PROPOSED REMEDIAL ACTION PLAN

BROADWAY PANTANO
WATER QUALITY ASSURANCE REVOLVING FUND SITE

TUCSON, ARIZONA

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Table of Contents

1.0 INTRODUCTION 1

2.0 SITE BOUNDARIES 2

3.0 REMEDIAL INVESTIGATION RESULTS 3

3.1 Site History and Description 3

3.1.1 Broadway North Landfill 3

3.1.2 Broadway South Landfill 4

3.2 Source of Contamination 4

3.3 Contaminants of Concern 5

3.3.1 Groundwater 5

3.3.2 Soil 5

3.3.3 Other Compounds 5

3.4 Nature and Extent of Contamination 5

3.5 Risk Evaluation Summary 5

3.6 Remedial Objectives 6

4.0 FEASIBILITY STUDY RESULTS 7

4.1 Identification and Screening of Remedial Technologies 7

4.2 Development of the Reference Remedy and Alternative Remedies 7

4.2.1 Reference Remedy 8

4.2.2 Less Aggressive Remedy 8

4.2.3 More Aggressive Remedy 9

4.3 Evaluation and Comparison of the Remedies 9

4.4 Proposed Remedy 9

5.0 EARLY RESPONSE ACTIONS 10

6.0 PROPOSED REMEDY AND ESTIMATED COST 11

6.1 Remedy Description 11

6.1.1 Proposed Remedial Action – Soil 11

6.1.2 Proposed Remedial Action - Groundwater 11

6.1.3 Proposed Contingencies 12

6.1.4 Inspections, Performance Monitoring, and Periodic Reviews 14

6.2 Estimated Cost 15

6.3 Duration 15

7.0 CONSIDERATION OF REMEDIATION GOALS AND SELECTION FACTORS 17

7.1 Rationale for Selection of the Remedy 17

7.2 Achievement of Remedial Objectives 17

7.3 Achievement of Remedial Action Criteria 18

7.4 Consistency with Water Management Plans 18

7.5 Consistency with General Land Use Planning 18

7.6 Lead Agency Statement for Proposed Remedy 18

7.7 Uncertainties 18

7.8 Public Comment Period 19

8.0 REFERENCES 20

Tables

Table 1 Summary of Remedial Alternatives
Table 2 Summary of Costs for Proposed Remedy

Figures

Figure 1 Site Location Map
Figure 2 Site Detail Map
Figure 3 Estimated Extent of Groundwater PCE- Plume, February – March 2016
Figure 4 Estimated Extent of Groundwater TCE Plume, February – March 2016
Figure 5 Asphalt Cap Construction Details
Figure 6 Soil Vapor Extraction (SVE) System Layout
Figure 7 In-Situ Chemical Oxidation (ISCO) System Layout and Well Locations

Appendices

Appendix A Detailed Cost Summary

Acronyms

A.A.C.	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
AWQS	Aquifer Water Quality Standard
A.R.S.	Arizona Revised Statute
BNL	Broadway North Landfill
BSL	Broadway South Landfill
CAB	Community Advisory Board
COC	Contaminant(s) of Concern
DEUR	Declaration of Environmental Use Restriction
DCE	Dichloroethene
ERA	Early Response Action(s)
FS	Feasibility Study
GPM	Gallons per Minute
ISCO	In-Situ Chemical Oxidation
LGAC	Liquid Phase Granular Activated Carbon
LOU	Landfill Operable Unit
MCL	Maximum Contaminant Level(s)
µg/L	Micrograms per Liter
MNA	Monitored Natural Attenuation
PCE	Tetrachloroethene
PRAP	Proposed Remedial Action Plan
RO	Remedial Objective(s)
ROD	Record of Decision
SVE	Soil Vapor Extraction
TCE	Trichloroethene
TEP	Tucson Electric Power
VGAC	Vapor Phase Granular Activated Carbon
VOC	Volatile Organic Compound(s)
WCS	Western Containment System Groundwater Treatment System
WQARF	Water Quality Assurance Revolving Fund
ZVI	Zero-Valent Iron

1.0 INTRODUCTION

The Arizona Department of Environmental Quality (ADEQ) prepared this Proposed Remedial Action Plan (PRAP) for the Broadway Pantano Water Quality Assurance Revolving Fund (WQARF) Site (Site), located in Tucson, Arizona (Figure 1). This PRAP was prepared in accordance with Arizona Revised Statute (A.R.S.) Section (§) 49-287.04 and Arizona Administrative Code (A.A.C.) R18-16-408. The PRAP is based on information contained in the following documents:

- *Remedial Investigation Report, Groundwater Operable Unit, Arizona Department of Environmental Quality, Broadway-Pantano Water Quality Assurance Revolving Fund Registry Site, Tucson, Arizona* (Stantec, 2012)

- *Final Remedial Investigation Report, Broadway-Pantano WQARF Site, Landfill Operable Unit, Tucson, Arizona* (Clear Creek, 2015*)*

- *Final Feasibility Study, Broadway Pantano Water Quality Assurance Revolving Fund Site, Tucson, Arizona* (AMEC, 2017)

The information presented in the PRAP is taken directly from the above-referenced reports without attribution other than that noted in this document. The detailed history of environmental investigations, Early Response Actions (ERAs), and preliminary screening of remedial alternatives completed for the Site is presented in the referenced documents and is not reiterated in detail in this document.

The purpose of the PRAP is to inform the public on the remedy selected from the alternatives evaluation presented in the Feasibility Study (FS), which addresses the site-specific Remedial Objectives (ROs). The PRAP is part of the final remedy selection process under the WQARF program where public input is solicited on the selected remedy and on the rationale for proposing the selected remedy. ADEQ will review the public comments and prepare a responsiveness summary to address the public comments. The responsiveness summary will be part of the Record of Decision (ROD). The remedy for the Site will be finalized by ADEQ in the ROD.

This PRAP, in accordance with A.R.S. §49-287.04, describes the following:

- The boundaries of the Site that is the subject of the remedial action.

- The results of the Remedial Investigation and the FS.

- The proposed remedy and estimated cost.

- How the remediation goals and selection factors in A.R.S. §49-282.06 and rules adopted by the ADEQ Director have been considered.

2.0 SITE BOUNDARIES

The boundaries of the Site subject to remedial action include the area located between Speedway Boulevard to the north, Pantano Wash to the east, 22nd Street to the south, and Craycroft Road to the west in Tucson, Arizona (Figures 1 and 2). The Site includes the closed Broadway North Landfill (BNL), the closed Broadway South Landfill (BSL), and the area that encompasses the current groundwater plume impacted with volatile organic compounds (VOCs).

3.0 REMEDIAL INVESTIGATION RESULTS

This section presents a summary of the remedial investigations conducted at the Site. The results of the remedial investigations are presented in the following documents:

- *Remedial Investigation Report, Groundwater Operable Unit, Arizona Department of Environmental Quality, Broadway-Pantano Water Quality Assurance Revolving Fund Registry Site, Tucson, Arizona* (Stantec, 2012)

- *Final Remedial Investigation Report, Broadway-Pantano WQARF Site, Landfill Operable Unit, Tucson, Arizona* (Clear Creek, *2015)*

3.1 Site History and Description

The BNL and BSL were identified as the potential sources of contamination at the Site. The BNL and BSL are unlined landfills constructed before federal regulations were established to regulate the management of non-hazardous municipal solid waste. A brief description of each landfill is presented below.

3.1.1 Broadway North Landfill

Beginning in the mid-1940s, the area currently occupied by the BNL was used for sand and gravel mining operations. The former gravel pits at the BNL were filled with municipal, agricultural, commercial, construction, and industrial waste between approximately 1959 and 1972.

The BNL and the parcels on which it is located are generally undeveloped and unoccupied (Figure 2). The waste placement areas at the BNL are currently bordered by a perimeter fence on the southern and western boundaries of the landfill (adjacent to off-site residential areas). The waste is currently covered with a soil cover and the cover is currently in good condition. Native vegetation is present over most of the landfill extent.

The BNL includes three separate waste areas as shown by Figure 2.

- Northern Area: The northern landfill area is comprised of fourteen acres and is located north of the 5th Street alignment and east of the Tucson Electric Power (TEP) power substation. Waste was placed in this area at thicknesses ranging from approximately 10 to 30 feet. The soil cover thickness in this area ranges from approximately one to 10 feet thick.

- Middle Area: The middle landfill area is comprised of 65 acres and is located between the northern and southern areas of the BNL. Waste was placed in this area at thicknesses ranging from less than one foot to 24 feet. The soil cover thickness in this area ranges from less than one to 14 feet.

- Southern Area: The southern landfill area is a construction debris waste area located north of Broadway Boulevard. The thickness of this waste ranges from less than one foot to 20 feet. The soil cover thickness in this area is less than 1.5 feet. Dross material (a metallic waste of unknown origin) was identified in a portion of the construction debris waste area during an effort to redevelop the property in the mid-1990s (Figure 2). The thickness of the dross material ranges from a few inches to a few feet. The southern portion of the construction debris waste area has been developed into the Broadway Star Plaza (a retail shopping strip mall).

The property owner currently operates a methane mitigation system at the BNL under the direction of the City of Tucson.

3.1.2 Broadway South Landfill

Prior to 1953, the BSL property was used for agriculture and then leased for sand and gravel operations. The BSL was operated from approximately 1953 to 1962. Landfilling at the BSL progressed from north to south. The BSL was filled with municipal, agricultural, commercial, construction, and industrial waste. The BSL was filled by 1958 and covered by 1962. The thickness of the waste is variable and ranges from approximately 0.5 to 30 feet. The soil cover over the waste ranges in thickness from approximately 0.5 to 10 feet. The BSL landfill soil cover is currently in good condition. The undeveloped portions of the landfill are covered with native vegetation.

Portions of the BSL have been developed since the closure of the landfill. The northern portion of the BSL includes a Culver's restaurant and a Hilton Hotel. The southern portion of the BSL includes portions of Broadway Proper (a retirement community) and Gollob Park.

A methane mitigation system was installed at the BSL in 1986 (Clear Creek, 2015a). The methane mitigation system is operated and maintained by the property owner under the direction of the City of Tucson. Additionally, the Hilton Hotel and the Broadway Proper buildings are equipped with methane sensor/alarm devices.

3.2 Source of Contamination

Data collected during the remedial investigation indicate that contaminant releases occurred in soil and groundwater at the Site. These data identified two sources of contamination including:

- VOCs in the landfill waste at the BNL and BSL which impacted soil and groundwater; and

- Metals in the dross material landfilled at the BNL which impacted the soil within the dross area at the Site (Figure 2).

The landfill waste and dross remain at the Site and may pose a risk to current or future receptors.

3.3 Contaminants of Concern

The Contaminants of Concern (COCs) at the Site include compounds that have been detected above regulatory levels.

3.3.1 Groundwater

The COCs in the groundwater at the Site include tetrachloroethene (PCE), trichloroethene (TCE), vinyl chloride, methylene chloride, and dichloroethene (DCE). These contaminants have been detected at concentrations at or above regulatory levels in groundwater at the Site. Currently, only PCE and TCE are present in the groundwater at concentrations that exceed the Aquifer Water Quality Standard (AWQS).

3.3.2 Soil

The COCs in soil at the Site include VOCs and metals (arsenic, cadmium, and lead). The metals are located within the dross area at the BNL (Figure 2). Currently, only the metals within the dross area have been detected in the soils at concentrations that exceed the Arizona soil cleanup standards.

3.3.3 Other Compounds

Other chemicals that have periodically been detected at concentrations above applicable regulatory standards at the Site include 1,2-dichloroethane, 1,2-dichloropropane, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, benzene, chloroform, ethylbenzene, and Freon 12. None of these compounds are considered COCs at the Site.

3.4 Nature and Extent of Contamination

The predominant COC at the Site is PCE. The lateral distribution of the PCE in groundwater defines the extent of VOC contamination at the Site. The current estimated extent of PCE in groundwater at concentrations exceeding the AWQS (5 micrograms per liter [µg/L]) is presented on Figure 3. The only other COC currently present in groundwater at concentrations exceeding the AWQS is TCE (Figure 4). The maximum PCE and TCE concentrations currently detected in the groundwater are 120 µg/L and 35 µg/L, respectively. The groundwater data indicate that the upper 80 to 100 feet of the aquifer are impacted with VOCs.

In addition to the VOC contamination at the Site, landfill waste (dross material) containing high concentrations of metals has been identified at the Site. This waste is limited to near surface soils located in the southern portion of the BNL (Figure 2).

3.5 Risk Evaluation Summary

Multiple investigations have been conducted at the Site since VOCs were initially detected in the groundwater at the BNL in 1983. The data from these investigations were used to evaluate the risks that

the soil, soil vapor, and groundwater pose to the public and the environment. The risk evaluations indicate there is no current human health risk from soil, soil vapor, or groundwater contamination.

3.6 Remedial Objectives

The results of the Remedial Investigation, including the Land and Water Use Study, were used to develop the ROs for remediation at the Site pursuant to A.A.C. R18-16-406.

The ROs for land use at the Site are as follows:

- ***Residential***: The RO for existing and future residential use of Landfill Operable Unit (LOU) properties is to protect against exposure to COCs within or released from the LOU waste. This action is needed at the present time and for as long as the landfilled and dross wastes remain at the property (Clear Creek, 2015a).

- ***Non-Residential***: The RO for existing and future non-residential use of LOU properties is to protect against exposure to COCs within or released from the LOU waste. This action is needed at the present time and for as long as the landfilled and dross wastes remains at the property (Clear Creek, 2015a).

The LOU was defined in the Final Remedial Investigation Report (Clear Creek, 2015) as the closed BNL, the closed BSL, and the vadose zone directly beneath and in close proximity to the BNL and BSL boundaries. The boundaries of the BNL and BSL are presented on Figure 2.

The ROs for groundwater use at the Site are as follows:

- ***Potable Water***: The groundwater RO is to restore, replace or otherwise provide for the current and future potable use of the regional aquifer threatened or impacted by PCE, TCE, and vinyl chloride contamination emanating from the WQARF Site. “Potable” is defined here as water which meets state and federal primary drinking water standards (a.k.a. Maximum Contaminant Levels [MCLs]) and Arizona AWQS. This action is needed for as long as the level of contamination in the groundwater resource prohibits its use as a potable water supply (ADEQ, 2012).

- ***Non-Potable Water***: The groundwater RO is to protect for the future non-potable use of the regional aquifer threatened by PCE, TCE, and vinyl chloride contamination emanating from the WQARF Site. “Non-potable” is defined here as water which is not required to meet state and federal primary drinking water standards (a.k.a. MCLs) and Arizona AWQSs. This action is needed for the present time and for as long as the level of contamination in the groundwater resource threatens its use as a non-potable water supply (ADEQ, 2012).

There are no ROs needed for surface water because there are no appreciable surface waters within the boundaries of the Site and no anticipated future surface water use within the area of the Site.

4.0 FEASIBILITY STUDY RESULTS

This section presents a summary of the FS conducted for the Site. The results of the FS are presented in the following document:

- *Final Feasibility Study, Broadway Pantano Water Quality Assurance Revolving Fund Site, Tucson, Arizona* (AMEC, 2017)

4.1 Identification and Screening of Remedial Technologies

The FS identified several remedial technologies for addressing the soil and groundwater contamination at Site including Institutional Controls, Engineering Controls, Inspections and Environmental Sampling, Monitored Natural Attenuation (MNA), Soil Vapor Extraction (SVE), In-Situ Biological Reduction, In-Situ Thermal Remediation, In-Situ Chemical Oxidation (ISCO), In-Situ Chemical Reduction with a zero-valent iron (ZVI) Permeable Reactive Barrier, Groundwater Pump and Treat, Wellhead Treatment, and Replacement Water Supply.

These remedial technologies were screened based on the anticipated ability of the technology to address the ROs at the Site and reduce the contaminant concentration, mass, and/or toxicity. Each technology was screened for effectiveness, implementability, health and safety concerns, flexibility, expandability, and cost. Based on the screening results, Institutional Controls, Engineering Controls, Inspections and Environmental Monitoring, MNA, SVE, ISCO, Groundwater Pump and Treat, Wellhead Treatment, and Replacement Water Supply were retained for use at the Site.

4.2 Development of the Reference Remedy and Alternative Remedies

The retained remedial technologies were used to develop a reference remedy and two alternative remedies (a less aggressive remedy and a more aggressive remedy). The reference remedy and the alternative remedies are capable of achieving the ROs. The development of the reference remedy and alternative remedies considered the following:

- The data obtained from the remedial investigations;
- The best available engineering and scientific information concerning available remedial technologies; and
- Preliminary analysis of the comparison criteria and the ability of the remedies to comply with A.R.S. §49-282.06.

4.2.1 Reference Remedy

The Reference Remedy includes a combination of remedial technologies for source control, the remediation of soil, and the remediation of groundwater including the following:

- **Engineering Controls** – The existing landfill cover and development caps (i.e., asphalt parking lots, buildings, sidewalks, etc.) to control direct exposure to the landfill waste and an asphalt cap for the dross area to control direct exposure to the dross.

- **Institutional Controls** – Declaration of Environmental Use Restriction (DEUR) to be placed on the parcels where the landfill waste is present to ensure current and future property uses are protective of potential receptors and to ensure the Engineering Controls are properly managed and maintained.

- **MNA** – MNA would include groundwater monitoring and sampling to monitor the natural degradation of the groundwater contamination at the Site.

- **Inspections and Environmental Sampling** – Inspections and sampling would be conducted to confirm the Engineering Controls continue to limit exposure to the landfill waste and to evaluate the performance of the SVE and ISCO.

- **SVE** – SVE would remediate the soil contamination present in the vadose zone at the BSL that is a source of groundwater contamination.

- **ISCO** – ISCO would remediate the groundwater contamination present at the BNL to mitigate the down-gradient migration of groundwater contamination.

- **Wellhead Treatment (Contingency)** – Wellhead treatment would be a contingency to treat impacted groundwater that is withdrawn from the aquifer from a drinking water well.

- **Replacement Water Supply (Contingency)** – This is an alternative to wellhead treatment and would be implemented for a small, private drinking water well (production rate of less than 35 gallons per minute [gpm]) if the groundwater withdrawn from the well becomes impacted.

4.2.2 Less Aggressive Remedy

The Less Aggressive Remedy is similar to the Reference Remedy. The Less Aggressive Remedy includes all of the technologies proposed for the Reference Remedy except ISCO.

4.2.3 More Aggressive Remedy

The More Aggressive Remedy is similar to the Reference Remedy. The More Aggressive Remedy includes all the remedial technologies proposed for the Reference Remedy plus Groundwater Pump and Treat. The Groundwater Pump and Treat technology would include remediation of the groundwater plume using a combination of existing and proposed extraction and injection wells as well as restarting the existing Western Containment System (WCS).

4.3 Evaluation and Comparison of the Remedies

A comparative evaluation was conducted for the Reference, Less Aggressive, and More Aggressive Remedies to demonstrate that each remedial alternative will achieve the ROs in accordance with A.A.C. R18-16-407(H). The criteria used to evaluate each remedial alternative included practicability, risk, cost, and benefit. A summary of the evaluation for each remedial alternative is presented in Table 1.

Table 1 - Summary of Remedial Alternatives

Alternative	Practicability	Risk	Cost*	Benefit
Reference Remedy	• Moderately Feasible • Moderately Implementable • Potentially Effective • Potentially Long Duration (>30 Years)	• Highly Impacted by Changing Conditions • Some Potential Risk	$126.4M	• Protects Water Supply • ISCO Decreases Uncertainty of Mass Retained in Landfill
Less Aggressive Remedy	• Moderately Feasible • Moderately Implementable • Potentially Effective • Potentially Long Duration (>30 Years)	• Highly Impacted by Changing Conditions • Some Potential Risk	$178.6M	• Protects Water Supply
More Aggressive Remedy	• Moderately Feasible • Least Implementable • Likely Effective • Clean-Up Duration of 29 Years	• Highly Impacted by Changing Conditions • Some Potential Risk	$27.4M	• Protects Water Supply • ISCO Decreases Uncertainty of Mass Retained in Landfill

Notes:
*The costs include 3% Inflation.
The costs presented in this table were taken directly from the FS Report.

4.4 Proposed Remedy

The remedy proposed by the FS for the Site was the More Aggressive Remedy. The More Aggressive Remedy was proposed because it was found to be the most effective, to have the least amount of risk, to be the most beneficial, and to be the least expensive to implement. The More Aggressive Remedy was

proposed because it will achieve the ROs, it meets the remedial action criteria pursuant to A.R.S. §49-282.06, and it is consistent with current and future land and water use.

5.0 EARLY RESPONSE ACTIONS

The following ERAs were performed at the Site to remove contamination at the Site and/or to mitigate the exposure of the contamination to potential receptors:

- Source removal was implemented at the BNL using soil vapor extraction/air injection to remove soil gas impacted with VOCs. This system removed over 5,300 pounds of VOCs between June 2000 and September 2002. It was shut down after multiple rebound tests showed no appreciable rebound of VOCs in the vadose zone at the BNL.

- The WCS was constructed and operated to contain the PCE groundwater plume associated with the BNL. The WCS operated from March 2003 until October 2012. The WCS was shut down due to influent PCE concentrations that were below the AWQS (Clear Creek, 2015).

- A wellhead treatment system was operated at the St. Joseph Hospital water production well (411-P) to treat groundwater impacted with PCE. The system was operated from 1997 to 2009. The system was shut down due to well corrosion and sanding problems (Clear Creek, 2015). The well and wellhead treatment system are currently offline.

- In the spring of 2019, an asphalt cap was installed in the northern portion of the dross area to mitigate the exposure of the dross materials to human and environmental receptors (ADEQ, 2018 and Wood, 2019b). The as-built construction details of the cap are presented on Figure 5. The asphalt cap replaced the temporary soil cover and fence previously installed at the dross area.

- In the spring of 2019, a SVE system was installed at the BSL to remediate elevated VOC concentrations in the soil vapor that are a source of groundwater contamination (ADEQ, 2018b). The SVE system layout is presented on Figure 6. The components of the SVE system include eight SVE wells (SVE-01 through SVE-04 and VMP-01 through VMP-04) that will serve as either vapor extraction or monitoring wells, temporary piping, a SVE blower with temporary power, and vapor phase granular activated carbon (VGAC) for treatment of the extracted vapors.

- In the spring of 2019, an in-situ ISCO remediation system was installed to remediate the elevated VOC concentrations in the groundwater at the BNL (ADEQ, 2018a, Wood, 2019, and Wood, 2019a). The system uses a recirculation system to extract groundwater from two extraction wells, treat the extracted water with an oxidizing agent, and inject the treated groundwater back into the aquifer using injection wells. The system layout is presented on Figure 7. The system includes two extraction wells, six injection wells, and a secure treatment compound to store and meter the oxidant.

6.0 PROPOSED REMEDY AND ESTIMATED COST

The More Aggressive Remedy proposed in the FS is the remedial alternative proposed in the PRAP. This section presents a description of the remedy and the estimated cost of the remedy.

6.1 Remedy Description

The proposed remedy includes a combination of remedial technologies for remediating the soil and groundwater at the Site. Each of these remedial technologies is described in the following subsections.

6.1.1 Proposed Remedial Action – Soil

Engineering Controls

The existing landfill soil cover, development caps (i.e., asphalt parking lots, buildings, sidewalks, etc.), and asphalt cap over the dross area will be incorporated into the remedy to control exposure to the landfill waste and the dross material. The existing engineering controls created a barrier that will mitigate the exposure of the landfill waste and dross materials to human and environmental receptors. The property owner(s) will operate and maintain the engineering controls (i.e., landfill soil cover and asphalt cap) for perpetuity or until the property is developed.

Institutional Controls

A Declaration of Environmental Use Restriction (DEUR) will be placed on each parcel where landfilled waste or dross is present to ensure that current and future property uses are protective of potential receptors and that the engineering controls are properly managed, maintained, and inspected. New water supply well installation will also be limited within the WQARF Site pursuant to A.R.S. § 45-454(C). As of the date of this PRAP, DEURs are in process for 10 of the 13 BNL parcels that contain landfill waste and DEURs are in place for two of the 11 BSL parcels that contain landfill waste. The costs associated with obtaining and maintaining the DEURs will be the responsibility of the property owner(s).

Soil Vapor Extraction at the BSL

The operation of the SVE system installed at the BSL as an ERA in 2019 will be incorporated into the remedy to remediate the elevated VOC concentrations in the soil vapor that are a source of groundwater contamination. The SVE system will be operated for a period of up to one year. The remedy includes a contingency to operate the SVE system up to four additional years as warranted by the VOC concentrations in the vadose zone. ADEQ will oversee the operation of the SVE system.

6.1.2 Proposed Remedial Action - Groundwater

ISCO at the BNL

The operation of the ISCO system installed at the BNL as an ERA in 2019 will be incorporated into the remedy to remediate the elevated VOC concentrations in groundwater at the BNL. ISCO includes the injection of oxidizing agents directly into the subsurface to degrade contamination. These reagents

increase the oxidation state of certain materials converting them from hazardous to non-hazardous or less toxic compounds.

A groundwater recirculation system enhanced with an ISCO amendment will be used to target the elevated PCE groundwater concentrations at the BNL. In general, the recirculation strategy will involve extracting groundwater from two extraction wells, treating the extracted groundwater with an ISCO amendment, and injecting the treated groundwater back into the subsurface using the injection wells (Figure 7). Each extraction and injection well will be operating at approximately 40 gpm. The ISCO recirculation system will operate for a period of up to seven years in order to achieve three circulations of groundwater in the target treatment area and promote the effective distribution of the oxidant. ADEQ will oversee the operation of the ISCO injection and recirculation system.

MNA

MNA is a remedial measure that involves routine groundwater sampling and analysis to monitor the results of one or more naturally occurring physical, chemical, or biological processes that reduce the mass, toxicity, volume, or concentration of chemicals in groundwater. MNA is a mechanism by which COCs are reduced by natural means without other control, removal, treatment, or aquifer-modifying activities. These in-situ processes may include dilution, adsorption, volatilization, precipitation, and biological degradation of the contaminants in the groundwater. Of these processes, reductive dechlorination (using biological and/or abiotic degradation processes) is usually the most significant degradation process for chlorinated solvents such as the COCs.

MNA will consist of routine groundwater monitoring and sampling to monitor groundwater contamination at the Site. The groundwater monitoring data will be used to evaluate plume migration, plume stability, and natural attenuation of the plume. The data will also be used to trigger appropriate contingency actions (i.e., wellhead treatment at an impacted water supply well) to manage risk associated with the groundwater plume migration. MNA will continue until the concentrations of the COCs drop below the AWQS.

The MNA program will be conducted at the Site for a period up to 30 years. The program will include bi-annual water level monitoring of up to 70 wells; groundwater sampling of up to 16 semi-annual wells, 23 annual wells, and 28 bi-annual wells; and annual reporting. The number of wells to be monitored and the frequency of monitoring will be adjusted over time in response to changing groundwater conditions. At a minimum, the number of wells and the frequency of monitoring will be evaluated and updated every five years. ADEQ will oversee the MNA program.

6.1.3 Proposed Contingencies

Groundwater Pump and Treat

Groundwater pump and treat systems remediate contaminated groundwater through extraction, treatment of the water at the surface, and then either discharge to an appropriate end user or reinjection of the treated groundwater back into the aquifer. When the extraction wells are properly located, this

approach has the advantage of creating a capture zone which contains and prevents the contamination from migrating.

Groundwater pump and treat was proposed in the FS (AMEC, 2017) as a component of the More Aggressive Remedy. Additional evaluation by ADEQ identified several concerns with the pump and treat component of the More Aggressive Remedy that could delay the implementation of the remedy and/or increase the cost of the remedy. These concerns included the following:

- The feasibility and cost of installing over 14,500 feet of underground pipeline needed to transport impacted groundwater from the proposed extraction wells to the treatment system.

- The time required to conduct a feasibility study to confirm the viability and route of the underground pipeline associated with the treatment system.

- The time required to conduct an environmental impact study for each new component (i.e., underground pipeline, proposed extraction well located within 150 to 200 feet of an elementary school, etc.) of the treatment system. The environmental impact study could not be finalized until the pipeline feasibility study was completed.

- The groundwater pump and treat alternative included extraction from existing well R-092A and injection at existing well R-090A. Both of these wells were constructed in 2002 using low carbon steel casing and screen. The typical lifespan of low carbon steel casing and screen is approximately 25 years. These wells are expected to be operational until at least 2045. Thus, one or both of these wells may need to be replaced during the implementation of the remedy at an estimated cost of $750,000 to $1 million per well. In addition, wells constructed with low carbon steel casing and screen typically require rehabilitation every five years at an approximate cost of $40,000 per well per rehabilitation.

- The groundwater pump and treat alternative included a replacement extraction well (C-022A-R) to be drilled at the location of existing Tucson Water well C-022A. The lot size and access at this location is insufficient for mobilizing a drill rig to the site and drilling a replacement extraction well. Additional funds would be required to purchase property adjacent to the existing well site or a different property in order to drill the replacement extraction well.

In addition to these concerns, it is unclear if the PCE concentrations at the Site will be high enough to justify operating a groundwater pump and treatment system. As previously mentioned in Section 5.0, the WCS was shut down in October 2012 due to influent PCE concentrations that were below the AWQS. Thus, the proposed remedy includes groundwater pump and treat as a contingency. Groundwater pump and treat will not be implemented at the Site unless the MNA results indicate additional groundwater remediation is needed at the Site to meet the ROs.

If implemented, the groundwater pump and treat system will use the existing WCS treatment system and a combination of new and existing extraction wells and injection wells. The groundwater will be extracted using one or more extraction wells. The extracted groundwater will be treated using liquid phase granular activated carbon (LGAC). After treatment, the treated groundwater will be injected back into the ground using one or more injection wells. The selection of the wells to be used as extraction and injection wells will be based on the effectiveness of the MNA, the migration of the groundwater plume, the concentrations of the contaminants within the groundwater plume, and the locations of downgradient water supply wells that could be impacted by the groundwater plume. It is assumed that up to two new extraction wells will be needed if the groundwater pump and treat system contingency was implemented and that the system will operate for a period of up to 20 years. ADEQ will oversee the operation and maintenance of the groundwater pump and treatment system.

Wellhead Treatment

Wellhead treatment will be implemented if an existing or future Tucson Water or other water purveyor production well is impacted with groundwater contamination associated with the Site. Wellhead treatment will consist of adding LGAC treatment to a production well when COC concentrations extracted from the well exceed 75 percent of the applicable AWQS (i.e., 3.75 µg/L for PCE). The cost of installing wellhead treatment at a production well is well specific and would be variable depending on the well location, well production rate, and the timing of bringing the well online. This contingency assumes that one production well pumping at a production rate of 350 gpm will need wellhead treatment for a period of 20 years.

Water Supply Replacement

The provision of water supply replacement would apply to small (private) water supply well users with negligible groundwater withdrawals (i.e., less than 35 gpm) and includes providing city water to users of existing small (private) water supply wells when COC concentrations extracted from the well exceed 75 percent of the applicable AWQS (i.e., 3.75 µg/L for PCE). This contingency assumes that one small (private) well owner will need replacement water for a period of 20 years.

Additional Soil Vapor Extraction at the BSL

The operation of the SVE system within the BSL could be extended up to four additional years based on the soil vapor VOC concentrations in the deep vadose zone.

6.1.4 Inspections, Performance Monitoring, and Periodic Reviews

Inspections, performance monitoring, and periodic reviews will be used to judge the effectiveness and adequacy of the remedy. The monitoring will include the following:

- **Inspections** - Inspections will be conducted to evaluate the condition of the engineering controls (landfill covers, development caps, and asphalt cap in the dross area) and whether they continue to limit waste exposure to Site receptors. The inspections will be conducted as required by the DEURs for the Site. The inspection requirements including the inspection frequency will be specified in the DEURs.

- **SVE System Monitoring** – Routine process monitoring will be conducted during the operation of the SVE system at the BSL to ensure the system is operating effectively and meeting air permitting requirements. The process monitoring will include the collection of samples from process wells and the carbon adsorption system.

- **Deep Vapor Monitoring** – Deep soil vapor monitoring will be conducted to verify that soil vapor concentrations have not rebounded after ceasing SVE operations at the BNL (previously conducted as an ERA) and BSL (proposed in the PRAP). The results of the monitoring will be used to confirm that the soil concentrations are below the remediation levels and to confirm the waste currently contained within both landfills is no longer a source of groundwater contamination. At the BSL, vapor monitoring will be conducted annually for a period of five years followed by monitoring conducted once every five years for a period of up to 20 years. At the BNL, vapor monitoring will be conducted once every five years for a period of up to 20 years.

- **Groundwater Performance Monitoring** – Focused groundwater monitoring, in addition to MNA, will be conducted to evaluate the performance and the post treatment impacts of ISCO at the BNL. The performance monitoring would include up to 12 sampling events conducted at up to 10 wells located within the target treatment zone during the implementation of ISCO.

- **Periodic Reviews** - Periodic reviews of remedial progress will be conducted as necessary to determine the effectiveness of the remedy in achieving the ROs. These reviews will be conducted, at a minimum, every five years.

6.2 Estimated Cost

The estimated cost of the proposed remedy is $10 million. The estimated cost with contingencies is $28.3 million. A summary of the costs associated with the remedy is presented in Table 2. The detailed costs are presented in Appendix A.

6.3 Duration

The overall duration of the remedy is up to 30 years. The duration is the estimated number of years required for the proposed remedy to achieve the ROs.

Table 2 - Summary of Costs for Proposed Remedy	
Remedial Technology	**Cost**
Engineering Controls at BSL and BNL (Operation & Maintenance)	$0*
Institutional Controls at BNL (Operation & Maintenance)	$0*
Soil Vapor Extraction and Vapor Monitoring (Operation & Maintenance [up to 20 years])	$986,200
In-Situ Chemical Oxidation at BNL (Operation & Maintenance [up to seven years])	$3,540,000
Monitored Natural Attenuation at Site (Operation & Maintenance [up to 30 years])	$4,413,700
Well & System Abandonment at Site	$1,078,200
SUBTOTAL	***$10,018,100***
Contingencies	
Groundwater Pump and Treat (up to 20 years)	$12,188,000
Wellhead Treatment (up to 20 years)	$4,827,200
Water Supply Replacement (up to 20 years)	$57,000
Additional SVE at the BSL (additional 4 years)**	$1,200,000
SUBTOTAL	***$18,272,200***
TOTAL	**$28,290,300**

Notes:
Cost assumes 3% annual inflation rate
*Property Owner responsible for cost
**SVE system operation & maintenance cost is $300,000/year per Table A-1

7.0 CONSIDERATION OF REMEDIATION GOALS AND SELECTION FACTORS

This section presents how the remediation goals and selection factors outlined in A.R.S. §49-282.06 and the rules adopted by the ADEQ Director were considered for the proposed remedy.

7.1 Rationale for Selection of the Remedy

The proposed remedy includes source control, containment, and monitoring of the contamination. The proposed remedy provides the best combination of remedial effectiveness, practicability, cost, and benefit for the restoration and use of the groundwater resource. There are currently no unmitigated human health risks associated with the contamination at the Site and the components of the proposed remedy will be protective of the public health and the environment.

Each component of the proposed remedy is a proven, reliable remedial alternative that will be protective of the public health and the environment. The risk to human health and the environment with this remedy is low and all known exposure pathways have been addressed. Over time, the remedial actions will reduce the concentrations and the volume of contaminated soil, soil vapor, and groundwater at the Site. Environmental sampling and groundwater monitoring are included to verify that the remedy is protective of public health and the environment during and after remedy implementation. The combined components of the proposed remedy are consistent and compatible with current and anticipated future land and resource use. Upon implementation, this remedy is considered to have a positive impact in terms of enhancement of future land uses and impacts on the local economy.

7.2 Achievement of Remedial Objectives

Per A.C.C. R18-16-408(B)(3), the proposed remedy must achieve each of the ROs established by ADEQ for the Site as presented in this PRAP.

The proposed remedy for soil will achieve ROs for land use by restricting environmental and human exposure to landfill and dross waste through engineering controls (existing landfill covers, existing development caps, and the asphalt cap) and institutional controls (DEURs). The DEURs will regulate intrusive work at the Site and require routine inspections and maintenance to ensure the engineering controls remain effective for as long as the landfill and dross waste remain at the Site.

The proposed remedy for groundwater will achieve ROs for groundwater use by treating the source of contamination with SVE and ISCO and using MNA to remediate the groundwater plume. The proposed remedy will clean up the groundwater to levels that are less than the AWQS. Environmental and performance monitoring will be used to confirm the groundwater ROs are being met.

7.3 Achievement of Remedial Action Criteria

A.R.S. § 49-282.06 requires that remedial actions shall:

- Assure the protection of public health and welfare and the environment.
- To the extent practicable, provide for the control, management or cleanup of the hazardous substances in order to allow the maximum beneficial use of the waters of the state.
- Be reasonable, necessary, cost-effective, and technically feasible.

As demonstrated in this PRAP, the proposed remedy for the Site meets the requirements of A.R.S. § 49-282.06. The proposed remedy is protective of human health and the environment, compliant with applicable laws, and allows for the maximum beneficial use of the waters of the State with the lowest cost. The proposed remedy is the best combination of practicability, risk, cost, and benefit to achieve the ROs.

7.4 Consistency with Water Management Plans

The proposed remedy is consistent with the water management plans of local water providers. There are no active supply wells currently impacted by the plume and the proposed remedial actions will restore water quality. This remedy will allow for the maximum beneficial use of the waters of the State, protect the groundwater supply for future use, and ensure that wider areas are not impacted for future water development options.

7.5 Consistency with General Land Use Planning

The proposed remedy is consistent with the current land use and is not anticipated to negatively impact current or future land use at the Site.

7.6 Lead Agency Statement for Proposed Remedy

Based on the information currently available, ADEQ believes the proposed remedy provides the best balance of tradeoffs among the other alternatives with respect to the comparison criteria. ADEQ expects the proposed remedy will satisfy the remedial action criteria pursuant to A.R.S. § 49-282.06 and the ROs.

7.7 Uncertainties

Uncertainties associated with the proposed remedy at the Site include the following:

- **The quantity of residual COC mass present in the BNL and BSL waste is unknown.** The volume of COCs that went into the landfills and the volume of COCs currently present in the landfills is unknown.

- **The duration of time required to remediate the groundwater at the Site.** A groundwater model was used to estimate the duration of time required to remediate the groundwater at the Site. The assumptions used in the groundwater model for the aquifer properties, magnitude of contamination in the sources areas, vertical distribution of contamination in groundwater, and future impacts of groundwater pumping wells may not be representative of conditions at the Site. Thus, the estimated duration required to remediate the groundwater at the Site could be more or less than the time frame estimated by the model.

7.8 Public Comment Period

The PRAP will be issued for a 90-day public comment period. A Community Advisory Board (CAB) meeting will be held during the public comment period. ADEQ will accept written comments on this PRAP that are postmarked within the comment period and submitted to:

Arizona Department of Environmental Quality
Attention: Tom Titus, Project Manager
1110 West Washington Street
Phoenix, Arizona 85007
Email: Titus.Thomas@azdeq.gov

8.0 REFERENCES

AMEC Foster Wheeler (AMEC), 2017. Final Feasibility Study, Broadway Pantano Water Quality Assurance Revolving Fund Site, Tucson, Arizona. June 28.

Arizona Department of Environmental Quality (ADEQ), 2012. Final Groundwater Remedial Objectives Report, Broadway Pantano WQARF Site, Tucson, Arizona. June 1.

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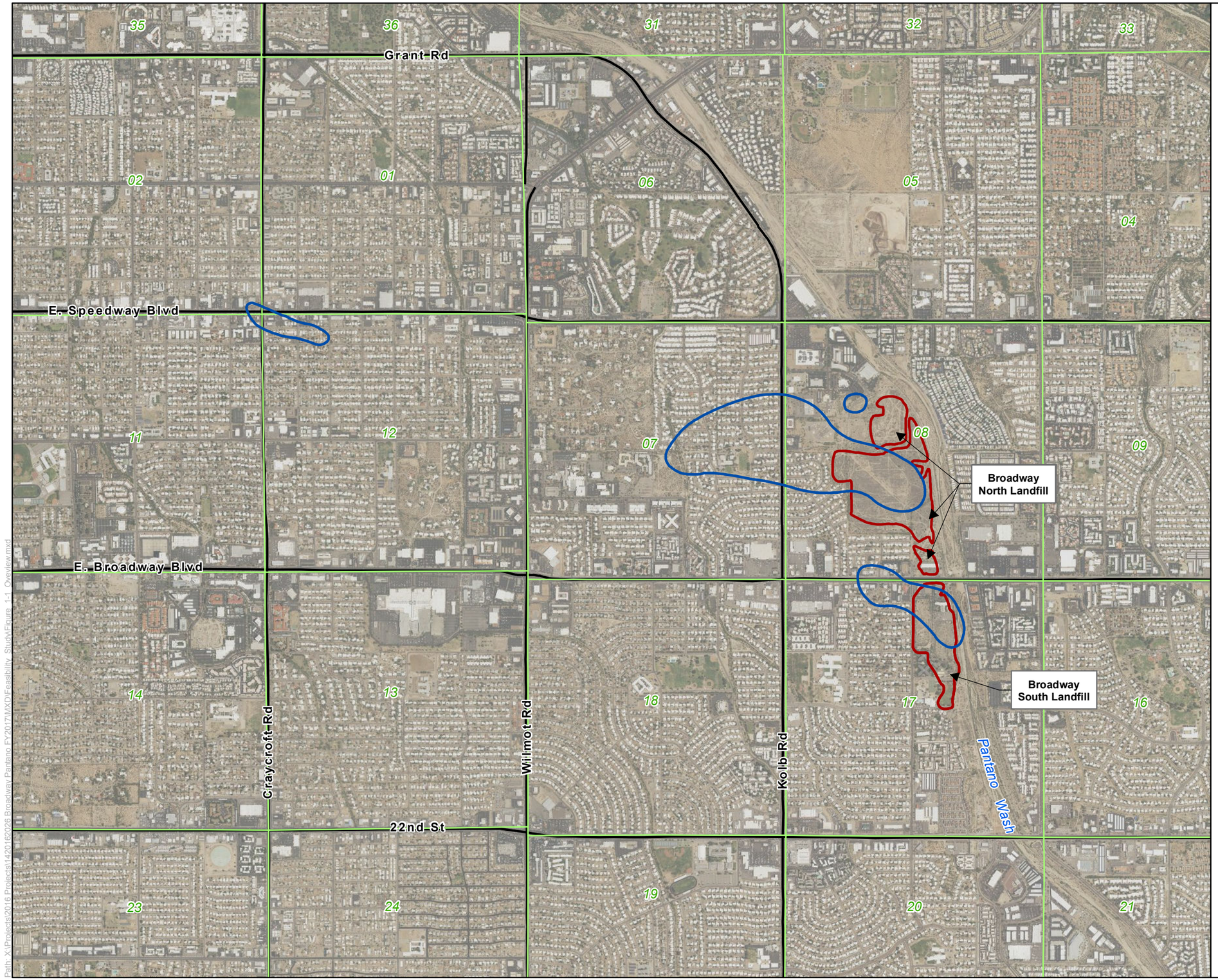
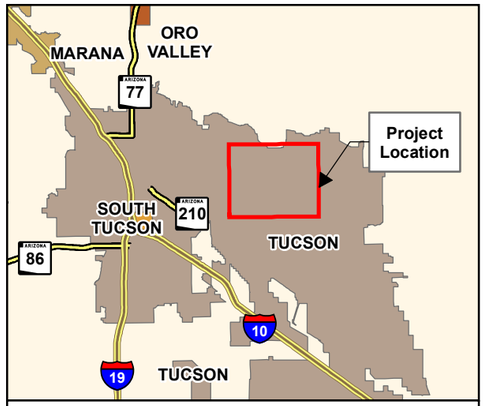
FIGURES





Area of Detail

Legend

- Approximate Extent of Groundwater Operable Unit Based on 2016 Data
- Approximate Extent of Landfill Operable Unit
- 12 Section and Number

Notes:
LOU Extent from Clear Creek Associates, 2015
Aerial Imagery: National Agriculture Imagery Program (NAIP), 2015

0 1,000 2,000 4,000 Feet

N

Broadway Pantano WQARF Site
Tucson, Arizona

Site Location Map

FIGURE **1**

Job No.:	14-2016-2026
PM:	NC
Date:	5/18/2017
Scale:	1" = 2000'

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TEP Substation

14 Acres

5th St Alignment

Broadway North Landfill

65 Acres

Pantano Wash

Home Depot

Broadway Star Plaza

Dross Area 1.9 Acres

Construction Debris Waste Area 3.5 Acres

Broadway Blvd

Culver's

Hilton Hotel

Broadway South Landfill

42 Acres

Broadway Proper

Gollob Park

YMCA

Kenyon Dr

Kenyon Terrace

Prudence Rd

Prudence Landfill

Legend

- Dross Management Area Fence
- Dross Disposal Area
- Site Perimeter Fence (inferred from imagery)
- Parcel Boundary
- Landfill OU Boundaries (dashed lines indicate where removal of waste may have occurred)
- Estimated Extent of Removed Waste

LOU Extent from Clear Creek Associates, 2015
Dross Area Extent from Aplomado, 2000
Construction Debris Extent from Stantec, 2012
Aerial Imagery: National Agriculture Imagery Program (NAIP), 2015

0 250 500 1,000 Feet

Job No.:	14-2016-2026
PM:	NC
Date:	6/5/2017
Scale:	1" =500'

N

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Broadway Pantano WQARF Site
Tucson, Arizona

Site Detail Map

FIGURE 2

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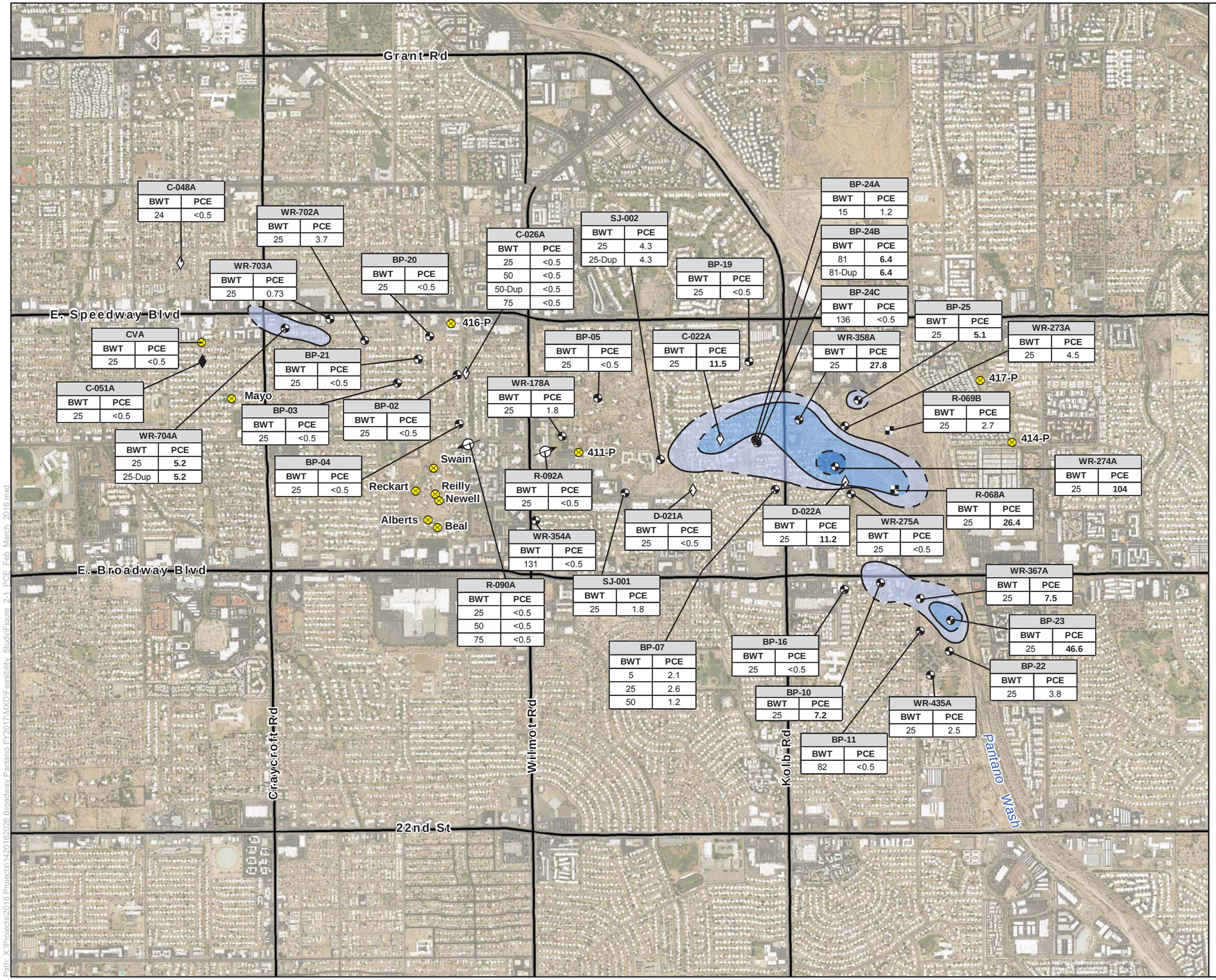

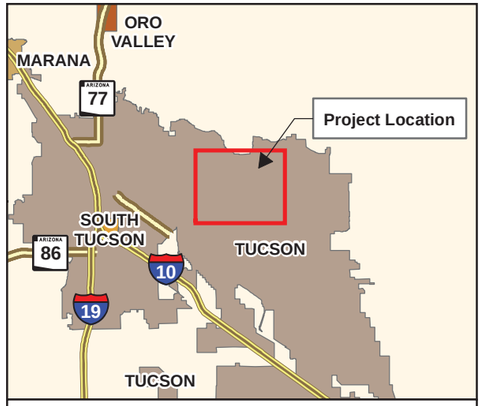

Area of Detail

Legend

Key to Well Symbology

- Active Monitoring Well
- Active Production Well
- Inactive Production Well
- Air Injection/Monitoring Well
- Western Containment Injection Well
- Western Containment Extraction Well
- Private Well

PCE Concentration (Dashed Where Inferred)

- 5µg/L
- 10µg/L
- 100µg/L

Results that are **BOLD** are equal to or exceed the AWQS of 5 µg/L limit.

Notes:

WR-274A	Well Identification
BWT	Below water table
PCE	Tetrachloroethene - Sampling Interval: 2/15/2016 - 3/1/2016
µg/L	Micrograms per liter
AWQS	Arizona Aquifer Water Quality Standards
Aerial Imagery:	National Agriculture Imagery Program (NAIP), 2015

0 1,000 2,000 4,000 Feet

N

Broadway Pantano WQARF Site
Tucson, Arizona

Estimated Extent of Groundwater PCE Plume, February-March 2016

FIGURE **3**

Job No.:	14-2016-2026
PM:	NC
Date:	6/27/2017
Scale:	1" = 2000'

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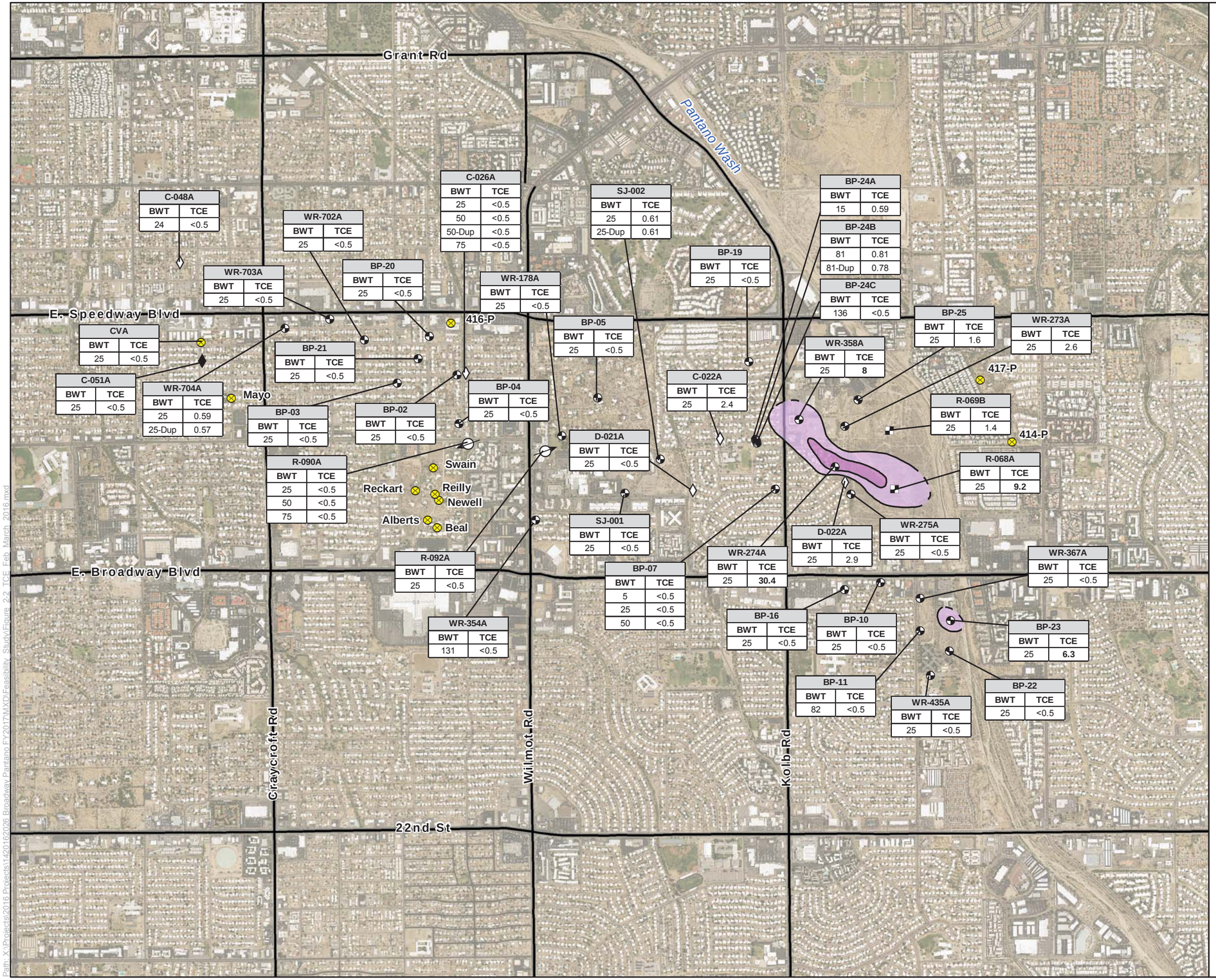
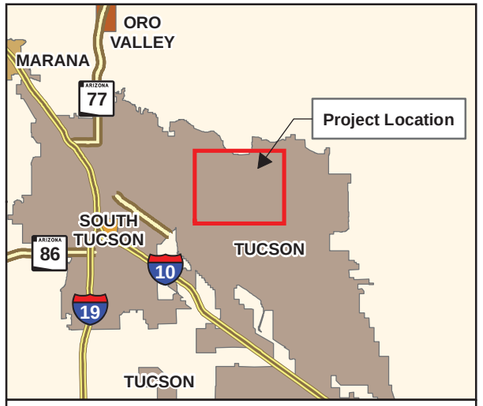
Path: X:\Projects\2016 Projects\142016\2026 Broadway Pantano FY2017\MXD\Feasibility Study\Figure 2-1 PCE Feb March 2016.mxd





Area of Detail

Legend

Key to Well Symbology

- Active Monitoring Well
- Active Production Well
- Inactive Production Well
- Air Injection/Monitoring Well
- Western Containment Injection Well
- Western Containment Extraction Well
- Private Well

TCE Concentration (Dashed Where Inferred)

- 5µg/L
- 10µg/L

Results that are **BOLD** are equal to or exceed the AWQS of 5 µg/L limit.

Notes:

WR-274A	Well Identification
BWT	Below water table
TCE	Trichloroethene - Sampling Interval: 2/15/2016 - 3/1/2016
µg/L	Micrograms per liter
AWQS	Arizona Aquifer Water Quality Standards
Aerial Imagery:	National Agriculture Imagery Program (NAIP), 2015

0 1,000 2,000 4,000 Feet

N

Broadway Pantano WQARF Site
Tucson, Arizona

Estimated Extent of Groundwater TCE Plume, February-March 2016

FIGURE **4**

Job No.:	14-2016-2026
PM:	NC
Date:	6/27/2017
Scale:	1" = 2000'

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CONSTRUCTION NOTES

1	4" ASPHALT CONCRETE PAVEMENT CAP	59,273 SF
2	REMOVE EXISTING CHAIN LINK FENCE	884 LF
3	CLEAR AND GRUB LIMITS OF ASPHALT PAVEMENT	62,018 SF
4	DUMPED RIP RAP, D_{50} = 6" (MIN. 12" DEEP)	--

NOTE: ALL SCALE NOTATIONS ARE BASED ON 22x34 PLANS. IF PRINTED ON 11X17, THE SCALE WOULD BE DOUBLE (FULL SIZED IS 1"=20' and 11X17 IS 1"=40').

0 5' 10' 20' 40'

SCALE: 1"=20'

REVISIONS:

Environment & Infrastructure Solutions, Inc.
4600 E. WASHINGTON STREET, SUITE 600
PHOENIX, ARIZONA 85034
PHONE: 602-733-6000
FAX: 602-733-6100

wood.

Asphalt Cap Construction Details

PROJECT:

BROADWAY-PANTANO

TUCSON, ARIZONA

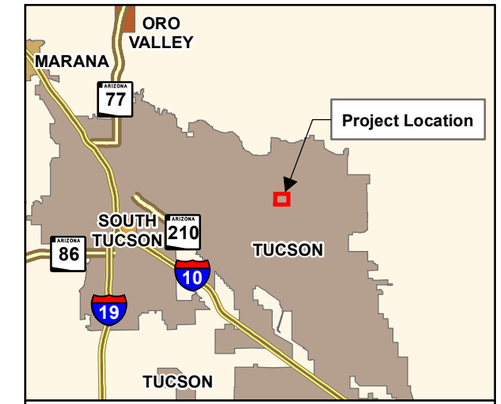
DESIGNED BY:
DRAWN BY:
CHECKED BY:

PROJECT NO.

FIGURE

5

File: G:\Environmental-Development\2018 Projects\14-2018-2072 FY 2019 Broadway Pantano TO #2\4.0 Project Deliverables\4.3 Drawings\Sheets\As-builts\04 GRADING.dwg



Area of Detail

Legend

- Proposed Soil Vapor Extraction Well
- Proposed Soil Vapor Monitoring Well
- Soil Vapor Extraction System
- Existing Groundwater Monitoring Well
- Deep-Nested Soil Gas Probe
- Proposed Above Ground Pipeline
- Proposed Underground Pipeline
- Landfill OU Boundary (dashed lines indicate where removal of waste may have occurred)

Notes:

WR-274A	Well Identification
cfm	cubic feet per minute
PCE	tetrachloroethene
OU	operable unit
WQARF	Water Quality Assurance Revolving Fund

0 150 300 600 Feet

N

Broadway Pantano WQARF Site
Tucson, Arizona

FIGURE 6 **Soil Vapor Extraction (SVE) System Layout**

Job No.	1420182049
PM:	DSF
Date:	8/2/2018
Scale:	1" = 300'

wood.

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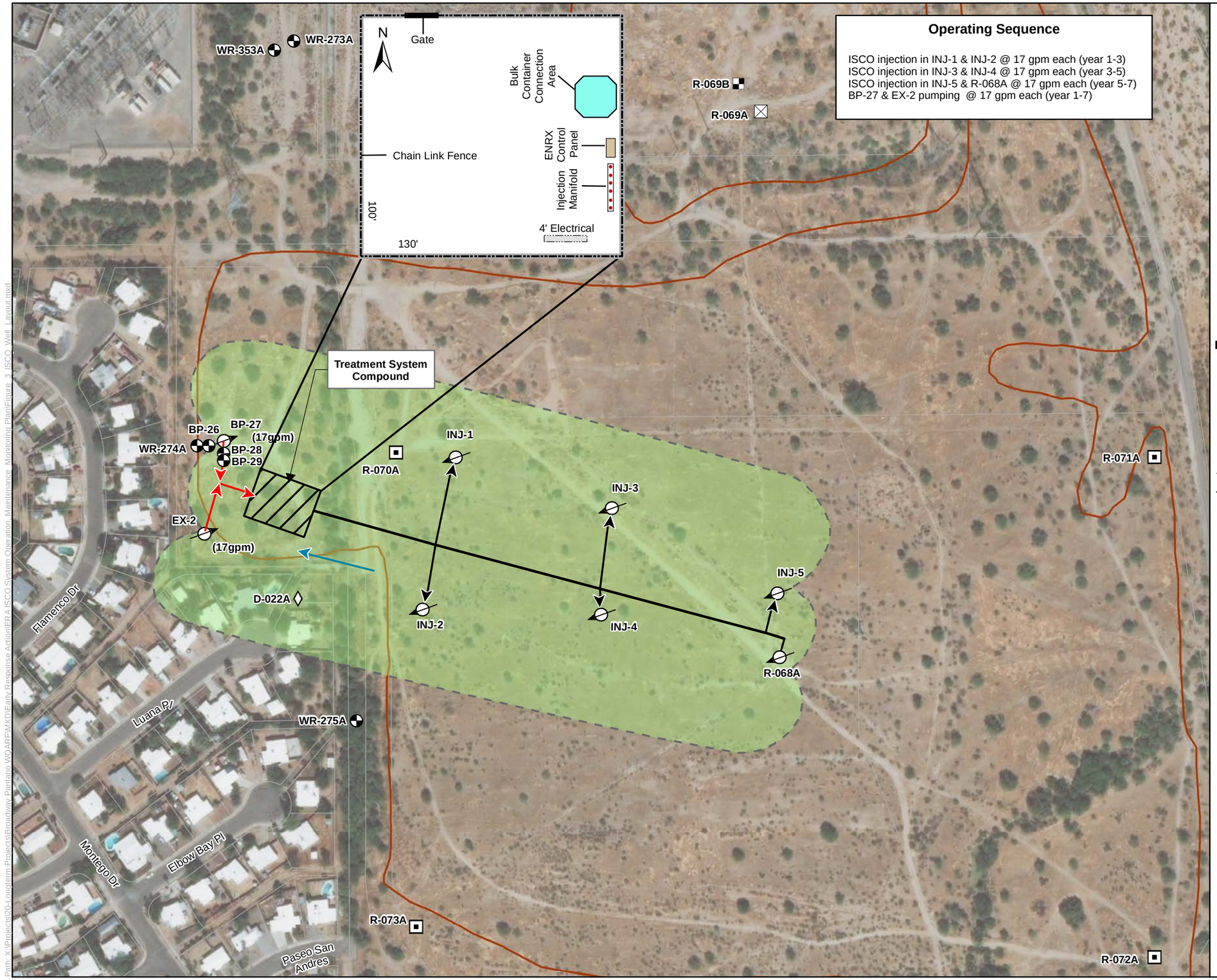
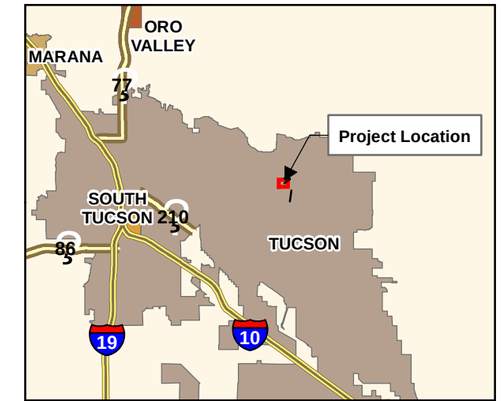
Path: X:\Projects\20-Longterm Projects\Broadway Pantano WQARF\MXD\Early Response Action\1420182049\Figure 1 SVE Layout.mxd



Operating Sequence

ISCO injection in INJ-1 & INJ-2 @ 17 gpm each (year 1-3)
ISCO injection in INJ-3 & INJ-4 @ 17 gpm each (year 3-5)
ISCO injection in INJ-5 & R-068A @ 17 gpm each (year 5-7)
BP-27 & EX-2 pumping @ 17 gpm each (year 1-7)



Area of Detail

Legend

Key to Well Symbology

- Active Monitoring Well
- Inactive Production Well
- Air Injection/Monitoring Well
- Air Extraction Well
- Air Injection Well
- Injection Well
- Extraction Well

- Groundwater Flow Direction
- Extraction Pipeline
- Injection Pipeline
- Treatment System Compound
- Capture Zone
- Landfill OU Boundary

Notes:

WR-274A	Well Identification
gpm	gallons per minute
OU	operable unit

0 100 200 400 Feet

N

Broadway Pantano
Early Response Action ISCO System
Operation, Maintenance & Monitoring Plan

FIGURE **7**

ISCO System Layout and Well Locations

Job No.	1420182048
PM:	NC
Date:	4/4/2019
Scale:	1" = 200'

wood.

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Path: X:\Projects\20 Longterm Projects\Broadway Pantano WQARF\MXD\Early Response Action\ERA ISCO System Operation, Maintenance, Monitoring Plan\Figure 3 ISCO Well Layout.mxd

APPENDIX A – Detailed Cost Summary

Table A-1
SVE Operation and Maintenance Cost Summary

Description	Year	Subtotal
BSL Shallow Vapor Monitoring (13 wells); BSL Deep Vapor Monitoring (44 wells); SVE System O&M; and Annual Reporting	1	$364,300
BSL Shallow Vapor Monitoring (13 wells); BSL Deep Vapor Monitoring (44 wells); and Annual Reporting	2	$68,300
BSL Shallow Vapor Monitoring (13 wells); BSL Deep Vapor Monitoring (44 wells); and Annual Reporting	3	$70,300
BSL Shallow Vapor Monitoring (13 wells); BSL Deep Vapor Monitoring (44 wells); and Annual Reporting	4	$72,400
BSL Shallow Vapor Monitoring (13 wells); BSL Deep Vapor Monitoring (44 wells); BNL Deep Vapor Monitoring (30 wells); Annual Reporting; and SAP Update	5	$114,000
BSL Deep Vapor Monitoring (22 wells); BNL Deep Vapor Monitoring (30 wells); Annual Reporting; and SAP Update	10	$96,300
BSL Deep Vapor Monitoring (22 wells); BNL Deep Vapor Monitoring (15 wells); Annual Reporting; and SAP Update	15	$92,900
BSL Deep Vapor Monitoring (22 wells); BNL Deep Vapor Monitoring (15 wells); Annual Reporting; and SAP Update	20	$107,700
TOTAL		**$986,200**

Notes and Assumptions:
SVE = Soil Vapor Extraction
BSL = Broadway South Landfill
BNL = Broadway North Landfill
SVE = Soil Vapor Extraction
O&M = Operation and Maintenance
SAP = Sampling and Analysis Plan
Inflation Rate = 3% per year
Shallow Vapor Monitoring Cost = $700/well
Deep Vapor Monitoring Cost = $800/well
Annual Reporting Cost = $20,000/year
SAP Update Cost = $10,000/update
SVE System O&M = $300,000/year

Table A-2
ISCO Operation and Maintenance Cost Summary

Description	Year	Subtotal
ISCO System O&M and ISCO MNA Monitoring (20 wells)	1	$455,000
ISCO System O&M and ISCO MNA Monitoring (20 wells)	2	$483,000
ISCO System O&M and ISCO MNA Monitoring (20 wells)	3	$497,000
ISCO System O&M and ISCO MNA Monitoring (20 wells)	4	$512,000
ISCO System O&M and ISCO MNA Monitoring (20 wells)	5	$527,000
ISCO System O&M and ISCO MNA Monitoring (10 wells)	6	$525,000
ISCO System O&M and ISCO MNA Monitoring (10 wells)	7	$541,000
TOTAL		**$3,540,000**

Notes and Assumptions:
ISCO = In-Situ Chemical Oxidation
MNA = Monitoring Natural Attenuation
O&M = Operation and Maintenance
Inflation Rate = 3% per year
MNA Monitoring Cost = $1,500/well
ISCO System O&M Cost = $425,000/year

Table A-3
MNA Operation and Maintenance Cost Summary

Description	Year	Subtotal
MNA Monitoring (55 wells); Water Level Monitoring (70 wells); and MNA Reporting	1	$73,200
MNA Monitoring (84 wells); and MNA Reporting	2	$92,500
MNA Monitoring (55 wells); Water Level Monitoring (70 wells); and MNA Reporting	3	$77,600
MNA Monitoring (84 wells); and MNA Reporting	4	$113,300
MNA Monitoring (55 wells); Water Level Monitoring (70 wells); MNA Reporting; Well Abandoment (2 wells); and SAP Update	5	$99,700
MNA Monitoring (84 wells); and MNA Reporting	6	$104,200
MNA Monitoring (55 wells); Water Level Monitoring (70 wells); and MNA Reporting	7	$87,400
MNA Monitoring (84 wells); and MNA Reporting	8	$110,500
MNA Monitoring (55 wells); Water Level Monitoring (70 wells); and MNA Reporting	9	$92,700
MNA Monitoring (84 wells); MNA Reporting: Well Abandonment (2 wells); Well Replacement (1 Well); and SAP Update	10	$270,500
MNA Monitoring (55 wells); Water Level Monitoring (70 wells); and MNA Reporting	11	$98,300
MNA Monitoring (84 wells); and MNA Reporting	12	$124,400
MNA Monitoring (55 wells); Water Level Monitoring (70 wells); and MNA Reporting	13	$104,300
MNA Monitoring (84 wells); and MNA Reporting	14	$131,900
MNA Monitoring (55 wells); Water Level Monitoring (70 wells); MNA Reporting; Well Abandoment (2 wells); and SAP Update	15	$154,300
MNA Monitoring (84 wells); and MNA Reporting	16	$140,000
MNA Monitoring (55 wells); Water Level Monitoring (70 wells); and MNA Reporting	17	$117,400
MNA Monitoring (84 wells); and MNA Reporting	18	$148,500
MNA Monitoring (55 wells); Water Level Monitoring (70 wells); and MNA Reporting	19	$124,500
MNA Monitoring (84 wells); MNA Reporting; Well Abandonment (2 wells); Well Replacement (1 well); and SAP Update	20	$363,500
MNA Monitoring (55 wells); Water Level Monitoring (70 wells); and MNA Reporting	21	$132,100
MNA Monitoring (84 wells); and MNA Reporting	22	$167,100
MNA Monitoring (55 wells); Water Level Monitoring (70 wells); and MNA Reporting	23	$140,200
MNA Monitoring (84 wells); and MNA Reporting	24	$177,300
MNA Monitoring (55 wells); Water Level Monitoring (70 wells); MNA Reporting; Well Abandoment (2 wells); and SAP Update	25	$207,400
MNA Monitoring (84 wells); and MNA Reporting	26	$188,100
MNA Monitoring (55 wells); Water Level Monitoring (70 wells); and MNA Reporting	27	$157,800
MNA Monitoring (84 wells); and MNA Reporting	28	$199,500
MNA Monitoring (55 wells); Water Level Monitoring (70 wells); and MNA Reporting	29	$167,400

Table A-3
MNA Operation and Maintenance Cost Summary

Description	Year	Subtotal
MNA Monitoring (84 wells); MNA Reporting; and SAP Close-out Report	30	$248,100
TOTAL		**$4,413,700**

Notes and Assumptions:
MNA = Monitored Natural Attenuation
SAP = Sampling and Analysis Plan
Inflation Rate = 3% per year
MNA Monitoring Cost = $800/well
Water Level Monitoring Cost = $100/well
MNA Reporting Cost = $20,000/year
SAP Update Cost = $15,000/update
Well Abandonment = $6,500/well
Well Replacement = $86,000/well (400 foot at $215/foot)

Table A-4
Abandonment Cost Summary

Description	Subtotal
Deep Monitoring Wells - 44 Wells (Abandon at Year 30)	$534,000
Shallow Monitoring Wells - 27 Wells (Abandon at Year 30)	$164,000
WCS 12-Inch Extraction/Injection Wells - 3 Wells (Abandon at Year 30)	$183,000
SVE (Abandon at Year 6)	$25,000
ISCO (Abandon at Year 8)	$50,700
WCS (Abandon at Year 30)	$121,500
TOTAL	**$1,078,200**

Notes and Assumptions:
WCS = Western Containment System
SVE = Soil Vapor Extraction System
ISCO = In-Situ Chemical Oxidation System
Inflation Rate = 3% per year
Deep Monitoring Well = $5,000/well
Shallow Monitoring Well = $2,500/well
WCS 12-Inch Diameter Extraction/Injection Well = $25K/well

Table A-5
Groundwater Pump and Treat Contingency Capital Cost Summary

Description	Quantity	Units	Unit Cost	Subtotal
Extraction Well Installation				
Extraction Well	2	Well	$400,000	$800,000
Well Construction Subtotal				*$800,000*
Conveyance Pipeline Installations				
Excavation	5225	BCY	$10	$52,250
Piping and Valves	14000	LF	$35	$490,000
ABC Backfill	550	CY	$40	$22,000
Compaction	5275	ECY	$2	$10,550
Asphalt Paving	3200	SY	$20	$64,000
Trench Plate	2	Each	$5,000	$10,000
Traffic Control	2	Each	$10,000	$20,000
Horizontal Borings	500	LF	$450	$225,000
Utility Conflicts	40	Each	$5,000	$200,000
Pipeline Construction Subtotal				*$1,093,800*
WCS Modifications				
Carbon Vessels	2	Each	$32,000	$64,000
Bag Filters	4	Each	$15,000	$60,000
Control System	1	Each	$80,000	$80,000
Intial Carbon Fill	1	Each	$120,000	$120,000
Well Rehabilitation	2	Each	$25,000	$50,000
Contractor Labor	1	Each	$10,000	$10,000
WCS Construction Subtotal				*$384,000*
Construction Subtotal				***$2,277,800***
Contractor Mark-Up				
General Conditions (10% of Construction Subtotal)				$227,800
Survey (2% of Construction Subtotal)				$45,600
Mobilization (8% of Construction Subtotal)				$182,300
Engineering (6% of Construction Subtotal)				$136,700
Construction Management (6% of Construction Subtotal)				$136,700
QA/QC Testing (4% of Construction Subtotal)				$91,100
Markup Subtotal				*$820,200*
TOTAL (Pre-Inflation)				**$3,098,000**
TOTAL (With Inflation [3% per year] - Assume construction in 2028)				**$4,163,500**

Notes and Assumptions:
BCY = Bank Cubic Yard
ECY = Embankment Cubic Yard
LCY = Loose Cubic Yard
SY = Square Yard
CY = Cubic Yard
LF = Linear Foot

Table A-6
Groundwater Pump and Treat Opeation and Maintenance Contingency Cost Summary

Description	Year*	Subtotal
Treatment at WCS, Operation of BSL Extraction Well, BNL Extraction Well, and Injection Well	2029	$243,600
Treatment at WCS, Operation of BSL Extraction Well, BNL Extraction Well, and Injection Well	2030	$250,900
Treatment at WCS, Operation of BSL Extraction Well, BNL Extraction Well, and Injection Well	2031	$258,400
Treatment at WCS, Operation of BSL Extraction Well, BNL Extraction Well, and Injection Well	2032	$266,100
Treatment at WCS, Operation of BSL Extraction Well, BNL Extraction Well, and Injection Well	2033	$274,100
Treatment at WCS, Operation of BSL Extraction Well, BNL Extraction Well, and Injection Well	2034	$282,400
Treatment at WCS, Operation of BSL Extraction Well, BNL Extraction Well, and Injection Well	2035	$290,800
Treatment at WCS, Operation of BSL Extraction Well, BNL Extraction Well, and Injection Well	2036	$299,600
Treatment at WCS, Operation of BSL Extraction Well, BNL Extraction Well, and Injection Well	2037	$308,500
Treatment at WCS, Operation of BSL Extraction Well, BNL Extraction Well, and Injection Well	2038	$317,800
Treatment at WCS, Operation of BSL Extraction Well, 2 BNL Extraction Wells, and Injection Well	2039	$485,900
Treatment at WCS, Operation of BSL Extraction Well, 2 BNL Extraction Wells, and Injection Well	2040	$500,500
Treatment at WCS, Operation of BSL Extraction Well, 2 BNL Extraction Wells, and Injection Well	2041	$515,500
Treatment at WCS, Operation of BSL Extraction Well, 2 BNL Extraction Wells, and Injection Well	2042	$530,900
Treatment at WCS, Operation of BSL Extraction Well, 2 BNL Extraction Wells, and Injection Well	2043	$546,900
Treatment at WCS, Operation of 2 BNL Extraction Wells, and Injection Well	2044	$499,600
Treatment at WCS, Operation of 2 BNL Extraction Wells, and Injection Well	2045	$514,600
Treatment at WCS, Operation of 2 BNL Extraction Wells, and Injection Well	2046	$530,100
Treatment at WCS, Operation of 2 BNL Extraction Wells, and Injection Well	2047	$546,000
Treatment at WCS, Operation of 2 BNL Extraction Wells, and Injection Well	2048	$562,300
TOTAL		**$8,024,500**

Notes and Assumptions:
WCS = Western Containment System
BSL = Broadway South Landfill
BNL = Broadway North Landfill
*Assumes operation begins no earlier than 2029 (system would operate up to last 20 years of remedy)

Table A-7
Wellhead Treatment Contingency Cost Summary

Description	Quantity	Unit	Unit Cost	Subtotal
Wellhead Treatment System (350 gpm)				
Subgrade and Slab Construction	1	Lump	$10,000	$10,000
Carbon Vessels	2	Each	$100,000	$200,000
Bag Filters	2	Each	$30,000	$60,000
Valves, Piping, Booster Pump, and Flow Meter	1	Each	$30,000	$30,000
Instrumentation	1	Each	$15,000	$15,000
System Enclosure	1	Each	$20,000	$20,000
Electrical	1	Each	$15,000	$15,000
Contractor Labor	1	Each	$40,000	$40,000
Construction Subtotal				*$390,000*
Contractor Mark-Up				
General Conditions (10% of Construction Subtotal)				$39,000
Survey (2% of Construction Subtotal)				$7,800
Mobilization (8% of Construction Subtotal)				$31,200
Engineering (6% of Construction Subtotal)				$23,400
Construction Management (6% of Construction Subtotal)				$23,400
QA/QC Testing (4% of Construction Subtotal)				$15,600
Markup Subtotal				*$140,400*
Wellhead Treatment System Construction Subtotal (Pre-Inflation)				***$530,400***
Wellhead Treatment System Construction Subtotal (With Inflation [3% per year] - Assumed Construction in 2028)				***$780,000***
Wellhead O&M (20 Years)				
Year 1 (Assumed to be in 2029)				$151,300
Year 2 (Assumed to be in 2030)				$155,800
Year 3 (Assumed to be in 2031)				$160,500
Year 4 (Assumed to be in 2032)				$165,300
Year 5 (Assumed to be in 2033)				$170,300
Year 6 (Assumed to be in 2034)				$175,400
Year 7 (Assumed to be in 2035)				$180,700
Year 8 (Assumed to be in 2036)				$186,100
Year 9 (Assumed to be in 2037)				$191,700
Year 10 (Assumed to be in 2038)				$179,400
Year 11 (Assumed to be in 2039)				$203,300
Year 12 (Assumed to be in 2040)				$209,400
Year 13 (Assumed to be in 2041)				$215,700
Year 14 (Assumed to be in 2042)				$222,200
Year 15 (Assumed to be in 2043)				$228,800
Year 16 (Assumed to be in 2044)				$235,700
Year 17 (Assumed to be in 2045)				$242,800
Year 18 (Assumed to be in 2046)				$250,000
Year 19 (Assumed to be in 2047)				$257,500
Year 20 (Assumed to be in 2048)				$265,300
Wellhead O&M Subtotal (With Inflation [3% per year])				***$4,047,200***
TOTAL (With Inflation)				**$4,827,200**

Table A-8
Water Supply Replacement Contingency Cost Summary

Description	Subtotal
Year 1 (Assumed to be in 2029)	$2,220
Year 2 (Assumed to be in 2030)	$2,180
Year 3 (Assumed to be in 2031)	$2,245
Year 4 (Assumed to be in 2032)	$2,315
Year 5 (Assumed to be in 2033)	$2,380
Year 6 (Assumed to be in 2034)	$2,455
Year 7 (Assumed to be in 2035)	$2,530
Year 8 (Assumed to be in 2036)	$2,605
Year 9 (Assumed to be in 2037)	$2,680
Year 10 (Assumed to be in 2038)	$2,765
Year 11 (Assumed to be in 2039)	$2,845
Year 12 (Assumed to be in 2040)	$2,930
Year 13 (Assumed to be in 2041)	$3,020
Year 14 (Assumed to be in 2042)	$3,110
Year 15 (Assumed to be in 2043)	$3,205
Year 16 (Assumed to be in 2044)	$3,300
Year 17 (Assumed to be in 2045)	$3,400
Year 18 (Assumed to be in 2046)	$3,500
Year 19 (Assumed to be in 2047)	$3,605
Year 20 (Assumed to be in 2048)	$3,710
TOTAL	***$57,000***

Notes and Assumptions:
Water Replacement Volume = 300 gallons per day for 365 days per year
Estimated Tucson Water Water Rate (Including Tax) = $1,400/year before inflation
Inflation Rate = 3% per year