sites region. The UAU within the ECP WQARF sites consists of predominantly fine-grained sands, silts and silt with sand, to sandy silts with trace amounts of gravel. The groundwater surface within the site lies within the UAU.

Groundwater elevations in the UAU have been monitored since April 1992 (**Table 1** and **Appendix B**). Monitoring wells installed at the site are screened across both shallow (water table) and deeper intervals within the UAU (**Table 2**). Water levels in co-located shallow and deeper screened monitoring wells are generally nearly identical.

During the period of record for monitoring wells installed to investigate the Former Carnation/Former McKean's property, the depth to water has ranged from approximately 83.49 ft bgs (24MW-08B) in 2015 to approximately 102.10 ft bgs (24MW-01A/B) in 2014 (**Table 1** and **Figures 2** and **4**).

Groundwater elevations throughout the 24th Street and Grand Canal WQARF site fluctuated by approximately 17 ft between 2013 and 2015. This may be due to the pumping operations of SRP well 17E-8.0N (H+A, 2015a) and drought conditions.

Seasonal fluctuations in the groundwater elevation are commonly observed in the Phoenix AMA due to an increase in SRP (and COP) production well pumping rates during the summer months. However, a review of the historical groundwater elevations (**Table 1**) does not suggest significant seasonal groundwater fluctuations occurred within the boundary of the WQARF site (**Figure 2**).

The direction of groundwater flow (**Figure 6**) historically has been to the west-southwest with gradients ranging between approximately flat and 0.007 ft per foot. Vertical gradients between the shallow and deeper zones of the UAU monitored at the site are generally negligible. The estimated horizontal hydraulic conductivity of the UAU is variable due to the heterogeneity of the UAU and ranges from 1 to 250 ft per day. The highest estimates of hydraulic conductivity in the WSRV are found near the Salt River (Corkhill *et al.*, 1993; Freihoefer *et al.*, 2009).

2.7 Ecology

The site is located in an urban setting that provides low-quality habitat for native terrestrial or aquatic biota. Given the presence of roads and extensive man-made structures, it is likely that the natural vegetation, soils, and hydrology have been altered by filling, grading, and improvement activities in the past. There is a low potential for native terrestrial or aquatic biota to occur in the area. According to Google Maps, the closest large, natural open-space (Los Olivos Park) is located approximately 500 ft to the northwest of the site.

Based on information provided through the United States Fish and Wildlife Service (USFWS) online Information, Planning and Conservation (IPaC) System and by the Ecological Services Program, there are seven federally listed endangered species with the potential to occur on lands within Maricopa County, including: ocelot (*Leopardus* or *Felis pardalis*), Sonoran pronghorn (*Antilocapra americana sonoriensis*), California least tern (*Sterna antillarum browni*), Mexican spotted owl (*Strix occidentalis lucida*), Southwestern willow flycatcher (*Empidonax traillii extimus*), yellow-billed cuckoo (*Coccyzus americanus*), and Yuma clapper rail (*Rallus longirostris yumanensis*). Additionally, there are a six species of endangered fish and four species of flowering plants (USFWS, 2018). The site and immediate vicinity do not contain suitable habitat for these species.

3. PRELIMINARY ASSESSMENTS AND INVESTIGATIONS

This section presents a summary of PA, Phase I ESAs, and PIs performed at the 24th Street and Grand Canal WQARF site, prior to the commencement of ERA investigations and remediation activities. Analytical results from laboratory reports and electronic files (**Appendices C through F**) are included in **Tables 4 through 7**.

3.1 24th and Grand Canal WQARF Site

The 24th and Grand Canal WQARF site has been the focus of environmental investigations since 1985 when groundwater samples were collected from SRP Well 16E-6.8N (ADWR 55-607726; **Figure 2**), located east of the intersection of 24th Street and Grand Canal (**Figure 4**) (ADEQ, 2018a). Grand Canal is a historic water canal constructed in 1878 to deliver water to COP.

In January 1995, PCE was reported at a concentration of 8.8 micrograms per liter (µg/L) in SRP Well 16E-6.8N, the highest concentration observed by that time and exceeding the AWQS of 5 µg/L (ADEQ, 2011a). This well has historically had exceedances of the AWQS from 1992 to 2006 with PCE concentrations ranging from 5.2 µg/L in 1994 to 11 µg/L in 2006 (HGL, 2014).

On 18 May 2000, the 24th Street and Grand Canal WQARF site was placed on the WQARF Registry with a score of 29 out of a possible 120. By then, reported PCE concentrations in samples collected from SRP Well 16E-6.8N had generally been conducted annually and consistently exceeded the AWQS.

Due to the PCE detections, several properties in the ECP region were investigated to locate potential sources for these impacts to groundwater. The two dry-cleaning facilities, and one printing facility listed below operated on the property and were investigated:

- Arizona's Best 1-Hour Cleaners / Carnation 1-Hour Cleaners / ABC Cleaners at 2402 East Thomas Road;
- McKean's Model Laundry and Dry-Cleaning / Thriftway Laundry and Cleaners at 2915 North 24th Street; and
- Flash Printing (Stantec, 2008).

Preliminary investigations at the 24th Street and Grand Canal WQARF site were initiated in 2000. The investigations conducted at each facility are summarized in the following subsections in chronological order.

3.2 2001 Phase I Environmental Site Assessment

In 2001, a Phase I ESA for an area that included the 24th Street and Grand Canal WQARF site identified two historical dry-cleaning facilities, the Former Carnation and Former McKean's facilities, that formerly operated on-site. Additionally, two former service stations in the immediate vicinity of the assessment area were identified to have potentially impacted the site. An unnamed service station reportedly operated on the northwest corner of the intersection of 24th Street and Thomas Road from around 1950 to the early 1980s. A 7-11/Shell Service Station reportedly operated on the southeast corner of the intersection of 24th Street and Thomas Road from around 1960 to 1991 (Terracon, 2001a).

3.3 2001 Phase II Environmental Site Assessment

In 2001, a Phase II ESA was conducted at the Former Carnation/Former McKean's property to investigate potentially-impacted soils. Seven borings (B1 through B7) were drilled to terminal depths (15 ft bgs for B2, 20 ft bgs for B1, and 30 ft bgs for B3 through B7) around the existing building and two borings (HA-1 and HA-2) to 1.5 ft bgs inside the existing building, near the dry-cleaning suite (**Figure 4**). Laboratory results determined that PCE was detected in soil samples from HA-1 and HA-2 at concentrations of 3.1 milligrams per kilogram (mg/kg) and 0.19 mg/kg, respectively, below the associated residential groundwater protection level (GPL) of 13 mg/kg and soil remediation level (SRL) of 53 mg/kg. VOCs were not detected above their laboratory reporting limits (RLs) in the other samples analyzed (Terracon, 2001b).

3.4 2001 Soil and Groundwater Investigation

Following detections of PCE in soil, a groundwater investigation was conducted at the Former Carnation/Former McKean's property. In October 2001, three temporary groundwater monitoring wells (T-1 through T-3) were installed to 95 ft bgs on the property (**Figure 4**).

Groundwater samples were collected from each location via temporary monitoring wells prior to backfilling the borings. As indicated on the boring logs, groundwater was first

encountered at 89.5, 90, and 91 ft bgs, respectively (**Appendix A**). Laboratory results indicated that VOCs were not detected above their laboratory RLs in the soil samples. PCE was reported in groundwater samples from two of the three locations at concentrations of 29 µg/L in T-2 and 1.0 µg/L in T-3, exceeding the AWQS in T-2.

From 2002 to 2006, routine groundwater monitoring activities were performed at the 24th Street and Grand Canal WQARF site. PCE concentrations exceeding the AWQS in the SRP Well 16E-6.8N (**Figure 2**) ranged from 7.4 µg/L to 11 µg/L (Table 1 of HGL, 2014). Other COCs were not included in the results.

3.5 2003 Soil Investigation

A subsurface soil investigation was conducted at the property. In February 2003, two borings (B-8 and B-9) were advanced to 15 and 10 ft bgs, respectively, at the locations of the previous borings HA-1 and HA-2 (**Figure 4**). Soil samples were collected at 2.5 and 5 ft bgs from both borings and additionally at 10 ft bgs from B-9 and 15 ft bgs from B-8. PCE was detected in five of the six samples at concentrations ranging from 0.15 mg/kg in B-9 at 10 ft bgs to 1.3 mg/kg in both B-8 and B-9, both at 2.5 ft bgs. These concentrations were below the associated GPL and SRL. No other VOC analytes were detected above the laboratory RLs. Four Corners did not recommend further soil or groundwater investigations (Four Corners, 2003).

3.6 2005 Phase I Environmental Site Assessment

A Phase I ESA conducted at the property in 2005 identified the historical presence of dry-cleaners and PCE-impacted soils beneath the WQARF site. The report noted that prior investigations concluded the PCE concentrations in soil investigated did not exceed the applicable screening levels, and the impacts to groundwater indicated that PCE is "ubiquitous" in groundwater both upgradient and downgradient of the property (Shaw, 2005).

4. REMEDIAL INVESTIGATION

In June 2007, ADEQ provided notices per A.R.S. § 49-287.03 initiating the RI at the 24th Street and Grand Canal WQARF site (ADEQ, 2011a). RI activities were conducted from June 2007 through August 2018 and are described in the following sections. In March 2008, Shaw prepared a *Subsurface Investigation Workplan* that proposed the collection of soil, soil vapor, and groundwater samples in the immediate vicinity of the property (Shaw, 2008a).

4.1 Soil Investigations

In July 2008, a boring (24AS-01) was advanced to approximately 120 ft bgs at the Former Carnation/Former McKean's property (**Figure 4**) and collected soil samples from 10, 40, 60, 70, 75, and 85 ft bgs. Laboratory analyses detected PCE in one soil sample from 85 ft bgs at a concentration of 0.20 mg/kg, below the GPL and SRL. No other VOCs were detected above their laboratory RLs (Shaw, 2008b).

In March 2016, borings 24SG-01 through 24SG-07, 24SV-05, and 24SV-06 (**Figure 4**) were advanced and soil samples were collected at discrete depths during drilling. Soil samples were collected from 4 to 5 and 14 to 15 ft bgs and analyzed for physical parameters including, but not limited to, moisture content, organic matter content, and porosity. Soil samples were collected from 14 ft bgs in each soil vapor boring and from 10, 30, and 49.5 ft bgs in each SVE well. VOC analytes were not detected above their laboratory RLs in any of the samples (AMEC, 2016) (**Appendix C**).

In February 2018, Geosyntec collected soil samples from SV-07, SV-08, and SV-09 at 60, 70, 80, 90, and 100 ft. No VOCs were detected above their laboratory RLs (Geosyntec, 2018b).

4.2 Soil Vapor Investigations

In July 2008, soil vapor samples were collected from 10, 20, 30, 40, 50, 51, 60, 70, 75, and 85 ft bgs from 24AS-01 (also known as AS-1; **Figure 4**). PCE concentrations ranged from 230,000 micrograms per cubic meter (µg/m^3) at 30 ft bgs to 8,800,000 µg/m^3 at 70 ft bgs. Acetone was reported in one soil vapor sample from 60 ft bgs at a concentration of 33,000 µg/m^3. No other VOCs, including TCE, were detected above their laboratory RLs (Shaw, 2008b).

In February 2015, SVPs were installed at four locations around the exterior of the on-site building along the north, south, and west sides, which corresponded to the locations of historical dry-cleaning operations. Soil vapor was collected from boreholes during drilling. Detected concentrations of PCE ranged from less than 67.8 to 17,300 µg/m^3 between 10 and 85 ft bgs. These borings were completed as 4-inch diameter soil vapor monitor wells (24-SV-01 through 24-SV-04) to provide a more robust monitoring network for future investigation and potential site remediation.

From April through November 2015, additional SVPs were installed, and monitoring was conducted at 24SV-01 through 24SV-04 and 24-SG-01A through 24-SG-07B (**Figure 4**). Reported PCE concentrations ranged from 11 µg/m^3 in 24SG-06A to 1,300,000 µg/m^3 in 24SV-01 at 30 ft bgs. Reported TCE concentrations ranged from non-detect in 24SV-01 at 30 ft bgs and 24SV-02 at 30 and 35 ft bgs to 230 µg/m^3 in 24SV-01 at 30 ft bgs. Several other VOCs were also reported in the soil vapor samples: 1,2,4-TMB, 2-butanone, 4-methyl-2-pentanone, acetone, alpha-pinene, carbon disulfide, chloroform, cyclohexane, d-limonene, ethanol, ethyl acetate, ethylbenzene, m/p-xylene, methylene chloride, naphthalene, n-heptane, n-hexane, o-xylene, propene, styrene, and toluene (H+A, 2015a; H+A, 2015c).

From August to December 2017, Geosyntec conducted soil vapor sampling in the existing SVE wells (SVE-01 through SVE-06) and SVPs (SG-01 through SG-07 at 5 and 15 ft bgs) at the property. Detected PCE concentrations in SVE wells ranged from non-detect in 24-SV-01 to 2,510 µg/m^3 in 24-SV-04. Detected PCE concentrations in SVPs ranged from non-detect in SG-03 at 5 ft bgs to 1,570 µg/m^3 in SG-05 at 5 ft bgs. TCE was detected only in samples from SVE-04 and SVE-05 at concentrations of 5.6 µg/m^3 and 6.3 µg/m^3, respectively. Chloroform, toluene, m/p-xylene, o-xylene, 1,2,4-TMB, benzene, acetone, and tetrahydrofuran were also reported in the soil vapor samples (Geosyntec, 2017; Geosyntec, 2018a).

In February 2018, Geosyntec installed SVPs SV-07, SV-08, and SV-09 and collected soil vapor samples at 60, 70, 80, 90, and 100 ft bgs. Neither PCE nor TCE were detected above their laboratory RLs in any of the other samples; however, several other VOC analytes were reported in the samples: 2,2,4-trimethylpentane, 2-butanone, benzene, bromodichloromethane, chloroform, cyclohexane, heptane, hexane, methylcyclohexane, octane, and toluene (Geosyntec, 2018b).

4.3 Groundwater Investigations

From 1982 to 2009, various consultants sampled SRP Well 16E-6.8N (**Figure 2**). PCE in groundwater samples ranged from 0.1 µg/L in 1987 to 12 µg/L in 2005, 2007, and 2008, exceeding the AWQS for PCE of 5 µg/L (ADEQ, 2012).

From July 2008 to May 2018, various consultants installed 15 groundwater monitoring wells, sampled water using Hydropunch™ methodology, and conducted site-wide sampling. Reported PCE concentrations ranged from non-detect in several samples to 2,900 µg/L in 24AS-01 in August 2016. Reported TCE concentrations ranged from non-detect in the majority of wells to 4.6 µg/L in 24AS-01 in August 2016. Additionally, benzene, chloroform, cis-1,2-DCE, 1,2-DCA, toluene, 1,2,4-TMB, 1,3,5-trimethyl-benzene, total xylenes, bromodichloromethane, and dibromochloromethane were reported in some samples, but at concentrations below their respective AWQS values (Shaw, 2008b; ADEQ, 2011a; H+A, 2014; H+A, 2015a; H+A, 2017; H+A, 2018b; **Appendix E**).

In October 2016, borehole 24MW-10B was advanced to aid in the delineation of groundwater impacts. Groundwater was sampled using Hydropunch™ methodology at 106, 125, 145, 165, 185, 205, 225 and 245 ft bgs, respectively. This boring was abandoned and not completed as a groundwater monitoring well. PCE concentrations identified ranged from 0.62 µg/L at a depth of approximately 225 ft bgs to a maximum concentration of 46.0 µg/L at a depth of approximately 125 ft bgs. Samples collected from 106, 125, 145, 165, 185, and 205 ft bgs contained PCE at levels exceeding AWQS.

In November 2016, borehole 24MW-11 was advanced to delineate the southern extent of groundwater impacts. Groundwater was sampled using Hydropunch™ methodology at 96, 115, 135, 155, 166, 185, and 205 ft bgs, respectively. This boring was abandoned and not completed as a groundwater monitoring well. PCE concentrations identified ranged from 2.00 µg/L at a depth of approximately 185 ft bgs to a maximum concentration of 17.0 µg/L at a depth of approximately 115 ft bgs. Three samples collected from 96 and 135 ft bgs contained PCE at levels exceeding AWQS.

In February 2018, Geosyntec collected groundwater grab samples using Hydropunch™ methodology and a disposable bailer during drilling from 24-SV-07, 24-SV-08, and 24-SV-09 at 105 ft bgs and analyzed the samples for VOCs by USEPA Method 8260. PCE was reported in the three borings at concentrations ranging from 0.59 µg/L in 24-SV-07 to 480 µg/L in 24-SV-08. TCE was reported only in 24-SV-08 at a concentration of

0.87 µg/L, below the AWQS. Several other VOCs were also reported in the samples (Geosyntec, 2018b).

In August 2018, Geosyntec conducted groundwater sampling at the site: 24AS-01, 24MW-01A, 24MW-02A, 24MW-03A, 24MW-04A, 24MW-06B, 24MW-07A, 24MW-09A, 24MW-10A, 24MW-13A, 24MW-14 (**Figures 2** and **4)**. Reported PCE concentrations ranged from non-detect to 600 µg/L in 24AS-01, exceeding the AWQS.

Geosyntec created a hydrograph using available groundwater data from December 2013 to August 2018 (**Appendix B**). **Figure 6** shows a groundwater elevation contour map for August 2018, and **Figure 7** shows chlorinated volatile organic compound (CVOC) concentrations in groundwater for August 2018.

5. EARLY RESPONSE ACTIONS

SVE was implemented as an ERA at the 24th Street and Grand Canal WQARF site to address residual vadose zone VOC impacts.

In 2016, an SVE system was constructed to mitigate soil, soil vapor, and groundwater impacts beneath the property. Extracted soil vapor is routed through two 1,000-pound capacity vapor-phase granular activated carbon (GAC) vessels configured in series. After GAC treatment, the treated soil vapors are discharged to atmosphere through effluent piping (i.e., the stack).

The extraction network consists of six SVE wells (24-SV-01 through 24-SV-06) (**Figure 8**). These wells include 30 to 40-foot screens, with intervals from 10 to 50 ft bgs for 24-SV-01, 20 to 50 ft bgs for 24-SV-02 through 24-SV-04, and 10 to 50 ft bgs for 24-SVE-05 and 24-SVE-06.

Baseline soil vapor samples were collected from the SVPs and the individual SVE wells prior to startup of the SVE system. Detected concentrations of PCE in soil vapor in the Baseline event ranged from 3,183 $\mu g/m^3$ (24-SG-01 at 5 ft bgs) to 130,200 $\mu g/m^3$ (24-SG-05 at 15 ft bgs).

After startup, the system operated generally continuously until August 2017, with brief periods of shutdown associated with maintenance, GAC changeouts, and minor troubleshooting. Flow balancing and other standard system optimization procedures were routinely performed to maximize VOC mass removal rates throughout system operation.

On 30 August 2017, the system was shut down due to low VOC mass yield and to perform a soil vapor rebound evaluation. 'Shutdown' soil vapor samples were collected on 31 August and 1 September 2017 from both screen depths of the seven SVPs (5 and 15 ft bgs) and from the individual SVE wells. Detected PCE concentrations for samples collected during the Shutdown soil vapor sampling event ranged from 31 $\mu g/m^3$ (SVP 24-SG-04 at 15 ft bgs) to 2,510 $\mu g/m^3$ (SVE well 24-SV-04). 'Rebound' soil vapor samples were collected over three months later, in December 2017. Detected PCE concentrations for the Rebound soil vapor monitoring event ranged from 14 $\mu g/m^3$ (SVP 24-SG-01 at 5 ft bgs) to 1,390 $\mu g/m^3$ (SVE well 24-SV-04). No significant soil vapor rebound was observed (Geosyntec, 2018a).

In February 2018, Geosyntec advanced three borings, 24-SV-07 through 24-SV-09, to assess VOCs in the deep vadose zone (Geosyntec, 2018b). The borings were advanced with a contingency plan to convert them to SVE wells if warranted based on results of VOC analysis of soil vapor samples collected during advancement of the borings. However, PCE was not detected in the samples, and no SVE well construction was recommended. Several non-chlorinated hydrocarbons were detected in the samples. The source of the hydrocarbons was not identified, but it was concluded that they may have been related to one of the nearby closed LUST listings (discussed in **Section 1.3.3**) and were not related to the dry-cleaner facilities associated with the 24th Street and Grand Canal WQARF site.

In October 2018, Geosyntec performed a HHRA for the 24th Street and Grand Canal WQARF site (Geosyntec, 2018c). The HHRA evaluated the results from the December 2017 soil vapor rebound monitoring event for potential vapor intrusion risk under a commercial/industrial exposure scenario, and also under a conservative potential future residential site redevelopment exposure scenario. The results of the vapor intrusion HHRA indicate that concentrations of COCs in soil vapor do not pose an unacceptable risk to site receptors, with a calculated cumulative excess lifetime cancer risk less than 10^{-6} (one in a million). The results of the HHRA also support a conclusion that no further action is required to address residual vadose zone soil vapor COCs concentrations, and as such, the SVE ERA is no longer warranted. Further, the shallow vadose zone has been remediated to standards that should allow for unrestricted future site redevelopment.

Formal decommissioning of the SVE system is currently planned for the beginning 2019. The extraction and treatment components of the SVE system will be demobilized from the Former Carnation/Former McKean's property and the SVPs will be properly abandoned. However, the SVE wells, conveyance piping, and the block wall enclosure will likely remain at the property pending an evaluation of potential remediation of the underlying groundwater impacts; the infrastructure may be useful for such a groundwater remedy.

Approximately 76 pounds of VOCs are estimated to have been removed from the subsurface by the SVE system between July 2016 and August 2017.

6. RISK EVALUATION

An objective of the WQARF program is to evaluate potential public and environmental health concerns or risks associated with the site to support remedial action decision-making. The following tasks were performed as part of this evaluation:

- Characterize environmental and health hazards associated with exposure to site COCs;
- Describe the applicable regulatory criteria for site media impacted with site COCs;
- Identify potential receptors within the vicinity of the site;
- Identify the potential migration / exposure pathways to potential receptors, and the potential completion of such pathways; and
- Evaluate the potential risk to receptors based on the concentrations of site COCs in site media.

6.1 Environmental and Human Health Hazards

The predominant site COCs from source operations are PCE and TCE; thus, this section focuses on these two VOCs. PCE is a clear, colorless, nonflammable solvent that readily evaporates at room temperature. PCE is widely used for dry-cleaning of fabrics and degreasing/drying of metals. TCE is a nonflammable, colorless solvent that readily evaporates at room temperature. TCE is used mainly for degreasing/drying of metals and cleaning of fabrics.

When present in groundwater or soil vapor, PCE and TCE can emit vapor and move through voids in the soil into buildings, potentially through cracks in the building foundation or slab. The vapors may accumulate in homes and other occupied buildings to levels that may cause health effects. This movement of VOCs into buildings is called vapor intrusion (Arizona Department of Health Services [ADHS], 2016). Due to the nature and location of the release in relation to commercial/industrial and residential areas, potential health hazards from the vapor intrusion pathway were evaluated and are discussed further below.

PCE and TCE are both included on a list of 10 chemical substances that are the subject of USEPA's initial chemical risk evaluations, currently being performed as required by

USEPA under the Toxic Substances Control Act (TSCA), as amended by the Frank R. Lautenberg Chemical Safety for the 21st Century Act. USEPA recently published two comprehensive risk assessment documents for these compounds, one describing the scope of the risk evaluation, and one stating the problem formulation. The content of these documents was reviewed to provide the summary information below, which represents USEPA's latest understanding of environmental and health hazards from exposure to these VOCs.

6.1.1 PCE Hazards

6.1.1.1 Human Health

According to the *Problem Formulation of the Risk Evaluation for Perchloroethylene (Ethene, 1,1,2,2-Tetrachloro), CASRN: 127-18-4* (USEPA, 2018a), and based on reasonably available information to USEPA, these are the potential human health hazards associated with PCE exposure:

- Non-cancer hazards: the central nervous system (neurotoxicity), kidney toxicity, liver toxicity, reproductive/developmental toxicity, and irritation.
- Genotoxicity and cancer hazards: likely to be carcinogenic in humans by all routes of exposure. Associated with several cancer types, including non-Hodgkin's lymphoma, multiple myeloma and bladder cancer, with more limited evidence for esophageal, kidney, lung, cervical and breast cancer.

6.1.1.2 Ecological Health

USEPA calculated acute and chronic toxicity PCE concentrations of concern to aquatic and terrestrial species from a review of existing literature. According to the "Ecological Hazard Characterization of PCE" (Table 2-9, USEPA, 2018a), which presents a summary of USEPA's calculations, PCE can impact some species' mortality, growth, biomass/abundance, and reproduction.

6.1.2 TCE Hazards

6.1.2.1 Human Health

According to the *Problem Formulation of the Risk Evaluation for Trichloroethylene, CASRN: 79-01-6* (USEPA, 2018b), and based on reasonably available information to USEPA, these are the potential human hazards associated with TCE exposure:

- Non-cancer hazards: acute toxicity, liver toxicity, kidney toxicity, reproductive/developmental toxicity, neurotoxicity, immunotoxicity, and sensitization.
- Genotoxicity and cancer hazards: carcinogenic to humans by all routes of exposure and calculated quantitative estimates of risk from oral and inhalation exposures. Studies in humans have shown convincing evidence of a causal association between TCE exposure in humans and kidney cancer as well as human evidence of TCE carcinogenicity in the liver and lymphoid tissues. TCE is considered to have genotoxic carcinogenic, non-genotoxic carcinogenic, and teratogenic mechanisms.

6.1.2.2 Ecological Health

USEPA calculated acute and chronic toxicity TCE concentrations of concern to aquatic species, terrestrial species, and microorganisms from a review of existing literature. According to the "Ecological Hazard Characterization of TCE" (Table 2-8, USEPA, 2018b), which presents a summary of USEPA's calculations, TCE can impact some species' mortality, growth, deformities, abundance and reproduction. In microorganisms, TCE can impact respiration and growth.

6.2 Applicable Regulatory Standards and Screening Criteria

The following section describes the applicable regulatory standards for site COCs in soil, indoor air and groundwater, historically and present-day. ADEQ has not established state-wide soil vapor screening criteria.

6.2.1 Soil Remediation Standards

A discussion of soil remediation levels is presented herein to explain historical investigation results in relation to applicable criteria. The soil remediation standards

conservatively selected by ADEQ for the site are based on the potential for future residential use, meaning those uses of remediated property where natural persons are reasonably expected to be in frequent, repeated contact with soil (A.R.S. §49-15l). In addition, ADEQ has selected a cumulative excess lifetime cancer risk of 1 x 10^{-6} (10^{-6} risk) level for site soil remediation standards, which are defined as concentrations of site COCs remaining in the soil after remediation that would result in a 10^{-6} risk and a hazard index (HI) no greater than 1.0, based on residential exposure assumptions. Although the property is zoned commercial/industrial, there are residential parcels and properties within the estimated PCE plume boundary (**Figure 2 and 4**). Remediation to a residential 10^{-6} risk level was selected to provide the most conservative protection to potential future occupants of the site.

The pre-determined residential soil remediation levels (RSRLs) for carcinogenic compounds with a 10^{-6} risk level are listed in Appendix A of A.A.C., Title 18, For site COCs, they are as follows:

- PCE RSRL = 0.51 mg/kg; and
- TCE RSRL = 3.0 mg/kg.

Tabulated historical soil results for PCE are included in **Table 4**. PCE was detected in soil above the RSRL in three samples, collected in 2001 and 2003. According to previous investigation reports, other VOCs, including TCE, were not detected in soil above laboratory RLs.

6.2.2 Groundwater Protection Levels

The minimum GPLs (soil cleanup levels protective of groundwater quality) were used to evaluate groundwater data collected from the site. The minimum GPL for PCE is 1.3 mg/kg. The minimum GPL for TCE is 0.61 mg/kg.

PCE was detected in soil at or above the GPL in three samples collected in 2001 and 2003 (**Table 4**).

6.2.3 Indoor Air Screening Levels

Indoor air investigations were not conducted at the property to evaluate the quality of indoor air and to determine the level of VOC exposure to commercial/industrial workers; however, a discussion of indoor air screening levels is presented to describe the indoor

air criteria utilized in the HHRA. The USEPA Region 9 indoor air Regional Screening Levels (RSLs; IARSLs) were used as the applicable indoor air screening values. The following IARSLs are currently applicable for PCE and TCE for residential indoor air Regional Screening Level (RIARSL) and industrial indoor air Regional Screening Level (IIARSL) exposure scenarios:

- PCE RIARSL = 11 µg/m^3;
- PCE IIARSL = 47 µg/m^3;
- TCE RIARSL = 0.48 µg/m^3; and
- TCE IIARSL = 3.0 µg/m^3.

These have been the applicable USEPA RSL values since May 2014.

6.2.4 Groundwater Standards

AWQS are State of Arizona maximum levels for COCs that apply to groundwater in aquifers designated for drinking water use. The following AWQS are applicable:

- PCE = 5 µg/L;
- TCE = 5 µg/L; and
- cis-1,2-DCE = 70 µg/L.

The only site COC detected in groundwater above these standards was PCE, which was detected in the majority of groundwater wells for the site during multiple sampling events that occurred between 1992 and 2018.

6.3 Potential Receptors

Prior to performing the exposure pathway evaluation, potential receptors to site COCs were identified. The boundary (**Figure 1**) includes an area encompassing residential and commercial/industrial settings. Potential receptors are identified as current and future residential individuals, commercial/industrial workers, and construction workers occupying areas within the boundary.

Residential individuals include children and adults occupying residential locations within the boundary. A residential location is typically one where someone is present for an

average of more than eight hours a day. It includes, but is not limited to, schools, dwellings, residences, correctional facilities, any other human activity areas of repeated, frequent use and/or chronic duration and locations that typically house sensitive populations such as grade schools, hospitals, childcare centers and nursing homes. Several apartment complexes are located within the boundary, including, but not limited to, Jamestown Condominiums, Fairmount Villa Apartments, Fairmount Garden Condominiums, and Lofts at Arcadia (Figure 1C of H+A, 2013). Individual residential properties are also located within the boundary.

Commercial/industrial workers include adults working at the businesses within the Former Carnation/Former McKean's property boundary, which includes retail shopping areas.

Construction workers include adults who are performing construction work for a substantial period (e.g., months to years), resulting in sub-chronic exposures for only that period equal to the duration of the project.

Two categories of sensitive receptors, schools and medical centers, are located within a half-mile radius of the estimated PCE plume boundary. A list of these schools and medical centers was prepared from reviewing Google Earth and Google Map data (accessed online in October 2018) and is presented in **Table 8**.

6.4 Ecological Risk Evaluation

As defined in A.A.C., an ecological receptor is "a specific ecological community, population, or individual organism, protected by federal or state laws and regulations, or a local population that provides an important natural or economic resource, function, and value" (A.A.C., Title 18, Ch. 7, 201). Wildlife or vegetation that is present in the study area is likely non-native to the area, is habituated to human presence, or has been maintained in a horticultural setting. Areas and land use within the boundary (**Figure 2**) do not contain suitable habitat for the five federally listed species. Due to the presence of COCs at depth, the urban character of the site, and lack of ecological receptors within the boundary, an evaluation of ecological receptors is not warranted.

6.5 Exposure Pathways and Potential Risk

An exposure or migration pathway is the route by which the potential hazard (identified COCs) migrates from the source (soil vapor, soil, surface water, or groundwater) to a receptor. Pathways can include:

- Inhalation of impacted vapors;
- Dermal contact with impacted soil, groundwater, or surface water; or
- Ingestion of impacted soil, groundwater, or surface water.

An exposure pathway is complete when all four of these components are present: 1) a source and mechanism of chemical release; 2) a retention or transport medium (pathway); 3) an exposure point (i.e., a setting where potential human contact with the chemical -affected medium or media occurs); and 4) a route of exposure at the exposure point (e.g., ingestion, dermal, inhalation).

The land use at the property is commercial/industrial, and at the broader site is commercial/industrial, residential, and public open space. This exposure pathway evaluation, therefore, assesses potential pathways by which long-term commercial workers, short-term construction workers, visitors to the site and residents may be exposed to the predominant site COCs, PCE and TCE. This section evaluates whether the pathways are currently complete and if so, assesses the potential risk to receptors based on the concentrations of site COCs.

6.5.1 Conceptual Site Model

The impacts present at the 24th Street and Grand Canal WQARF site are suspected to be the direct result of releases of dry-cleaning solvents, primarily PCE, at the Former Carnation and Former McKean's facilities. **Figure 9** depicts the conceptual site model for 24th Street and Grand Canal WQARF site. This figure is intended to convey how the impacts originated beneath the Former Carnation and Former McKean's facilities, traveled through the vadose zone, and ultimately how the resultant groundwater plume has migrated to its current observed extent.

Figure 9 also indicates vadose zone impacts beneath the source of the COC releases. These are currently depicted in the conceptual site model; however, it is believed that

these impacts have been successfully remediated by SVE implementation as an ERA. The ERA activities are detailed in **Section 5** of this report.

Based on the assessment work completed, COCs from the Former Carnation and Former McKean's facilities traveled vertically until encountering groundwater at a depth of approximately 80 ft bgs. and then migrate downward until contacting a relatively consistent lean clay layer at approximately 103 ft bgs.

The COCs then migrated in a southwesterly direction while vertically migrating downward until contacting a relatively consistent lean clay layer at approximately 103 ft bgs. The lean clay layer appears to have restricted, vertical migration of COC impacts allowing the groundwater plume to stay relatively shallow as it continued to migrate in relatively coarse-grained geology. The resulting plume is approximately 5,000 ft long with most of its mass at a depth of less than 120 ft bgs. Past 5,000 ft, the COCs on the leading edge of the plume were below their applicable AWQS.

Also relevant to the site conceptual model is the presence of the Grand Canal and SRP well 16E-6.8N shown in **Figure 9**. Although the figure appears to indicate SRP well 16E-6.8N is directly adjacent to the groundwater plumes, it is located approximately 1,000 ft south of the current plume extents. As such, there is currently an incomplete groundwater pathway from the 24th Street and Grand Canal WQARF site to the Grand Canal, as COC impacts in the vicinity of SRP well 16E-6.8N do not exceed the drinking water AWQS. However, if pumping of SRP well 16E-6.8N was to increase in the future, the potential exists for COCs to be drawn toward the well could result in groundwater with COC concentrations above the applicable AWQS being pumped water into Grand Canal.

6.5.2 Vapor Pathway

Transport of vapor-phase COCs present in soil vapor to indoor air could result in exposure to human health risk via inhalation. Indoor air samples have not been collected from buildings at the Property. However, a site-specific HHRA was performed by Geosyntec on behalf of ADEQ to develop post-SVE depth-specific soil vapor Risk-Based Screening Levels (RBSLs) for the vapor intrusion pathway and to evaluate potential health risks for a commercial worker and for a future hypothetical resident of the Property (Geosyntec, 2018c). The vapor intrusion model estimates the current health risk based on concentrations of VOCs in soil vapor after implementation of SVE and attenuation factors to calculate potential indoor air concentrations that may result from vapor intrusion.

Two soil vapor sampling events were performed in 2017: one in August-September 2017 after SVE system shutdown ("Shutdown") and one in December 2017 ("Rebound"). Results of the 2017 soil vapor sampling events were reported in a 15 January 2018 technical memorandum (Geosyntec, 2018a) to ADEQ. The results from the Rebound soil vapor monitoring event were utilized for input into the HHRA. The HHRA was prepared using the latest USEPA RSLs and Johnson & Ettinger (J&E, 1991) subsurface vapor intrusion modeling (USEPA, 2017b), to develop depth-specific soil vapor RBSLs for indoor air quality. The potential for volatile contaminants of potential concern (COPC) to migrate from the subsurface into above-ground structures was evaluated using soil vapor data collected at the Property. Site COPCs were identified as analytes detected in one or more soil vapor samples collected from SVPs during the December 2017 Rebound sampling event (**Section 8**). Based on these data, the COPCs for the site are PCE, chloroform, m/p-xylenes, o-xylene, and toluene. Of these COPCs, only PCE is considered a site COC. The receptors that were evaluated in the HHRA for the vapor intrusion pathway included on-site future hypothetical residents and on-site current and future commercial workers.

Based on soil vapor investigation activities conducted at the property, soil vapor RBSLs were calculated for SVP depths of 5 and 15 ft bgs (RBSL-5 and RBSL-15, respectively). USEPA RSLs (USEPA, 2018c) for ambient air were used to derive the soil vapor RBSLs. The residential and commercial RSLs are based on a target cancer risk of 10^{-6} and a target noncancer hazard index of 1.0.

The cumulative cancer risk and cumulative noncancer hazard posed by the presence of multiple COPCs were estimated for each SVP location and at each sample depth (5 ft and 15 ft bgs). Using RBSLs based on attenuation factors derived using the USEPA v6 J&E model, in summary per the HHRA:

- The maximum cumulative cancer risk estimates for hypothetical residents and for commercial workers were $2x10^{-7}$ and $2x10^{-8}$, respectively, both based on the soil vapor sample from SG-01 at 15 ft bgs;
- The cumulative cancer risk estimates are less than the target risk of $1x10^{-6}$;
- The maximum cumulative noncancer HI estimates for hypothetical residents and commercial workers were $2x10^{-2}$ and $2x10^{-3}$, respectively, both based on the soil vapor sample from SG-05 at 5 ft bgs; and
- The cumulative noncancer HI estimates are less than the target hazard of 1.0.

The HHRA concluded that based on the current commercial use and future hypothetical residential use of the site, the concentrations of COPCs in soil vapor measured at SVPs SG-01 through SG-07 at depths of 5 ft and 15 ft bgs in December 2017 do not pose an unacceptable risk to site receptors. Results support a conclusion that no further action is required to address soil vapor COPC concentrations. As such, the SVE ERA is no longer warranted.

The transport mechanism for a soil vapor pathway is volatilization and vapor intrusion, and the secondary impacted media are indoor and outdoor air, as indicated in the attached exposure route pathways figure (**Figure 3**). Geosyntec's assessment is that the inhalation exposure route that could affect certain exposed receptors presents a potentially complete exposure pathway; however, the risk is less than the target risk for cancer or the target hazard index, and either has been or is currently being mitigated.

6.5.3 Soil Pathway

Limited soil sampling activities were conducted during initial site investigations at the Former Carnation/Former McKean's property. Reported historical PCE concentrations above the RSRL occurred at shallow depths (1.0 and 2.5 ft bgs). Reported PCE concentrations above the RSRL occurred at depth below barriers (i.e., concrete slabs, paved or asphalted surfaces) so they are inaccessible to direct contact by humans unless there is an excavation beneath the barrier. The land use for these properties is industrial/commercial. For a continued future industrial/commercial scenario, the soil direct contact pathway would remain incomplete.

The transport mechanisms for a soil pathway include excavation and fugitive dust (**Figure 3**). For excavation, the secondary impacted media is trench spoils. The dermal and incidental ingestion exposure route (to affect construction workers in contact with trench spoils) presents a potential exposure pathway. Limited soil sampling has been conducted on the property, and there are not recent results. However, soil vapor data collected during the final rebound event (discussed in **Section 5**) was used to estimate soil concentrations. The maximum reported concentration of PCE in soil vapor following the final rebound test was 1,390 µg/m^3. TCE in soil vapor was not reported above the applicable screening level. Using the ADEQ Soil Vapor Sampling Guide (ADEQ, 2011b) to relate the PCE soil vapor concentration to a soil concentration, Geosyntec calculated a soil PCE concentration of approximately 0.002 mg/kg, well below the PCE RSRL of 0.51

mg/kg. The results indicate that there is no unacceptable risk associated with residual CVOC soil impacts.

6.5.4 Groundwater Pathway

Possible exposure routes for VOC impacted groundwater include direct ingestion, inhalation, or dermal contact. Residential inhalation exposures to VOCs could occur from volatilization from water during activities such as showering, bathing, or washing. However, since the site is serviced by sewers and the public water supply, 24th Street and Grand Canal WQARF site groundwater is currently not used as a water supply. Potable use of groundwater is therefore not a complete pathway at the 24th Street and Grand Canal WQARF site. Several water supply wells that produce from the deeper portion of the aquifer are present in and adjacent to the site, as further discussed in **Section 7.3**. If these supply wells are utilized in the future for water supply, as discussed in **Section 7.4**, this exposure pathway would require re-evaluation.

The transport mechanism for a groundwater pathway is advection/dispersion and off-gassing/vapor intrusion; the secondary impacted media is indoor air (**Figure 3**). The indoor air inhalation exposure route presents a potentially complete exposure pathway from COCs off-gassing from groundwater, both on- and off-site, and associated vapor intrusion into indoor air; however, the risk is likely negligible and either has been or is currently being mitigated.

6.5.5 Surface Water Pathway

There are no points of natural discharge of groundwater to surface water within 1 mile of the site. The nearest surface water conveyance is the SRP Arizona Canal. Therefore, surface water is not a complete pathway at the site.

7. CURRENT AND FUTURE LAND AND WATER USE

Pursuant to A.A.C. R18-16-406 (A)(3) and (D), the scope of this RI includes the collection of information regarding current and reasonably foreseeable uses of land and/or waters of the state that have been or could be impacted by the release of site COCs, and projected time-frames for future changes in those uses. Reasonably foreseeable future land uses are those that are likely to occur at the site. Reasonably foreseeable future water uses are those that are likely to occur within 100 years unless a longer period is shown to be reasonable based on site-specific circumstances.

ADEQ prepared a standardized questionnaire requesting specific information regarding property, on-site wells, water use, and waste streams, and mailed it to municipalities and utilities in the site area. Responses were received from COP and SRP. Additional information was obtained from publicly available COP, SRP, and ADWR databases and/or documents. The Land and Water Use Report is included in **Appendix H**.

Evaluation of land and water uses took place as part of the draft RI Report public comment period; comments received are reflected in the Final Remedial Objectives (ROs) Report (**Appendix J**). The 30-day public comment period associated with the draft Proposed RO Report occurred subsequent to the draft RI report public comment period. The land and water use findings that are relevant to the ROs are summarized below.

7.1 Current Land Use

The site is located within the COP in Maricopa County. There are two villages impacted by the PCE plume: Camelback East Village and Encanto Village. The primary land use within the site is single family residential (38%), parks/open space (26%), multiple family residential (12%), commercial/industrial (12%), public/transportation (8%), and vacant (4%) (H+A, 2018a).

The Former Carnation/Former McKean's property is designated as C-2, Commercial–Intermediate Commercial.

7.2 Future Land Use

Requests for zoning changes must go through a public hearing and be approved by the City Council prior to finalization. According to the response received from COP, there are no current foreseeable plans to alter current zoning districts in the site vicinity.

According to the questionnaire response from the COP, there are no future zoning plans or area plans within the property boundary.

Grand Canalscape is a special project by COP being developed partly within the WQARF site. The Grand Canalscape project aims to create a nearly 12-mile continuous trail system along the Grand Canal from 1-17 to the Phoenix/Tempe border. Phase II, Segment Two of the project encompasses the Grand Canal section from 16th Street to 36th Street, which crosses the boundary. Phase II project improvements will include a hard surface trail along the north bank of the Grand Canal; it is planned for construction completion by spring of 2019 (http://www.grandcanalscape.com/).

7.3 Current Water Use

The site lies within the Phoenix AMA, one of the four original AMAs established by the 1980 Groundwater Management Code (the Code). The AMA is depicted in Figure F-5 in **Appendix H**. The Code set up a comprehensive management framework and established the ADWR to administer the Code's provisions. In accordance with the Code's provisions, a person must have a groundwater right or permit to pump groundwater legally, unless the person is withdrawing groundwater from an "exempt" well. A well is considered "exempt" if it has a maximum pump capacity of 35 gallons per minute (gpm) and "non-exempt" if its capacity exceeds 35 gpm. Within an AMA, water can be withdrawn from "non-exempt" wells under grandfathered rights, service area rights or withdrawal permits (ADWR, 2008). According to information supplied in the Land and Water Use Report (**Appendix H**) there are no grandfathered rights to groundwater at the site).

7.3.1 Non-Exempt Wells

A review of ADWR's registered withdrawal well records indicates that there are nine "non-exempt" withdrawal wells located within 1 mile of the estimated PCE plume boundary. Of these wells, six are owned by SRP, one is owned by COP, and the remainder appear to be owned by private entities. Well construction, ownership, and pump capacities are included in Table F-3 of the attached *Land and Water Use Report*, locations are depicted in Figure F-6, and ADWR well records are included in Appendix B of the attached *Land and Water Use Report*. The wells and usage are discussed by ownership below.

COP has indicated that recharge and recovery locations in the 2011 Water Resource Plan (WRP) are no longer accurate and that, as of the time of preparing this report, COP is in the process of revising the 2011 WRP. COP will provide ADEQ with a copy of the revised WRP as soon as it is published.

7.3.1.1 SRP

SRP provides surface water via deliveries from the Arizona Canal and Grand Canal through several lateral canals in the AMA. The site area receives water from the Arizona Canal and Grand Canal, which in turn receives water from SRP Well 16E-6.8N. Water from this SRP well is used for residential irrigation and discharges to the Grand Canal (Figure F-10 of **Appendix H**). The Arizona Canal, located approximately 1.75 miles to the northeast of the 24th Street and Grand Canal WQARF site, is the nearest surface water body. Groundwater typically comprises approximately 15% of the total water supplied by SRP to municipal treatment plants. The groundwater contribution varies seasonally with the highest contribution occurring March through August.

The land and water use evaluation was based on estimation of the extent of the PCE impacts specifically emanating from the property. According to SRP's 19 September 2017 questionnaire response, within the PCE plume boundary, SRP owns and operates water conveyance structures including the Grand Canal and groundwater supply well 16E-6.8N for its shareholders. In addition to SRP Well 16E-6.8N (**Figure 2**), SRP has multiple other groundwater supply wells in close proximity to the site. A total of seven groundwater supply wells are located within 1.25 miles of the source area PCE plume boundary, as depicted in Figure F-6 of the *Land and Water Use Report* (**Appendix H**). Of these wells, SRP provided the following status information and water quality data for wells that have shown elevated PCE or TCE levels since 1990:

- SRP Well 16E-6.8N (ADWR 55-607726) is active and located just south of the estimated plume, at the intersection of 24th Street and Grand Canal. It has a historical maximum PCE detection of 12 µg/L (2005), historical maximum TCE detection of 9.9 µg/L (2006), and in 2017, PCE and TCE were 4.1 µg/L and not detected above the laboratory RL, respectively;
- SRP Well 16E-8.0N (ADWR 55-607715) is active and located north of the estimated plume, at the corner of 24th Street and Indian School Road. It has a historical maximum PCE detection of 2 µg/L (1993), historical maximum TCE

detection of 0.6 µg/L (1999), and in 2017, PCE and TCE were 0.4 µg/L and not detected above the laboratory RL, respectively;

- SRP Well 16.9E-6.0N (ADWR 55-608380) is active and located at the corner of 32nd Street and East McDowell Road, south of the plume. It has a historical maximum PCE detection of 2.7 µg/L (2014), historical maximum TCE detection of 10 µg/L (2014), and in 2017, PCE and TCE concentrations were 1.2 µg/L and 6.2 µg/L, respectively;
- SRP Well 17.1E-7.4N (ADWR 55-607731) is active and east-northeast of the estimated plume. It has a historical maximum PCE detection of 5.8 µg/L (1990), TCE concentrations below laboratory RLs since 1990, and in 2017, PCE and TCE were 1.1 µg/L and not detected above the laboratory RL, respectively;
- SRP Well 17E-8.0N (ADWR 55-608431; **Figure 2**) is active and located northeast of the estimated plume, at the intersection of 32nd Street and Indian School Road. It has a historical maximum PCE detection of 82 µg/L (1996), historical maximum TCE detection of 1.5 µg/L (1996), and in 2017, PCE and TCE were 0.6 µg/L and not detected above the laboratory RL, respectively; and
- SRP Well 17.5E-7.0N (ADWR 55-607672) is inactive and located east of the estimated plume. No laboratory data was available.

As shown in **Table 6**, the reported concentrations of PCE in samples collected from SRP Well 16E-6.8N between 1990 and 2015 ranged from 1.20 µg/L to 12 µg/L.

7.3.1.2 City of Phoenix

The COP relies on four primary water supply sources: SRP, the Central Arizona Project (CAP) canal, groundwater pumped from COP wells, and reclaimed water. The non-exempt supply well owned by the COP (Coronado Park Well 55-626528) and located to the southwest of the PCE plume source area is not currently operating. It was installed for the adjacent Coronado Park at 12th Street and Coronado Street. As indicated in the COP questionnaire response, no active groundwater pumping by the COP occurs in or near the site. The City maintains this well and it is possible this well could be re-activated in the near future for municipal drinking water should severe drought conditions persist creating shortages of the City surface water supplies.

7.3.2 Exempt Wells

A review of ADWR's registered withdrawal well records indicates that there are four "exempt" withdrawal wells located within one mile of the PCE plume source area. Exempt wells refer to domestic wells with less than 35 gpm capacity, and this withdrawal is not a grandfathered right according to A.R.S. § 45-454. Water withdrawal from these wells are intended either for domestic irrigation or as a water source for cooling. There is no documented private drinking use of groundwater within the site (Table F-3, Figure F-6, and Attachment B in **Appendix H**).

7.4 Future Water Use

7.4.1 City of Phoenix

According to the *Land and Water Use Report*, several factors may impact the available COP water supply:

- Cyclical drought;
- Increasing demands in the Upper Colorado River Basin States (Utah, Colorado, Wyoming, and New Mexico) affecting Arizona's supply of Colorado River water;
- The availability of water supplies from the Arizona Water Banking Authority to the CAP to offset shortages;
- Climate variability impacts on long-term flows, reservoir storage and deliveries by SRP and CAP;
- The probability of low reservoir conditions occurring in both watersheds simultaneously;
- State legal, institutional, or policy changes impacting surface water availability;
- The availability and volume of groundwater supplies without aquifer replenishment; and
- Impacts of increased groundwater pumping in the SRP watershed on river flow and reservoir storage.

As a buffer to potential surface water supply reductions, the COP has been recharging to underground storage or banking unused CAP allotments for future use. These recharge and recovery locations are depicted in Figure F-8 in **Appendix H**, adapted from the

COP's 2002 General Plan, Water Resources Element. According to 10- and 20-year cyclical deficit scenarios adapted from the COP's 2011 Water Resources Plan, depicted in Figure F-9 in **Appendix H**, high demand coupled with severe SRP and CAP shortages could deplete these reserves by 2020 (H+A, 2018a).

Since local groundwater is an alternate water source for COP, planning is ongoing for the expansion of well capacity within the service area via well rehabilitation or the development of new service area wells (Appendix A in **Appendix H**).

As indicated in COP's questionnaire response, due to possible shortages of surface water supplies (CAP-Colorado River and SRP-Salt and Verde Rivers), the COP maintains an inventory of its active and inactive municipal water supply wells. When SRP and/or CAP water supplies are reduced, the COP supplements water supplies with groundwater pumped from COP wells. Inactive water supply wells such as the Coronado Park Well 55-626528 could be used in the future to augment supplies during a severe drought.

7.4.2 Salt River Project

According to SRP's 28 September 2017 questionnaire response (Attachment A in **Appendix H**), SRP anticipates its supply wells in the vicinity of the site will remain in use over the next 100 years. The SRP also responded with the following statement:

> *"Though SRP has no current plans to develop additional groundwater supplies within the ECP WQARF site, it is very likely they will be added in the future... To meet its water delivery needs SRP may elect to increase its groundwater use in close proximity to the WQARF site... SRP may do this by constructing additional groundwater supply wells or by connecting its existing water supply wells to direct municipal delivery to provide greater flexibility in its delivery operations."*

In addition, SRP responded that it is anticipating transitioning SRP-owned groundwater supply wells from irrigation to municipal service (potable supply). Additionally, it may become necessary in the future to construct additional groundwater supply wells near the ECP study area boundaries. SRP has also indicated that SRP groundwater production wells identified in SRP's 2017 Land and Water Use Study Questionnaire for Municipalities/Utilities within the East Central Phoenix (24th Street and Grand Canal) WQARF Registry Site (Questionnaire) dated September 19, 2017, will be located upstream of the City of Goodyear (Goodyear) water treatment plant (WTP) in the near future.

8. CONCLUSIONS

This section presents a summary of the interpretation of the findings of the RI activities and associated conclusions. Conclusions are provided separately for the vadose zone and groundwater. The effectiveness of ERAs implemented to date are also discussed.

8.1 Vadose Zone

Historical site characterization associated with the RI, as well as PIs, PAs, and ESAs, have demonstrated that the vadose zone was significantly impacted at the Former Carnation/Former McKean's property. Soil and soil vapor VOC impacts, primarily from PCE, have been observed. However, the vadose zone is considered to be fully characterized. Historical investigations and ongoing soil vapor monitoring using a network of dedicated SVPs and extraction wells have provided delineation of the VOC vadose zone impacts. The assessments have defined both the lateral and vertical extent of the impacts, with no vadose zone characterization data gaps noted.

Approximately two years of SVE remediation have effectively performed vadose zone cleanup, reducing soil vapor concentrations to below the site-specific cleanup goals, including during a rebound evaluation performed three months after final shutdown of the SVE system. Residual VOC concentrations do not pose unacceptable vapor intrusion risk under a residential site redevelopment scenario, which is significantly more conservative than the current commercial site use and exposure scenario.

8.2 Groundwater

8.2.1 Source Areas / Distribution Trends

The Former Carnation and Former McKean's dry-cleaning facilities that historically occupied the property appear to be the source of VOC impacts at the 24th Street and Grand Canal WQARF site. This determination was arrived upon after review of the numerous investigative studies completed at the 24th Street and Grand Canal WQARF site, combined with review of the data using Earth Volumetric Studio (EVS) software (C Tech, 2018). EVS modeling was conducted to improve the understanding of both the lithology and the distribution of PCE in groundwater at the ECP 24th Street and Grand Canal and 34th Street and Indian School Road WQARF sites.

The lithology model output, consisting of static cross-section images (**Figures 11** through **13**) and an interactive three-dimensional visualization image (**Figure 14**) was partly created from lithologic information provided in boring logs from 158 total borings advanced on-site by various consultants. United Soil Classification System soil classifications are grouped into five main lithologic types for the purposes of interpolation. The indicator Krig algorithm computes the most likely lithology for each model cell. A horizontal-to-vertical ratio (anisotropy) of 150 was used for the interpolation, dipping at 0.5 degrees to the southwest (225-degree bearing). These two values (anisotropy and direction) were determined experimentally by running various iterations and examining the connectivity of the units. Due to the sparseness of the boring log dataset, in some site areas the lithologies in the model were interpolated using data mainly from one or two borings. **Figures 12** and **13** show the cross sections through the lithologic model, and **Figure 11** shows the lines of section (in plan view).

The chemical impact volumetric model for PCE was interpolated in EVS using the Krig algorithm using concentrations from 28 groundwater monitoring wells sampled from November 2016 through August 2018 **(Figure 14)**. Concentrations were averaged for locations sampled more than once during this period. Non-detect results and results that were less than the laboratory RL were replaced with a value one-tenth of the RL. A horizontal-to-vertical ratio (anisotropy) of 52 was used with a directional anisotropy of 6 in the southwest direction (233-degree bearing) at a dip angle of 1.25 degrees to account for the groundwater gradient. These values were derived using professional judgement. The PCE impact volumetric models, coupled with the lithology model, were used to improve the understanding of subsurface conditions and the conceptual site model.

8.2.2 General Distribution Trend

Based on data collected in 2017 and 2018, the COC suspected source concentrations begin within generally lower permeability material at the Former Carnation/Former McKean's property. COCs historically migrated vertically through the vadose zone through relatively low permeability geology until they reached approximately 75 ft bgs. COCs then migrated through sandy silt, and silty gravel until they reached groundwater approximately 80 ft bgs. The COCs then migrated in a southwesterly direction while vertically migrating downward until contacting a relatively consistent lean clay layer at approximately 103 ft bgs. The lean clay layer appears to have restricted, vertical migration of COC impacts allowing the groundwater plume to stay relatively shallow as

it continued to migrate. The resulting plume is approximately 5,000 ft long with most of its mass at a depth of less than 120 ft bgs **(Figure 13)**.

When examining the extent of PCE impacts two-dimensionally in plan view, as shown by the PCE groundwater isoconcentration map (**Figure 9**), there appears to be an interaction (overlap) of the PCE plumes associated with the WQARF site and the PCE impacts to groundwater associated with the 32nd Street and Indian School Road WQARF site. The two plumes, however, are discrete, separate plumes traveling alongside each other and at different vertical elevations, with the plume associated with the 24th Street and Grand Canal WQARF site being shallower and located to the south. The independence of these plumes is shown in Geologic Cross Section B-B' (**Figure 13**) and in the three-dimensional EVS visualization of PCE impacts (**Figure 14)**. Groundwater COC impacts, exclusively PCE, at concentrations above 5 µg/L are limited to a plume originating at the Former Carnation/Former McKean's property, extending downgradient approximately 5,000 ft in a southwesterly direction.

Groundwater COC impacts, exclusively PCE, at concentrations above 10 µg/L are limited to a plume originating at the Former Carnation/Former McKean's property, extending downgradient approximately 3,500 ft in a southwesterly direction.

Groundwater COC impacts, primarily PCE, at concentrations above 20 µg/L are limited to a plume originating at the Former Carnation and Former McKean's dry-cleaning facilities, extending downgradient approximately 1,500 ft in a southwesterly direction.

Groundwater COC impacts, PCE, at concentrations above 100 µg/L are limited to a plume originating at the Former Carnation and Former McKean's dry-cleaning facilities, extending downgradient approximately 500 ft in a southwesterly direction.

Since 2016, TCE concentrations in groundwater above 5 µg/L (maximum concentration of 7.6 µg/L at a depth of 240 ft bgs) were limited to data collected by the Hydropunch™ method during the drilling of one location (VCMW-20) in December of 2016. This would suggest that TCE impacts associated with the Former Carnation and Former McKean's dry-cleaning facilities have been naturally attenuating over time.

In 2002, cis-1,2-DCE was detected above the AWQS at a maximum concentration of 250 µg/L in monitoring well UMW-01. In 2006, cis-1,2-DCE was detected above the AWQS at a maximum concentration of 270 µg/L in monitoring well UMW-09. Since 2006, no groundwater samples have been collected that have shown exceedances of

cis-1,2-DCE above the AWQS. This suggests that cis-1,2-DCE impacts to groundwater associated with the Former Carnation and Former McKean's dry-cleaning facilities have been naturally attenuating over time.

No other COCs have been detected in groundwater above AWQS.

Groundwater impacted from previous vadose zone sources have advected hydraulically downgradient. SVE implementation beneath the former dry-cleaner businesses effectively remediated vadose zone impacts in these areas, thereby mitigating ongoing impacts to groundwater. The current groundwater monitoring network is sufficient to fully delineate the PCE plume.

It is expected that the extent of the groundwater PCE plume will continue to migrate and expand unless remedial action to address groundwater impacts is implemented. Plume expansion may also be accelerated in future years if SRP and COP further develop their groundwater extraction well network and pumping capacities in the region.

8.2.3 Possible Additional Sources

Review of the historical groundwater data and the EVS PCE visualization model do not appear to suggest additional, unidentified sources of PCE downgradient of the Former Carnation and Former McKean's dry-cleaning facilities, the 24th Street and Grand Canal WQARF site primary suspected source area.

8.3 Final RI Document

This Final RI Report includes two documents that were related to the public comment period for the draft version of the report. The Final Remedial Objectives (RO) Report is presented in Appendix J. The Responsiveness Summary Report that discusses the public comments received is included in Appendix K.

9. DATA GAPS

Petroleum hydrocarbon impacts that were identified during the completion of the ERA at the Site should be delineated back to their original source area. It should be noted that these impacts are not associated with the Former Carnation and Former McKean's dry-cleaning facilities.

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11. LIMITATIONS

This remedial investigation was performed according to an agreed upon scope of work and does not represent an exhaustive investigation of all potential environmental impacts at the 24th Street and Grand Canal WQARF site. The findings of this report, to the best of our knowledge, are valid as of the date the work was performed. However, changes in the conditions of a site can occur with the passage of time, whether due to natural processes or the works of man on the 24th Street and Grand Canal WQARF site or adjacent properties. In addition, changes in applicable or appropriate regulations and standards may occur, whether they result from legislation, from the broadening of knowledge, or from other reasons. The work was performed using the degree of care and skill ordinarily exercised under similar circumstances by environmental consultants practicing in this or similar localities. No other warranty or guarantee, expressed or implied, is made as to the findings, opinions, conclusions, and recommendations included in this report.