Corrective Measures Study Report for Camp Stanley Storage Activity

Prepared for:

Camp Stanley Storage Activity
Boerne, Texas

October 2014

EXECUTIVE SUMMARY

INTRODUCTION

This report presents the results of the Resource Conservation and Recovery Act (RCRA) Corrective Measures Study (CMS) performed at Camp Stanley Storage Activity (CSSA) located in Boerne, TX. This CMS was conducted in order to fulfill the requirements of the U.S. Environmental Protection Agency (USEPA) Administrative Order on Consent (the Order) issued to CSSA on May 5, 1999. The purpose of the CMS was to screen and develop corrective measures alternatives for removal, containment, treatment, and/or other remediation of the contamination that has been identified at CSSA, described in the 2014 RCRA Facility Investigation (RFI) Report.

FACILITY BACKGROUND

CSSA is located in northwestern Bexar County, about 19 miles northwest of downtown San Antonio. The installation consists of 4,004 acres immediately east of Ralph Fair Road, and approximately 0.5 mile east of Interstate Highway 10. Camp Bullis borders CSSA completely on the east, and partially on the north and south.

The present mission of CSSA is the receipt, storage, issue, and maintenance of ordnance as well as quality assurance testing and maintenance of military weapons and ammunition. Because of its mission, CSSA has been designated a restricted access facility. No changes to the CSSA mission and/or military activities are expected in the future.

SUMMARY OF ENVIRONMENTAL HISTORY

During a routine screening site visit on August 9, 1991, the Texas Department of Health sampled CSSA several on-post water supply wells. Analytical results revealed that one well exceeded the maximum contaminant limits (MCLs) for *cis*-1,2-dichloroethene (*cis*-1,2-DCE), *trans*-1,2-dichloroethene (*trans*-1,2-DCE), trichloroethene (TCE), and tetrachloroethene (PCE). In 1992, CSSA initiated environmental investigations and USEPA issued the Order in 1999.

Following issuance of the Order, a total of 84 potential contamination sites, including 39 Solid Waste Management Units (SWMUs), 41 Areas of Concern (AOCs), and five Range Management Units (RMUs), were identified; and investigations and remedial actions necessary for closure in accordance with State of Texas requirements have been completed at 77 of the sites. In 2012, four SWMUs (B-2, B-8, B-20/21, and B-24) were combined with RMU-1 as they are part of the active firing range. This range will be closed in the future when it is no longer active. Contamination from past disposal activities resulted in multiple groundwater units, referred to as Plume 1 (SWMUs B-3 and O-1) and Plume 2 (AOC-65). Plume 1 has advectively migrated southward towards Camp Bullis, and west-southwest toward CSSA well fields and several off-post public and private wells. VOC concentrations over 400 µg/L are present in Middle Trinity aquifer wells near the source area. However, contaminant concentrations are below the MCLs over most of the Plume 1 area. Based on September 2013 groundwater monitoring results, the total area of Plume 1 with PCE concentrations above the MCL is approximately 88 acres. Little to no contamination within the Bexar Shale and CC Limestone has been consistently identified within Plume 1 except in association with former open borehole completions. The soil at 0.34-acre SWMU O-1 was closed per TCEQ's requirements and a cap was placed on top of the former oxidation pond. Due to its proximity to SWMU B-3, groundwater at SWMU O-1 was evaluated as part of the SWMU B-3 investigation.

Contamination at Plume 2 originated at AOC-65, and spread southward and westward from the post. The greatest concentrations of solvents are reported at the near subsurface adjacent to the source area. Deeper in the subsurface, concentrations in excess of 100 µg/L have been reported in perched intervals above the main aquifer body in the LGR. However, multi-port well sampling has shown that once the main aquifer body is penetrated, the concentrations are diluted to trace levels. Off-post, concentrations in excess of MCLs have been detected in private and public wells with open borehole completions. Based on September 2013 groundwater monitoring results, the total area of Plume 2 with PCE concentrations above the MCL is approximately 15 acres. Only sporadic, trace concentrations of solvents have been detected in Bexar Shale and CC Limestone wells within Plume 2.

In general, due to the depth of groundwater (greater than 100 feet), the faulted karst nature of the aquifer, the existence of plumes associated with two areas (SWMUs B-3/O-1 and AOC-65), and CSSA's ongoing groundwater monitoring program, investigation of groundwater was conducted on a sitewide scale rather than during the investigation and closure of each individual SWMU, AOC, or RMU. CSSA is actively implementing remediation options for groundwater contamination associated with SWMU B-3/O-1 (Plume 1) and AOC-65 (Plume 2).

SUMMARY OF RISK ASSESSMENT

Based on the results of the human health risk assessment (HHRA) (Parsons 2014), and a review of the risk assessment objectives, unacceptable risks to human health may occur in some locations off-post from exposure to contaminants in groundwater at CSSA. Cumulative carcinogenic risks greater than the USEPA acceptable range of 1×10^{-4} to 1×10^{-6} were calculated in several off-post wells. The highest cumulative carcinogenic risk calculated using the PCLs was in well RFR-10, while the highest cumulative carcinogenic risk calculated using the RSLs was in well LS-5. The risk assessment evaluated samples collected before GAC treatment. Both wells RFR-10 and LS-5 are equipped with GAC units.

Unacceptable risks to human health may occur in some locations on-post from exposure to contaminants in groundwater at CSSA. There are several locations on-post with cumulative noncarcinogenic hazards greater than 1. The highest cumulative hazard was calculated in well CS-9. Additionally, cumulative carcinogenic risks greater than the USEPA acceptable range of 1×10^{-4} to 1×10^{-6} were calculated in several on-post wells. The highest cumulative carcinogenic risk was calculated within the LGR geologic unit of Westbay monitoring well CS-WB05-LGR.

Hazards due to exposure to lead in groundwater may occur in some on-post locations. Detections in most of these wells are sporadic and typically coincide with heavy rainfall events. The highest lead hazard was calculated for wells CS-11 and CS-9 where lead has been consistently detected though the concentrations have only been sporadically above the action level. The maximum concentration detected at CS-9 is 58 µg/L, but 41 of the 52 detections there were below the action level, including the four most recent samples. The maximum concentration detected at CS-11 is 197 µg/L but 15 of the 19 detections there were below the action level, including the most recent sample. Lead detections in these two wells have been attributed to the materials used in well construction (remnants of broken casing, column pipe, and possibly equipment pumping at depths greater than 130 feet bgs). Neither well is used as a source of drinking water on-post, and because of the contamination, both wells are scheduled to be plugged and abandoned in 2015.

Indoor air sampling results collected in 2013 were compared with USEPA resident air regional screening levels (RSL) (November, 2013) for PCE and TCE (9.4 and 0.43 micrograms per cubic meter [$\mu g/m^3$]), respectively. All results were below USEPA resident air RSLs. Since there are no COPCs in indoor air, vapor intrusion was not evaluated further in the HHRA. As determined by the 2013 vapor intrusion study and subsequent HHRA, vapor intrusion is not a complete pathway; however, CSSA remains proactive in both emerging contaminants and potential vapor intrusion issues.

SUMMARY OF CORRECTIVE MEASURES STUDY

Corrective action objectives for soil and groundwater at CSSA were developed to identify the goals for reducing hazards to ensure protection of human health, safety, and the environment. The CAO for soil at CSSA was to clean up contaminated soil at each site to Tier 1 or Tier 2 Residential PCLs. All soil at identified SWMUs, AOCs, and RMUs at CSSA has been remediated to residential PCLs with the exception of RMU-1. RMU-1 will be remediated and closed when the range is no longer active.

The CAOs for groundwater at CSSA include:

- Control the migration of contaminated groundwater through source area treatment so that COCs above MCLs do not migrate to groundwater in adjacent areas where concentrations are below MCLs.
- Prevent human exposure to groundwater containing COCs at concentrations that exceed the MCLs.
- Control and monitor on-site worker dermal contact with, or ingestion of, COCs in shallow groundwater.

All potential technologies that may be used to achieve the CAOs were identified and preliminarily evaluated for potential further consideration as part of corrective measures alternatives (CMAs). Upon consideration of various containment technologies, four CMAs were developed and evaluated to address groundwater contamination at CSSA:

- Alternative 1 – No Action
    - No corrective measures to be implemented to reduce the exposure to contaminated groundwater at CSSA, and would involve continued use of the site in its current condition. This alternative is provided as a baseline against which other CMAs can be compared.
- Alternative 2 – Point-of-Use Treatment, Land Use Controls (LUCs), and Long-Term Monitoring (LTM)
    - Implement institutional and engineering LUCs to prevent contact with contaminated media.

   - Current off-post point-of-use treatment systems (GAC units) would continue to be operated and monitored, and new GAC units would be installed at additional off-post drinking water wells if necessary.
   - Any reduction in plume or source area contaminant concentrations would occur only through natural attenuation processes, and would be monitored as part of the LTM program.
- Alternative 3 – Source Area Treatment, Alternative Drinking Water Source, Land Use Controls, and Long-Term Monitoring
   - Implement institutional and engineering LUCs to prevent contact with contaminated media.
   - Off-post groundwater users supplied with drinking water from San Antonio Water System (SAWS).
   - Continued use of bioremediation (bioreactor) to treat the source area at SWMU B-3.
   - Continued use of *in situ* chemical oxidation (ISCO) to treat source area contamination at AOC-65.
- Alternative 4 – Source Area Treatment, Point-of-Use Treatment, Land Use Controls, and Long-Term Monitoring
   - Implement institutional and engineering LUCs to prevent contact with contaminated media.
   - Current off-post GAC units would continue to be operated and monitored, and new GAC units would be installed at additional off-post drinking water wells if necessary.
   - Continued use of bioremediation (bioreactor) to treat the source area at SWMU B-3.
   - Continued use of *in situ* chemical oxidation (ISCO) to treat source area contamination at AOC-65.

Alternative 4 (Source Area Treatment, Point-of-Use Treatment, LUCs, and LTM) is recommended for implementation because it achieves the CAOs, achieves the highest reduction in toxicity, mobility, or volume (TMV), and is effective over the short- and long-term. While Alternative 2 is estimated to be less costly, it does not meet all of the CAOs within a reasonable timeframe. Alternative 3 is difficult to implement both technically, logistically (as the US government cannot force private well owners to abandon their wells), and administratively. The government will also retain financial liability for any ingestion or dermal contact that results in health effects to residents or their animals. For these reasons, the extra cost of Alternative 4 is weighed against the lack of TMV reduction and inability to reasonably achieve all three CAOs under Alternative 2, as well as the extreme logistical difficulties under Alternative 3.

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ACRONYMS AND ABBREVIATIONS

µL	Microgram per Liter
AOC	Area of Concern
bgs	Below Ground Surface
CAH	Chlorinated Aliphatic Hydrocarbon
CAO	Corrective Action Objective
cis-1,2-DCE	*cis*-1,2-dichloroethene
CMA	Corrective Measures Alternative
CMS	Corrective Measures Study
CSH	Collective Solar Heating
CSP	Concentrated Solar Power
CSSA	Camp Stanley Storage Activity
DNAPL	Dense, Non-Aqueous Phase Liquid
DQO	Data Quality Objective
EAB	Enhanced Anaerobic Bioremediation
ERH	Electrical Resistance Heating
Fe(II)	ferrous iron
GAC	Granular-Activated Charcoal
H_2O_2	hydrogen peroxide
HHRA	Human Health Risk Assessment
ISCO	*in situ* Chemical Oxidation
ISFO	*in situ* Fenton oxidation
ISOO	*in situ* Ozone Oxidation
LTM	Long-Term Monitoring
LUC	Land Use Control
MCL	Maximum Contaminant Limit
NAPL	Dissolved-Phase and Liquid-Phase Contaminant
OB/OD	Open Burn/Open Detonation
OH	hydroxyl radical
Order, the	Administrative Order on Consent
PCE	tetrachloroethene
PCL	Protective Concentration Limit
PIM	Phosphate-Induced Metals Stabilization
PRB	Permeable Reactive Barrier
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RMU	Range Management Unit
$S_2O_8^-$	persulfate anion
SO_4^-	sulfate radical
SAWS	San Antonio Water System

ACRONYMS AND ABBREVIATIONS (*continued*)

SEE	Steam-Enhanced Extraction
SVE	Soil Vapor Extraction
SWMU	Solid Waste Management Unit
TCE	trichloroethene
TCEQ	Texas Commission on Environmental Quality
TCH	Thermal Conduction Heating
trans-1,2-DCE	*trans*-1,2-dichloroethene
USEPA	U.S. Environmental Protection Agency
UU/UE	Unrestricted Use/Unrestricted Exposure
VC	vinyl chloride
VEW	Vapor Extraction Well
VOC	Volatile Organic Compound

SECTION 1
INTRODUCTION

Camp Stanley Storage Activity (CSSA) is located in northwestern Bexar County, Texas about 19 miles northwest of downtown San Antonio and 11 miles southeast of Boerne (**Figure 1.1**). In 1991, routine water well testing by the Texas Department of Health detected the presence of dissolved tetrachloroethene (PCE), trichloroethene (TCE), and *cis*-1,2-dichloroethene (*cis*-1,2-DCE) in a CSSA water supply well (Well 16) above maximum contaminant levels (MCLs) and the well was taken out of service. Subsequent sampling showed volatile organic compound (VOC) contamination levels above MCLs in several other wells. Potential sources of the waste constituents were believed to be the former oxidation pond (SWMU O-1) and Burn Area 3 (later renamed SWMU B-3). Later, AOC-65 was also identified as another source of groundwater contamination.

As a result of the groundwater contamination and The U.S. Environmental Protection Agency's (USEPA) findings on an open burn/open detonation (OB/OD) area in CSSA's North Pasture (SWMU B-20), USEPA issued CSSA an Administrative Order on Consent (the Order) under Section 3008(h) of the Resource Conservation and Recovery Act (RCRA) on May 5, 1999. With the Order, USEPA is the lead agency for investigation and remediation of groundwater. The Texas Commission on Environmental Quality (TCEQ) is the lead agency for investigation and closure of waste disposal sites, although USEPA provides input.

Since the Order was issued in 1999, CSSA has aggressively closed sites under State of Texas regulations, with both TCEQ and USEPA oversight. A total of 85 sites, including 39 solid waste management units (SWMUs) 41 areas of concern (AOCs), and 5 range management units (RMUs), have been identified at CSSA since 1993, and investigations and interim removal actions (if warranted) were conducted at a total of 83 of those sites. As of July 2014, 77 waste disposal sites were either delisted or closed to unrestricted use/unrestricted exposure (UU/UE) in accordance with TCEQ requirements. A summary of past investigations and findings is provided in the 2014 RFI Report (Parsons, 2014).

Five of the seven remaining sites are part of the active firing range, and contaminated soil at these sites will be addressed under a separate investigation when the range is no longer active. The two remaining open sites at CSSA, SWMU B-3 and AOC-65, are the remaining sources of groundwater contamination, and will be the focus of groundwater remediation efforts going forward. Treatability studies to address the remaining open sites were initiated in 1996 (SWMU B-3) and 2002 (AOC-65) and are ongoing. Throughout the site closure and treatability study process, USEPA and TCEQ actively participated in site investigation and treatability study planning, as well as provided extensive document review.

1.1 CMS REPORT PURPOSE AND OBJECTIVES

The purpose of the Corrective Measures Study (CMS) was to screen and develop corrective measures alternatives for removal, containment, treatment, and/or other remediation of groundwater contamination identified at SWMU B-3 and AOC-65. The overall goal of this process is to obtain stakeholder concurrence on the final CMS report and provide sufficient data to facilitate any future remedial action. Project stakeholders include CSSA, USEPA, and the TCEQ.

1.2 CMS REPORT ORGANIZATION

The CMS is presented in the following sections and addresses the content requirements of the May 5, 1999 USEPA Order:

- Section 2 establishes the corrective action objectives (CAOs) for the corrective measures at CSSA;
- Section 3 identifies and describes several remedial technologies that were screened as potential corrective measures alternatives (CMAs);
- Section 4 details five potential CMAs for groundwater at CSSA;
- Section 5 presents the evaluation of the CMAs;
- Section 6 presents the conclusions of the CMS and recommends a final CMA; and
- Section 7 presents the references used in this CMS.

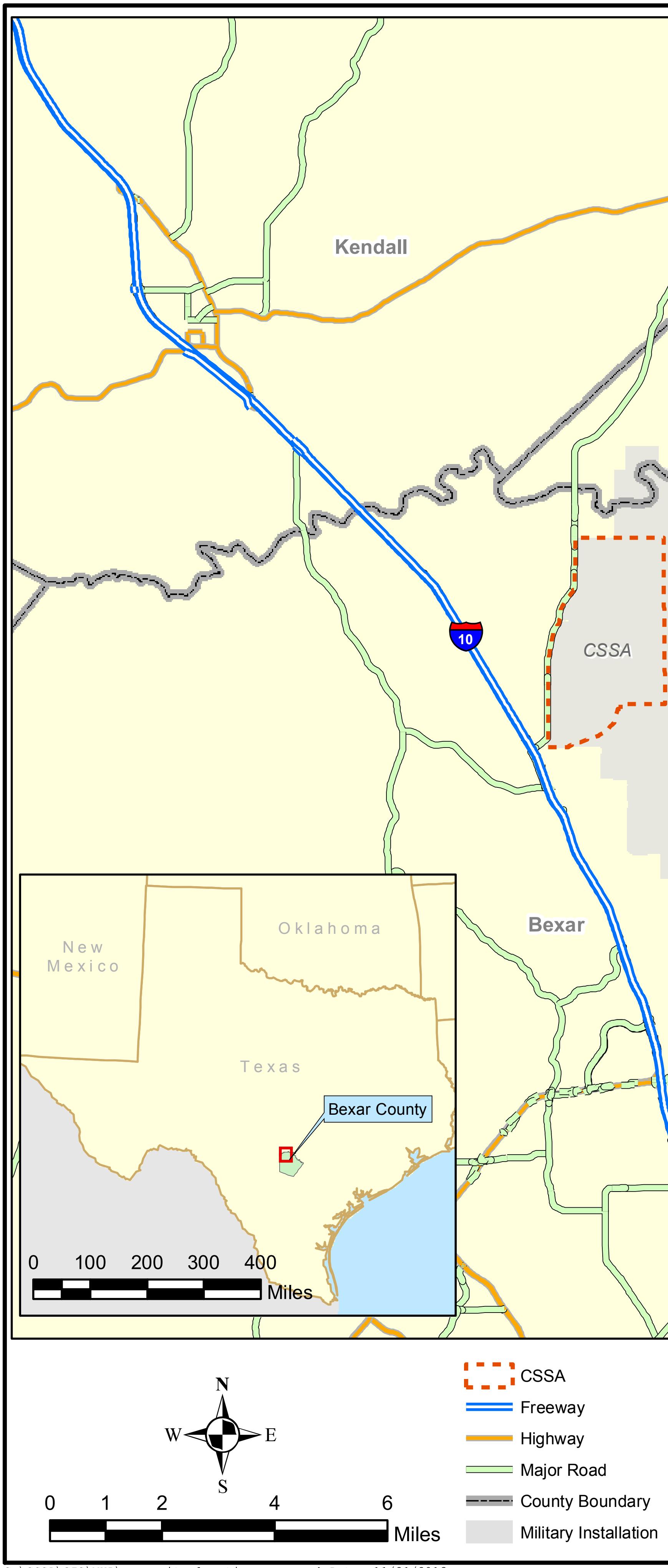

Figure 1.1

CSSA Location Map
Camp Stanley Storage Activity

PARSONS

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SECTION 2
CORRECTIVE ACTION OBJECTIVES

Corrective action objectives are developed to identify goals for reducing hazards to ensure protection of human health, safety, and the environment. CAOs are intended to be as specific as possible, without limiting the range of alternatives that can be developed or to prescribe a particular alternative. Typically, these objectives are identified for hazardous substances at a site and for a specific medium, such as soil or groundwater, by which humans and the environment can become exposed. Regulations often require that CAOs achieve certain mandated criteria (e.g., drinking water maximum contaminant level regulations). CAOs specify:

- Contaminant(s) and media of concern;
- Exposure route(s) and receptor(s); and
- Remediation goal(s) for each exposure route.

The typical method for developing CAOs at waste sites involves considering the nature and extent of contamination, the potential exposure pathways, current and future receptors, and current and future land use.

2.1 SOIL

The CAO for soil at CSSA was to clean up contaminated soil at each site to Tier 1 or Tier 2 Residential Protective Concentration Limits (PCLs). All soil at identified SWMUs, AOCs, and RMUs at CSSA was remediated to residential PCLs with the exception of RMU-1. RMU-1 will be remediated and closed when the range is no longer active.

2.2 GROUNDWATER

CAOs for groundwater at CSSA include:

1. Control migration of contaminated groundwater through source area treatment so COCs above MCLs do not migrate to groundwater in adjacent areas where concentrations are below MCLs.
2. Prevent human exposure to groundwater containing COCs at concentrations that exceed MCLs.
3. Control and monitor on-site worker dermal contact with, or ingestion of, COCs in shallow groundwater.

This approach is consistent with USEPA guidance on final cleanup goals for RCRA corrective action (USEPA, 2004).

SECTION 3
IDENTIFICATION, SCREENING, AND DEVELOPMENT OF CORRECTIVE MEASURE ALTERNATIVES

This section identifies potential remediation technologies that can potentially achieve CMOs identified in Section 2. Remediation technologies focused on volatile organic compounds were screened for achieving CMOs. Technologies unlikely to perform satisfactorily based on inherent technology limitations, site-specific limitations, or unlikely to achieve the CMOs within a reasonable time period, were eliminated from further consideration. A brief description is given for each technology.

As described in Section 2 of the RFI Report (Parsons, 2014), groundwater contamination was detected above MCLs at CSSA. These concentrations are present off-post as well as in an aquifer used as for drinking water by both CSSA and private well owners. Therefore, this CMS focuses on alternatives for remediating groundwater. However, although contaminated soil was remediated, treated, or removed post-wide, remedial technologies for contaminated soil are also presented below in the event additional contaminated soil is identified in the future.

3.1 GENERAL CORRECTIVE MEASURES ALTERNATIVES

No Action, land use controls (LUCs), and long-term monitoring (LTM) are generally used for comparison of other technologies or as components of multi-technology remedial alternatives. By themselves, these technologies can typically only meet remedial action objectives for plumes that are either stable or decreasing in mass and/or size. Since potential human exposure risks were already identified for PCE, these technologies will be used for remedial alternative comparison and/or as a component of a fully developed remedial alternative.

3.1.1 No Action

The No Action response is not a technology but is required as a baseline for comparison with other remedial actions. In this scenario, contamination remains in place with no efforts made to control access; limit exposure; or monitor, remove, treat, contain, excavate, or otherwise mitigate the potential spread of contaminants at CSSA. There is no reduction in risk, toxicity, mobility, or treatment of contaminants beyond that which occurs over time through natural attenuation processes. The No Action option is **retained** as a comparative baseline.

3.1.2 Land Use Controls

LUCs can be cost-effective, reliable, and immediately effective, and can be implemented either alone or in conjunction with other corrective measures. The administrative feasibility of and cost to implement LUCs depend on site-specific circumstances, including whether or not a site is under the direct operational control of CSSA or was transferred to non-federal ownership, as well as on the ability, willingness, and commitment of local authorities to implement LUCs. Inspections and monitoring are typically required to document the long-term effectiveness of LUCs. LUCs are **retained** as part of other potential remedial alternatives. A variety of potentially effective LUCs for addressing contaminated soil and groundwater are described below.

3.1.2.1. Engineering Controls

Engineering controls are physical features that minimize the potential for direct contact. Examples of engineered controls for soil include fences or soil covers that separate impacted soil from contact with humans or environmental receptors. A vertical impermeable barrier is an example of an engineered control to limit exposure by cutting off the route and preventing migration of contaminated groundwater or leachate from a contaminated property. Physical barriers such as fences can prevent or limit uncontrolled access to the contaminated area. In the case of soil contamination, such restrictions prevent access to both surface and subsurface contamination by potential receptors. Access controls that effectively minimize the potential for human exposure from direct contact with contaminated media are relatively easy to implement and low in cost when compared to other technologies. However, access controls would not be effective in preventing off-site contaminant migration or exposure to ecological receptors.

3.1.2.2. Institutional Controls

Institutional controls are non-engineering instruments such as legal controls that minimize the potential for human exposure to contaminants of potential concern by limiting land use. Institutional controls are generally used in conjunction with, rather than in lieu of, engineering measures such as waste treatment or containment. Some examples of institutional controls include easements, covenants, and site use restrictions. Deed restrictions are implemented to ensure that the site is used only for purposes compatible with future, post-remediation conditions.

3.1.3 Long-Term Monitoring

LTM provides a means to identify changes in the distribution of contamination spatially and temporally. Monitoring concentration trends allows for determining whether current remedial actions are effective or appropriate for achieving corrective action objectives. Implementation of an LTM program is appropriate for contaminated groundwater; however, it is typically implemented in conjunction with other remedial technologies (e.g., source area remediation, natural attenuation). LTM in the absence of active source area or plume remediation is limited to identifying changes in contaminant concentrations in groundwater associated with natural attenuation. LTM is **retained** as a means to measure alternative effectiveness of selected remedial alternative.

3.2 CORRECTIVE MEASURES ALTERNATIVES FOR SOIL

Remedial alternatives are developed from technologies and feasible process options that can address the objectives for the AOC and SWMU of concern. The basic objectives used to identify potential alternatives are to remediate, remove, or contain contamination. Each remedial alternative can consist of one or several remedial technologies classified into one of five groups, including no action, institutional controls, removal, containment, or treatment. Treatment can be *in situ* or *ex situ*.

Ex situ treatment refers to aboveground treatment systems, including source removal technologies that can eliminate or stop potential pathways of contamination. Material treated *ex situ* may be disposed off-site, reused or recycled, or put back in place.

In situ treatment refers to in-the-ground treatment of contaminants and is often preferable to *ex situ* treatment because treatment costs are generally lower, there is less potential for exposure, and no disposal issues associated with *in situ* treatment. However, *in situ* treatment is generally more difficult to implement and monitor than *ex situ* treatment processes. Treatment processes can be chemical/physical or biological and include phytoremediation. Many treatments have the same functional bases as the *ex situ* processes, but instead are employed without excavation of surface or subsurface soil.

3.2.1 Source Containment Technologies

Containment technologies involve constructing engineered barriers to isolate contaminated media. Containment may be 1) *in situ* (at the location of the waste unit), or 2) *ex situ* (away from the location of the waste unit). Properly constructed and maintained engineered barriers are effective and reliable to minimize or eliminate human and ecological exposure to contaminants and minimize leaching, direct radiation exposure, mobility, and bio-uptake of contaminated media.

The use of engineered containments such as capping and soil cover systems are very effective and have reasonable permanence, but must be maintained (monitored and repaired as a part of LUCs) as long as the contaminated media remains in place. Containments can be constructed of natural material and/or synthetic material (e.g., geotextile membranes); however, containments are most effective when constructed of natural material.

Although containment is reasonably effective at limiting exposure, it is only implemented when contaminated soil has not been removed. Additionally, containment does not abate contamination caused by waste beneath the surface cover or leaching of contaminants to groundwater; therefore, source containment technologies are **eliminated** from further consideration as a remedial alternative.

3.2.2 Source Excavation and Removal

Source removal refers to excavation of contaminated soil, with either on-site or off-site management of removed materials. When a well-defined, concentrated, continuing source is present, such as highly contaminated soil, source removal is the most effective way to prevent ongoing release of contamination. Contaminated soil would be excavated using conventional equipment. Excavated soil will require treatment to meet land disposal restriction requirements for on-site management within an Area of Contamination. Soil exceeding RCRA _toxicity characteristic leaching procedure criteria would be segregated and stabilized/treated before being transported to an on-site location for reuse. Excavated soil sent off-site for disposal would not require treatment prior to transport. Soil excavation with on- and off-site disposal is **retained** as an appropriate remedial alternative for future contaminated soil identified at CSSA.

3.2.3 Chemical/Physical Treatment Technologies

Chemical/physical treatment technologies include the mixing of reagents into soil to reduce leaching of contaminants of potential concern to groundwater and/or surface water. Phosphate-Induced Metals Stabilization (PIMS) is an example of a chemical/physical treatment technology implemented at CSSA. Although bench scale studies and *ex situ* treatment of contaminated soil using PIMs has proven successful at CSSA, the *in situ* effectiveness is unknown. Based on past performance at CSSA *ex situ* treatment utilizing PIMs is **retained** as a potential treatment technology for future contaminated soil.

3.2.4 Biological Attenuation

Biological treatment uses bacterial organisms to reduce the mobility of contaminants in soil through the creation of insoluble complexes in soil. Limited data on biological attenuation currently exist as a viable technical approach. Additionally, the effectiveness of such treatment is unknown and may prove impracticable to implement. Biological attenuation is **eliminated** as a potential treatment technology for future contaminated soil.

3.2.5 Phytoremediation

Phytoremediation is another contaminant of concern (COC)-stabilizing treatment technology in which plants bioaccumulate contaminants, thus reducing the potential for mobilization or leaching to groundwater. A phytoremediation treatability study conducted at CSSA used mustard grass from metals stabilization. Although metals were stabilized when bioaccumulated by the plants, when the plants died the metals they contained rendered the biomass a hazardous waste that required off-site disposal. Phytoremediation is **eliminated** as a potential treatment technology for future contaminated soil.

3.3 CORRECTIVE MEASURES ALTERNATIVES FOR GROUNDWATER

Remedial alternatives are developed from the technologies and feasible process options that can address the objectives for groundwater. Basic objectives used to identify potential alternatives are to remediate, remove, or contain contamination. Each remedial alternative can be classified into one of four groups, including, No Action, removal, containment, or treatment. Treatment can be *in situ* or *ex situ*.

Major factors affecting consideration of remedial alternatives for groundwater include:

- Wide variation in groundwater elevations, though generally greater than 150 feet below ground surface (bgs);
- Complex and variable fractured bedrock aquifer flow depending on groundwater elevation;
- Nearby private wells used for drinking water;
- Levels for off-post groundwater contaminant concentrations are above MCLs, though not significantly (PCE concentrations ranged from non-detect to 13.7 micrograms per Liter [µg/L] and TCE from non-detect to 8.73 µg/L in 2013);
- The only contaminants present in groundwater are PCE, TCE, and trace amounts of *cis*-1,2-DCE, and vinyl chloride (VC) (at SWMU B-3 only); and
- Regional drought and increasing demand for water resources in Texas.

3.3.1 No Action

The No Action response is not a technology but is required by RCRA as a baseline for comparison with other remedial actions. In this scenario, groundwater contamination remains in place with no efforts made to control access, limit exposure, or monitor, remove, treat, contain, or otherwise mitigate the potential spread of contaminants at CSSA. There is no reduction in risk, toxicity, mobility, or treatment of contaminants.

3.3.2 Soil Vapor Extraction

Volatilization technologies take advantage of the ongoing evaporation of liquid and dissolved-phase contamination. Soil Vapor Extraction (SVE) systems utilize vacuum blowers connected to wells installed within the vadose zone to remove soil gas and any volatilized contaminants. This technology treats the long-term source of groundwater contamination by removing volatilized contaminants within the vadose zone. SVE is often combined with other *in situ* treatment technologies that are based on increasing contaminant volatility, such as air sparging and thermal treatment technologies.

The constant evacuation of subsurface vapors speeds up normal volatilization of contaminants trapped in residual saturation, in the dissolved phase, or as a free-phase liquid. By removing vapors in the subsurface, equilibrium is shifted further from the state of dynamic equilibrium so evaporated contaminants do not have the opportunity to condense in the subsurface and return to the liquid state. In a fractured bedrock system ensuring full vacuum coverage is difficult, homogeneous permeability is uncommon, and vapor flow to each vapor extraction well (VEW) is not uniform.

Treatability studies were performed at SWMU B-3 and AOC-65 to treat both solvent plumes (Plume 1 and 2). Short-term results show that SVE is effective at removing contaminant mass from the subsurface immediately after system start up; however, over longer operational periods, productivity is diminished. Although attempts to optimize the AOC-65 SVE system and improve productivity by installing new VEWs and abandoning less productive VEWs were initially successful, the calculated annual removal rates showed that returns quickly diminished when less than a gallon of PCE was removed and SVE system operations were terminated. SVE is **eliminated** as a standalone treatment technology.

3.3.3 Air Sparging

Air sparging can be used singly or in conjunction with other similar technologies (SVE) to increase subsurface vapor flow. A typical air sparging system consists of an array of air injection wells connected to a blower with screens set in the vadose zone and or saturated zone. When used in conjunction with an SVE system, the air injection wells force air through the subsurface while the VEWs draw out the air and increase overall system flow. Effectively, this is a push-pull system where the air is pushed in via air sparging and pulled out via SVE.

Sparging wells can be set in the vadose zone or below the water table. When set in the vadose zone, the injection of air helps increase the vapor flow by pushing the subsurface vapors toward the VEWs. Additionally, increasing the air flow allows contaminants to volatilize more rapidly. Set below the water table, injected air bubbles up through the groundwater allowing dissolved phase contaminants to evaporate more readily and increases vapor flow in the unsaturated zone. Air Sparging as a standalone treatment technology is **eliminated** due to constraints imposed by the local geology and hydrogeology (fractured system, limited connectivity, and fluctuating groundwater levels).

3.3.4 Thermal Treatment Technologies

Thermal remediation is based on the premise that physical and chemical properties that control fate and transport of chlorinated solvents are temperature-dependent. As temperatures increase, liquid density and viscosity decreases, and solubility, diffusivity, vapor pressure, and the likelihood of chlorinated solvents to volatilize from liquids, increases. Increasing the temperature increases the mobilization and volatility of chlorinated aliphatic hydrocarbons (CAHs), which then may be removed from the liquid (groundwater) or vapor (soil gas) phases more efficiently.

The goal of all thermal remediation technologies is to enhance volatilization, mobilize, or destroy contaminants with the application of heat. Steam-enhanced extraction (SEE), thermal conduction heating (TCH), and electrical resistance heating (ERH) are examples of typical thermal remediation technologies. The main difference in each of these technologies is the method in which heat is generated and applied. For SEE, the heat energy is produced in a boiler and applied via steam injection. In TCH, heating elements and surface blanket heaters use electricity to generate heat, which is then transferred by conduction. And in ERH, heat is generated from friction as atoms become excited when an electrical current is passed between electrodes. In addition to these typical technologies, collective solar heating (CSH) is also discussed.

Thermal treatment technologies only partially heat the subsurface and are most effective at treating contamination within a localized area. When contamination is present within non-homogenous fractured bedrock, such as at CSSA, thermal technologies are generally not a viable option. Not only is it difficult to heat non-homogenous bedrock to a temperature high enough to sufficiently volatilize the contaminants, the fractures, acting as conduits, carry the contaminants away from the original source and eliminating the presence of a single localized source area.

3.3.4.1. Steam Enhanced Extraction

Steam-enhanced extraction is a thermal remediation process where steam is the vehicle for heat transfer. Steam is injected into the subsurface to dissolve, vaporize, and mobilize contaminants that are then recovered via SVE or dual-phase (vapor/groundwater) extraction. A generalized SEE system is composed of a steam source, steam injection system, vapor extraction or dual-phase extraction system, and a vapor and liquid treatment system.

One of the benefits of using a SEE system is that steam has a higher heat capacity than air, and thereby provides greater heat input to the subsurface than using heated air. However, the use of steam implies that the accumulation of condensate in the subsurface may mobilize aqueous phase contaminants and reduce SVE effectiveness.

A SEE treatability study performed at AOC-65 initially showed improved VOC volatilization with increases in PCE concentrations at individual VEWs and system exhausts; however, continued steam injection resulted in condensate buildup within steam injection wells. The rise in local water levels forced termination of steam injection, inhibited heat transfer from the injection well to subsurface media, and reduced VEW vapor recovery as water levels rose and reduced the surface area of exposed well screens.

Steam injection only partially heats the subsurface. Steam injected into fractures will heat any mass encountered in the fractures, but heat from the steam will only partially penetrate the matrix such that any contaminant mass diffused within the matrix may receive only limited heating. If a larger fracture intersects both the steam injection well and one of the VEWs, it is likely that only heating along and adjacent to that fracture will occur. SEE as an *in situ* thermal treatment technology is **eliminated** as a treatment technology at CSSA due to the reduction in subsurface vapor transport associated with condensate generation.

3.3.4.2. Electrical Resistance Heating

Electrical resistance heating is a thermal remediation process where heat is generated in the subsurface with the application of an electrical current. ERH systems are generally composed of an electrode array to provide heat and an SVE system to remove the volatilized contaminants. The soil and groundwater is heated by the passage of current along the most conductive path between electrodes. Because areas with high concentrations of chlorides resulting from reductive dehalogenation of chlorinated organic compounds are generally more conductive than the surrounding material, these groundwater zones or soil are heated first, regardless of permeability. Therefore, ERH is more effective than SEE and TCH for less permeable strata (clay).

ERH systems are generally employed in unconsolidated aquifers with relatively high soil moisture content. As soil and rock are generally non-conductive, most of the current travels through groundwater or soil moisture between probes. ERH is **eliminated** due to variable saturation in the treatment area that would limit the passage of current between electrodes.

3.3.4.3. Thermal Conduction Heating

TCH is a thermal remediation process in which heat originating from a heating element is transferred to the subsurface via thermal conduction and radiant heat transport. Temperatures above 500°C may be achieved using this method of heating resulting in the *in situ* destruction of contaminants. This process differs from both SEE and ERH in that it does not rely on steam as the source of heat or water as a conductive path, but rather on heating the soil itself. The higher temperatures destroy or volatilize contaminants *in situ* and are then extracted and treated at the surface.

TCH systems generally consist of subsurface heaters, though surface blanket heaters and vacuum insulated shrouds may also be used, to generate heat while an SVE system is used to capture the volatilized contaminants. Heat generated from the heating elements is transferred to the subsurface via thermal conduction and radiant heat transport. The high temperatures achievable by TCH allow for the *in situ* destruction of organic contaminants.

The primary benefit of TCH is the ability to heat the subsurface to much higher temperatures than many of the other thermal remediation methods, thereby promoting increased destruction of contaminants *in situ*. TCH also has several limitations. Safety hazards including electrocution, scalding and pressure induced ruptures are more likely with TCH than with conventional technologies. Mobilized contaminants may migrate off site, and therefore hydraulic and pneumatic control should be demonstrated before commencement of in-situ TCH. In addition to these limitations, the energy costs associated with heating the subsurface to the high temperatures required to volatilize/mobilize/or destroy contaminants are substantial. Elevated water levels may also affect these costs as the latent heat of vaporization must first be overcome before the soil can be heated. The higher temperatures achievable by TCH also pose problems to installed equipment. Monitoring wells installed around AOC-65 and SWMU B-3, primarily polyvinyl chloride material, would need to be replaced with temperature-resistant materials or pulled and plugged to avoid melting. TCH is **eliminated** as a treatment technology due to safety concerns, control of mobilized contaminants, the high energy demand associated with treating large source areas, and potential damage to infrastructure.

3.3.4.4. Collective Solar Heating

Collective solar heating utilizes solar energy to produce or augment heat energy required for thermal remediation.

Concentrated solar power (CSP) technologies are just one form of the broader solar power industry. Unlike photovoltaic technologies, which utilize semiconductors to convert solar radiation directly into energy via the photovoltaic effect, CSP stores the energy from solar radiation in the form of heat energy in a working fluid. In general, CSP technologies concentrate solar radiation on a collector, which then transfers the solar radiation energy to a working fluid. Heat stored in the working fluid can then be used to generate electricity, or the heat may be used in direct heat exchange to another media. CSH is **retained** for further consideration as a component of a multi-technology remedy.

3.3.5 *In Situ* Chemical Oxidation

In situ chemical oxidation (ISCO) requires injection of an oxidant into the subsurface so a redox reaction between the oxidant and the target compound takes place, oxidizing the compounds into benign compounds. There are several different oxidants that may be used in *in situ* chemical oxidation applications. Permanganate, Fenton's, and ozone, are a few of the more commonly used chemical oxidants, and persulfate is a relatively new oxidant used in environmental remediation applications. Each of these oxidants oxidize contaminants differently based on the stoichiometry of the redox reaction between the oxidant and contaminant. The oxidants differ in type of reaction, speed of reaction, and the persistence of the oxidant.

The chemical oxidation process involves increasing the oxidation state of a substance (i.e., chlorinated solvents) by introducing an oxidant into contaminated media. The targeted compounds are then transformed into new species that are less harmful than the originals. Oxidation of the substance may occur by the addition of an oxygen atom, the removal of a hydrogen atom, and/or the removal of electrons without the removal of a proton from the target compound. ISCO is **retained** for further consideration as a treatment technology.

3.3.5.1. Permanganate

Permanganate (MnO_4^-) oxidation generally involves electron transfer to oxidize contaminants. Oxidation in this manner has a relatively low reaction rate, which may be beneficial in that the oxidant has more time to reach contaminants farther away from the injection site. MnO_4^- may persist in the subsurface for several months depending on its concentration, injection volume, and natural oxidant demand. The slow reaction rate/long persistence of MnO_4^- also allows for greater dispersal and a larger area of treatment. Precipitation of MnO_4^-(s) may have adverse effects for MnO_4^- injection operations including negatively impacting the mass transfer at dissolved-phase and liquid-phase contaminant (NAPL) interfaces, and causing an overall reduction in permeability. In areas with high NAPL saturation, the accumulation of precipitated MnO_2(s) may form a precipitate "halo" that reduces oxidant delivery and contaminant oxidation. Permanganate is **eliminated** from further consideration as an injectable oxidant for ISCO application in favor of persulfate, described in Section 3.3.5.4, which was determined to be more appropriate for site conditions at CSSA .

3.3.5.2. Fenton's Oxidation

In situ Fenton oxidation (ISFO) generally involves combining a hydroxyl radical (OH), produced from an intermediate reaction of hydrogen peroxide (H_2O_2) and ferrous iron (Fe(II)), with the contaminant. The OH oxidizes the contaminant by stripping off one of its electrons in order to return to a more stable hydroxyl ion. Persistence of Fenton's in the subsurface is generally low as the oxidant is generally consumed within minutes to hours after injection. In general, the reaction rates for ISFO are very fast, thus the transport distance away from the site of formation is very short. This requires the H_2O_2, the Fe(II), and the target contaminant to be in the same location at the same time for ISFO to be effective.

The fast reaction time of the hydroxyl ion likely means that contaminants deeper in the subsurface and farther away from the injection wells will only be marginally affected, if at all. ISFO and related reactions are exothermic, resulting in heat release and accumulation near injection wells. Although some increase in temperature is good for natural attenuation, temperatures exceeding 200°C (hot enough to melt polyvinyl chloride) have been encountered when performing ISFO, which poses a risk to current remediation assets at AOC-65. Additionally, the release of oxygen as a byproduct of the reaction may be considered problematic. At CSSA, the formation of oxygen in the fractured media will likely lead to pneumatic transport of contaminated groundwater away from the injection well as pressure builds in the subsurface. ISFO is **eliminated** from further consideration as an injectable oxidant for ISCO application.

3.3.5.3. Ozone

In situ ozone oxidation (ISOO) involves injecting a mixture of air and ozone into the subsurface. ISOO injections can either be above or below the water table. Injecting air and ozone below the water table may be accomplished using vertical or horizontal wells. As the air and ozone flow upward through the saturated zone, contaminants are volatilized into the air or are oxidized directly or indirectly via reactions associated with ozone. The delivery system is effectively an air sparging system with an additional ozone generator and compressor. Recovery of volatile emissions is generally accomplished using a soil vapor extraction system, thus subject to the same shortcomings as Air Sparging and SVE systems employed at CSSA within the fractured bedrock. Ozone is **eliminated** from further consideration as an injectable oxidant for ISCO application.

3.3.5.4. Persulfate

Persulfate salts (i.e., sodium persulfate) in aqueous solutions dissociate to form the persulfate anion $S_2O_8^{2-}$. By itself $S_2O_8^{2-}$ is capable of degrading many types of contaminants, and has an oxidation potential of 2.1V, which is greater than the oxidation potential of permanganate (1.7V). Persulfate can be catalyzed to form the sulfate radical (SO_4^-), which has an even greater oxidation potential (2.6V). The catalysis of persulfate may be accomplished in a number of ways, including: increasing temperatures, photo (ultraviolet) activation, addition of general activators like Fe (II), copper, silver, manganese, cerium, and cobalt, with base conditions, or with H_2O_2. In addition to having a greater oxidation potential, the sulfate radical can also degrade a wider array of contaminants, the reaction rates are much quicker, and the formation of SO_4^- may initiate the formation of OH.

Sodium persulfate has high solubility, unlike potassium persulfate, and will not leave undesirable reaction products like ammonia from ammonium persulfate. Because the solubility of sodium persulfate is high, density of the injection fluid is greater than water. Density-driven transport may allow a high concentration solution to be delivered farther from the injection site and consequently affect a greater volume of contaminated media.

Persulfate is more stable than many of the other oxidants used for ISCO applications, like ozone and hydrogen peroxide. Similarly, the sulfate radical is more stable than OH. Although the reaction rate for persulfate is not as long as permanganate (up to a few weeks rather than months), it is long enough for density-driven and diffusive transport to affect areas much farther from the injection sites than ISFO. Treatability studies, including the injection of persulfate activated with high pH, at AOC-65 are ongoing and further monitoring is required to determine efficacy of ISCO applications within the fractured limestone. Persulfate is **retained** for further consideration as an injectable oxidant for ISCO application.

3.3.6 Surfactant/Cosolvent Flushing

Flushing technologies involve the injection of a surfactant or cosolvent solution. As the solution passes through contaminated soil, contaminants are mobilized. The solution-contaminant mixture is then extracted by a series of extraction wells down gradient from the injection wells. The number of injection and extraction wells and their placement is determined by geological, hydrological, and engineering considerations. A wastewater treatment system is required to treat the solution-contaminant mixture.

Surfactants are generally economical, especially when they are recycled; however, there are a few disadvantages that prevent their application at CSSA. There is no destruction/transformation of contaminants and if groundwater flow is not fully understood, the recovery system may not capture the mobilized contaminants prior to off-post migration toward private drinking water wells. At CSSA, Building 90 (AOC-65) is less than 150 feet from the fence line, and the closest potential receptor is less than 1,500 feet away. The fractured nature of the geology at CSSA prevents a full understanding of groundwater flow-paths and therefore a clear understanding of surfactant/contaminant migration pathways. In general, USEPA and state regulatory agencies do not support the use of surfactants and cosolvents as a groundwater remediation technology due to concerns about the toxicity of the surfactant, masking effects, transfer of contaminants from soil to groundwater, satisfactory hydrologic control, and adequate monitoring to ensure that processes taking place in the subsurface are understood (USEPA 1995). Flushing technologies, including surfactant and cosolvents, are **eliminated** from further consideration as a potential treatment technology.

3.3.7 Bioremediation

Bioremediation is the use of naturally occurring organisms to mineralize NAPL) contaminants *in situ*. Under normal conditions, bioremediation is one of the processes responsible for natural attenuation.

Enhanced anaerobic bioremediation (EAB) can be an effective method for degrading CAHs present in groundwater. The addition of an organic substrate to an aquifer has the potential to stimulate microbial growth and development, creating an anaerobic environment that can greatly enhance rates of reductive dechlorination. Applying EAB to contaminant source zones can significantly reduce contaminant mass in the subsurface and also reduce or prevent the continued migration of contaminants away from the source area. Advantages of EAB include complete mineralization of the contaminants *in situ* with little impact to infrastructure or the need for secondary treatment.

In general, biotic anaerobic reductive dechlorination occurs by sequentially removing chloride ions. Thus, the degradation path is the sequential transformation of PCE to TCE to the DCE isomers (*cis*-DCE or trans-DCE) to vinyl chloride to ethene. In this reaction, hydrogen, the electron donor, is oxidized. The chlorinated ethene molecule, the electron acceptor, is reduced.

A multi-year bioremediation treatability study was conducted at SWMU B-3 utilizing a bioreactor. Results from this study show that complete reductive dechlorination is occurring in areas within the vadose zone and saturated portions of the limestone bedrock. Bioremediation is **retained** as a viable treatment technology.

3.3.8 Barrier Technologies

Barrier technologies, including permeable reactive barriers (PRBs) and impermeable containment barriers are designed to contain or direct groundwater flow. PRBs treat contaminated groundwater as it flows through the barrier via a number of treatment technologies (i.e., zero-valent iron or EAB). Containment barriers isolate contaminated groundwater from clean groundwater, eliminating the possibility of plume migration. Containment barriers provide no reduction in contaminant concentrations.

PRB technologies are not designed to constrain the flow of groundwater; rather, they are designed to allow groundwater to flow through them easily and treat the incoming contaminated groundwater within the barrier itself as it passes. Immobilization and chemical transformation are two ways contaminants may be treated as groundwater passes through the reactive zone of a PRB. PRBs are essentially passive treatment systems installed in the subsurface to intercept a groundwater contamination plume and act as a barrier to the contaminants, not groundwater. Two types of barrier technologies include zero-valent iron reactive barriers and bio-barriers.

For either of these barrier technologies to succeed, a less permeable confining layer must be present to prevent untreated contaminated groundwater from flowing under the barrier. Both PRBs and containment barrier technologies are **eliminated** due to the depth to groundwater, large fluctuations in groundwater, and incomplete determination of groundwater flow paths at the site resulting from subsurface karst features.

3.3.9 Groundwater Extraction via Interceptor Trenches

Groundwater extraction involves removing contaminated groundwater from the aquifer to control plume migration. Groundwater may be extracted using wells or interceptor trenches. An understanding of the geology and hydrogeologic conditions at the site are requisites for installing any groundwater extraction system. Wells must be positioned appropriately to ensure complete plume capture via overlapping radii of influence and screened in appropriate hydrostratigraphic zones. Interceptor trenches should be constructed perpendicular to groundwater flow.

At CSSA, numerous studies have been conducted to enhance the understanding of site geologic and hydrogeologic conditions. In 2014, USGS prepared a 3D model which shoes a very complex geologic setting with numerous normal faults throughout. These faults affect groundwater flow, as do karst features, in ways that are not homogeneous or consisted, depending on the formations involved. In addition, flow may be different at different water elevations. In other words, greoundwater flow direction may change depending on how much water is in the aquifer at the time. Over 20 years of monitoring has shown over 60 feet in variability in groundwater elevations. Therefore, plume capture via interceptor trenches has been **eliminated** due to the groundwater depth and variable flow.

3.3.10 Groundwater Extraction via Wells

Contaminated groundwater can be pumped from the aquifer via a network of wells. The well design, pumping system, and treatment are dependent on the site characteristics and contaminant type. Often, several wells will extract groundwater at the same time. These wells may be screened at different depths to maximize effectiveness. A major component of any groundwater extraction system is a monitoring program to verify its effectiveness. Monitoring the cleanup effort allows adjustments to be made to the system in response to changes in subsurface conditions.

A major issue for pump-and-treat systems is determining when to turn them off. Termination requirements are generally based on the cleanup objectives defined in the initial stage of the remedial process, combined with site-specific aspects revealed during remedial operations.

Groundwater remediation approaches for dense, non-aqueous phase liquid (DNAPL) (e.g., TCE and PCE) in fractured bedrock environments such as CSSA have historically employed groundwater extraction and *ex situ* treatment (i.e., pump-and-treat). Unfortunately, pump-and-treat is typically unable to significantly improve groundwater quality, even after relatively long periods (i.e., decades) of operation. The limited performance of most pump-and-treat systems stems largely from the inability to significantly accelerate the rate of mass transfer from the DNAPL into the aqueous phase (e.g., dissolution). In a fractured flow system, it is also difficult to ensure complete plume capture. Groundwater extraction via wells as a standalone pump-and-treat remedial technology is **eliminated**; however, it is **retained** as a component of a multi-technology remedial alternative such as bioremediation. Wells are currently used as a component of the SWMU B-3 treatment system to recover contaminated groundwater for bioreactor reinjection.

3.3.11 Post Extraction Treatment

Treatment can range from physical treatment technologies, such as activated carbon treatment, air stripping, filtration, sedimentation, or reverse osmosis, or chemical treatments, including ion exchange and precipitation and flocculation. Contaminants are adsorbed to activated carbon granules within packed bed reactors.

GAC is a physico-chemical treatment that removes contaminants by adsorbing them directly from the groundwater stream. Advantages to GAC include:

- Appropriate for many organic compounds, including VOCs, SVOCs, and other non-VOCs;

- Low operator labor needs;
- Simple technology;
- Readily available from vendors;
- Relatively low capital and O&M costs.

GAC units are successfully used on-post at CSSA and as a point-of-use treatment at off-post drinking water wells. Seven off-post wells (six different users) have GAC units due to past VOC exceedances (LS-7, RFR-10, OFR-3, RFR-11, LS-5, and LS-6). These wells are monitored to ensure VOCs in the supply groundwater do not exceed MCLs. Samples from these wells have been collected from groundwater prior to and after passing through the GAC units. Analytical results indicate there are no exceedances in the samples collected after the groundwater has passed through the GAC units. The GAC units have been in place since 1999 with no complaints from the residents. The continued use of GAC to treat contaminated groundwater is **retained** as a component of multi-technology remedial alternatives.

Sedimentation, as well as precipitation and flocculation are **eliminated** as viable treatment technologies due to anticipated maintenance requirements and treatment and disposal requirements for potentially hazardous sludges derived from use of these technologies.

Reverse osmosis may be effective at removing organics and dissolved inorganics from extracted groundwater; however, this process requires an additional step prior to treatment. Solids must first be removed before extracted groundwater is forced through a semi-permeable membrane. Some limitations of reverse osmosis include (ITRC 2008):

- Membrane resilience and fouling;
- Produces a waste stream requiring management;
- Membrane filters have small pore sizes and require a higher operating pressure than other membrane treatment technologies; and
- The lack of ionic selectivity in the semipermeable membrane can alter the pH of the effluent stream and make it corrosive.

Additional cost and maintenance **eliminates** reverse osmosis from consideration as a remedial alternative at CSSA.

Chemical treatments, including the use of ion exchange and adsorption, are successfully used to treat groundwater containing arsenic (which is not an issue at CSSA). However, the media used within reactors for ion exchange (resins, greensands, or activated alumina) require regeneration or replacement, thereby generating a potentially hazardous waste stream and potentially significant operations and maintenance costs. Chemical treatments are therefore **eliminated** as a potential treatment technology.

3.3.12 Post-Extraction Disposal

Treated extracted groundwater may be discharged as irrigation water, to on-site surface water, or to an industrial water supply. All three of these options require analysis of the treated groundwater prior to discharge. On-site surface water discharge requires a long term National Pollution Discharge Elimination System permit, and discharge to an industrial water supply requires an industrial end use. These options are therefore eliminated from further consideration.

Discharge to a publicly owned treatment works or disposal facility via deep well injection also requires analysis of treated (or untreated) groundwater prior to discharge, but also requires prior authorization by the local sewage treatment authority and may also require transport of extracted groundwater to the facility and are therefore eliminated from further consideration. Extracted groundwater is currently re-injected into the bioreactor at SWMU B-3 as part of normal bioreactor operations to aid reductive dechlorination. Re-injection in association with bioremediation is **retained** as a component of multi-technology remedial alternatives at CSSA.

3.4 SCREENING OF TECHNOLOGIES

All groundwater remediation technologies considered technically implementable at CSSA were screened against three criteria: effectiveness, implementability, and cost. Each of these criteria is described in further detail below:

- Effectiveness: The assessment of effectiveness considers whether the technology is capable of achieving the CAOs;
- Implementability: Because technologies will not be considered initially unless they are technically implementable, this part of the screening focuses on the administrative and institutional implementability of the technology (e.g., likelihood of community and/or regulator acceptance or resistance based on safety or other concerns); and
- Cost: This criterion represents the relative cost of implementing and operating the technology.

All the technologies for groundwater described in Section 3.3 were subjected to screening against the three criteria described above. **Table 3.1** shows these technologies and the results of the screening for the CSSA. Technologies were retained for consideration and inclusion in the CMAs if they were deemed effective, implementable, and practical based on cost. Technologies were eliminated by this screening if they did not meet one of the three criteria. Following the screening, the technologies eliminated from further consideration were plume containment, source containment, PRB, phytoremediation, interceptor trench, filtration, and sedimentation. **Table 3.1** shows the reasons why the technologies listed either do or do not meet the screening criteria. Technologies retained for further evaluation in Section 4 are highlighted in blue.

Table 3.1
Preliminary Screening of Remediation Technologies for Contaminated Soil and Groundwater

General Response Action - Groundwater	Remedial Technology	Process Options	Description	Screening Comments	Effectiveness	Implement-ability	Cost	Retain for Further Consideration
No action	None	None	Leave groundwater as is. No monitoring or investigation.	Contamination is not mitigated. Does not comply with Corrective Action Objectives (CAOs).	Not effective	NA	None	Yes, as a baseline for other alternatives
Institutional control	Administrative Controls	None	Deed restriction would be implemented to ensure that the site is used for only purposes compatible with future, post-remediation conditions.	Institutional, engineering, and administrative controls are capable of attaining the remedial action objective of limiting human access to impacted soil and groundwater. Contamination is not mitigated. Does not comply with CAOs.	Because groundwater may contact impacted soil at SWMUs and AOCs, this alternative would not prevent or control the leaching of COPCs from soil to groundwater.	Easily implemented; long-term maintenance	Low	Yes, as part of other potential remedial alternative(s)
	Engineering Controls	Groundwater monitoring	Monitoring allows for tracking of plume migration. Usually combined with deed restrictions.	Groundwater monitoring will likely be a component of any remedial alternative.	Monitoring does not prevent site-related COPC migration via groundwater to surface water discharge points at concentrations greater than site specific calculated groundwater cleanup levels.	Easily implemented; long-term maintenance	Low	Yes, as part of other potential remedial alternative(s)
Plume containment	Containment	Extraction wells	Line of extraction well or well points are installed and pumped to capture the plume. Trenches may also be used to intercept and collect ground-water.	May be used as a barrier and for extraction of groundwater for treatment. Complete definition of plume is required. Continued LTM monitoring and maintenance required.	Effective in limiting further horizontal migration, does not, by itself remediate. Long periods of time needed to remove several pore volumes.	Readily implemented	Moderate to high	No

Table 3.1 *(continued)*
Preliminary Screening of Remediation Technologies for Contaminated Soil and Groundwater

General Response Action - Groundwater	Remedial Technology	Process Options	Description	Screening Comments	Effectiveness	Implement-ability	Cost	Retain for Further Consideration
Plume containment (cont.)	Vertical barriers	Slurry walls, grout curtains, sheet-piling cut-off walls	Low permeability cut-off walls are installed below ground to contain, capture, or redirect groundwater flow. Leachate recovery system must be included.	Full extent of plume must be defined. Does not mitigate contamination. May be used in conjunction with additional *in situ* treatment.	Limited, due to inability to create a totally impervious wall. Additionally does not prevent vertical migration.	Difficult to construct; depth limitations	High	No
Source containment	Capping	Low permeability caps and/or liners	Source sites capped with low permeability clays, geomembrane, asphalt, concrete or a combination to prevent surface water infiltration and creation of leachate.	Requires LTM. Leachate not a factor with source removal.	Generally effective in limiting further waste migration. Does not abate contamination below the water table. Does not prevent groundwater movement through affected areas.	Easily implemented	Moderate	No
	Vertical barriers	Upgradient slurry walls, grout curtains, sheet-piling, cutoff walls	Low permeability walls up-gradient prevent groundwater flow through source located below the water table.	Full extent of plume must be defined. Does not mitigate contamination. May be used in conjunction with additional *in situ* treatment.	Limited, due to inability to create a totally impervious wall.	Difficult to construct; depth limitations.	Moderate to High.	No
Source removal	Excavation	On-site management	Removal of contaminated soil would require excavation and potential further treatment and management.	Soils would require treatment to meet land disposal restriction requirements for management on-site with an Area of Contamination.	Most effective in source and hot spot control.	Easily implemented	Moderate	Yes

Table 3.1 (continued)
Preliminary Screening of Remediation Technologies for Contaminated Soil and Groundwater

General Response Action - Groundwater	Remedial Technology	Process Options	Description	Screening Comments	Effectiveness	Implement-ability	Cost	Retain for Further Consideration
In-Situ groundwater treatment	Permeable Reactive Barrier (PRB)	Passive treatment of contaminate groundwater	Installation of a passive treatment system, to address potential groundwater migration to surface water.	Plume must be fully defined. Additional wells may be required. Water is 250’-350’ deep, unlikely to migrate to surface. Groundwater flow direction must be fully characterized.	Has limited effectiveness due to water depth, fluctuating depth of water and incomplete determination of groundwater flow paths.	May be readily implemented	Moderate to high	No
	Enhanced anaerobic bio-remediation	Wells, trenches	Trenches maybe dug then backfilled with mulch to create anaerobic conditions. Wells can be installed for injections.	Pilot testing needed to determine most suitable in-situ groundwater treatment system and components.	Effective when radius of influence overlaps or permeable trenches int-ercept groundwater for further treatment in-situ.	Readily implemented and maintained	Moderate to high	Yes
	Phyto-remediation	Poplar Trees	Use of plants to contain contaminants in groundwater.	Groundwater located approximately 250’-350’ bgs. Phytoremediation is not applicable for containment at these groundwater depths. Also generates wastes that must be managed appropriately.	Phytoremediation not effective for groundwater at depths encountered in the Middle Trinity Aquifer.	Depth limitations	Moderate to high	No
Groundwater extraction	Wells	Enhanced Anaerobic extraction wells	Wells intended to provide enhanced anaerobic bioremediation efforts with groundwater.	Well screening must be done and well placement and depths located and reviewed.	Potentially effective.	Readily implemented and maintained	High	Yes, as part of other potential remedial alternatives
	Interceptor trench	Groundwater recovery	Trenches are dug then backfilled with a porous material to collect ground-water. Water is removed by pumping.	Used in slow recharge areas. Limited by depth.	Not effective at the depths required at CSSA, nor for fluctuating groundwater depths.	Depth limitations	High	No

Table 3.1 (*continued*)
Preliminary Screening of Remediation Technologies for Contaminated Soil and Groundwater

General Response Action - Groundwater	Remedial Technology	Process Options	Description	Screening Comments	Effectiveness	Implement-ability	Cost	Retain for Further Consideration
Post extraction treatment	Physical treatment	Activated carbon treatment	Extracted groundwater allowed to flow through a series of packed bed reactors. Metals are adsorbed to the carbon granules.	Periodically, the carbon granules must be regenerated or disposed of. Pretreatment may be required to remove suspended solids. Point of use treatment only.	Has proven very effective for removal of COPCs.	Easily implemented	Moderate to high	Yes
		Filtration	Suspended solids are removed from solution by forcing the fluid through a porous medium.	Requires backflushing to unclog filter. Usually used as part of a treatment train.	Has proven very effective for removal of suspended solids.	Easily implemented may be difficult to maintain	Moderate to high	No
		Sedimentation	Relies upon gravity to remove suspended solids. Collection of sediments in a tank or pond. A sediment removal system must be incorporated.	Generates a large volume of sludge and is relatively slow. Sludge will likely need further treatment/disposal at appropriate facility.	Effective for settleable solids.	More difficult to implement than other technologies	Moderate to high	No

Table 3.1 (continued)
Preliminary Screening of Remediation Technologies for Contaminated Soil and Groundwater

General Response Action - Groundwater	Remedial Technology	Process Options	Description	Screening Comments	Effectiveness	Implement-ability	Cost	Retain for Further Consideration
Post extraction treatment (cont.)	Physical treatment (cont.)	Reverse osmosis	The application of sufficient pressure to concentrate solution to overcome osmotic pressure and force the net flow through the membranes toward the dilute phase.	Pretreatment required for removal of solids.	Very effective for removal of organics and dissolved inorganics.	More difficult to implement than other technologies	Moderate to high	No
	Chemical treatment	Ion exchange resins, iron based adsorption media, and/or activated alumina	Contaminated groundwater is passed through ion-exchange resins, iron based adsorption media, (e.g., greensand), or activated alumina in a reactor to treat recovered groundwater in an ion exchange or adsorption removal process	Ion exchange and adsorption technologies have been successfully used to treat groundwater containing arsenic. Technology requires treatment media regeneration or replacement generating potential hazardous solid waste stream and potentially significant operations and maintenance costs.	Effective for As(v) compounds and not as effective for As(III) compounds. Competing ions may inhibit effectiveness of the technology.	More difficult to implement than other technologies due to operations and maintenance requirements	Moderate to high	No
		Precipitation/ flocculation	Removal of metals as hydroxides or sulfides is the most common precipitation application. Lime or sodium sulfide is added in a rapid mixing tank. Mixture flows to a flocculation chamber and precipitation occurs, followed by filtration or sedimentation.	Selection of suitable precipitate or of flocculant and dosage determined in the laboratory. Generates a large volume of sludge which must be disposed of, in addition to treated groundwater.	Has proven very effective for removal of dissolved metals.	Easily implemented	Low to moderate	No

Table 3.1 (continued)
Preliminary Screening of Remediation Technologies for Contaminated Soil and Groundwater

General Response Action - Groundwater	Remedial Technology	Process Options	Description	Screening Comments	Effectiveness	Implement-ability	Cost	Retain for Further Consideration
Discharge of groundwater	Disposal	Reinjection via Enhanced Anaerobic Bio-remediation	Once the conditioned water is through the bioreactor, it is allowed to infiltrate groundwater.	Due to location of extraction wells, water will be cycled back through bioreactor and conditioned further.	Effective when combined with Enhanced Anaerobic Bioremediation.	Easy to implement and maintain.	Low	Yes, as part of other potential remedial alternative(s)
		Deep well injection	Discharge treated or untreated groundwater to regulated deep well injection system.	Water would have to be transported to disposal facility.	Effective	Fairly easy to implement	High to very high	No
		Surface water	Discharge treated groundwater to on-site surface water.	Continual analysis of treated water prior to discharge.	Effective	Requires long term NPDES permit	Moderate to high	No
		POTW (publicly owned treatment works)	Discharge treated or untreated groundwater to local POTW.	Analysis of water prior to discharge required.	Effective	Requires approval from local sewage treatment authority	Moderate	No
		Irrigation	Discharge treated groundwater to irrigate golf course or other vegetation.	Requires analysis of treated water and permission.	Effective	Poor with public perception	Moderate	No
		Industrial water supply	Discharge treated groundwater to industrial water supply system.	Analysis of treated water and permission.	Effective	Easy to implement; need Industrial end use	Moderate	No

Table 3.1 (continued)
Preliminary Screening of Remediation Technologies for Contaminated Soil and Groundwater

General Response Action - Soil	Remedial Technology	Process Options	Description	Screening Comments	Effectiveness	Implement-ability	Cost	Retain for Further Consideration
Soil treatment	In-situ treatment	Chemical Fixation/Stabilization	Reagents may be mixed within the surface soils to reduce leaching of COPCs to groundwater and to potential surface water.	Effectiveness of in-situ stabilization is unknown; however benchscale studies may predict the effectiveness and longevity of the soil treatment.	Can be effective. May be difficult to evaluate performance.	Proper evaluation and design required for implementa-tion	Moderate	Yes
		Biological Attenuation	Biological treatment uses bacterial organisms to reduce the mobility of contaminants through the creation of insoluble complexes in soil.	Limited data on technical approach with several complicated variables needed for meeting CAOs.	Effectiveness is unknown and may be difficult to implement	Not recommended for field implementa-tion	Unknown	No
Soil Excavation	Removal of impacted soils	Excavation with off-site management	Removal of contaminated soils with off-site disposal.	Soils would not be treatment prior to off-site disposal.	Effective	Easily implemented	High to very high	Yes
		Excavation with on-site management	Removal of contaminated soil would require excavation and potential further treatment and management.	Soils would require treatment to meet land disposal restriction requirements for management on-site with an Area of Contamination.	Most effective in removing soil exposure pathway.	Easily implemented	Moderate	Yes
Source Barrier	Capping	Fill material	Source sites covered with barrier material such as fill soils or gravel to prevent exposure of site soils to human health of ecological receptors.	Requires LTM. Contaminated soil has been removed, capping not necessary.	Generally effective in limiting exposure. Does not abate contamination caused by waste below the surface cover or leaching of contaminants to groundwater.	Easily implemented	Moderate	No

SECTION 4

DEVELOPMENT OF CORRECTIVE MEASURES ALTERNATIVES

This section describes the development of CMAs for SWMU B-3 and AOC-65 at CSSA using the technology process options retained during the detailed screening process in Chapter 3. Development of CMAs is the final step of the multistep process for identifying, screening, and developing CMAs as presented in USEPA's guidance, titled *RCRA Corrective Action Plan (Final), OSWER Directive 9902.3-2A* (USEPA, 1994). The CMAs are developed to meet the CAOs for the applicable site; therefore, the range of CMAs can vary for different sites. Each CMA may comprise an individual technology or a combination of technologies. This section lists and briefly describes each CMA.

4.1 RATIONALE FOR ALTERNATIVE DEVELOPMENT

CMAs for CSSA were developed based on the CSM (Parsons, 2014); the current and possible future land uses for SWMU B-3 and AOC-65; and the CMOs for groundwater outlined in Section 2.2.

Based on the above considerations, as well as the factors affecting consideration of remedial alternatives for groundwater outlined in Section 3.3, the CMAs developed for CSSA are as follows:

- Alternative 1: No Action;
- Alternative 2: Point-of-Use Treatment, LUCs, and LTM;
- Alternative 3: Alternative Drinking Water Source, LUCs, and LTM; and
- Alternative 4: Source Area Treatment, Point-of-Use Treatment, LUCs, and LTM.

Detailed descriptions of the CMAs developed for CSSA are included in the following sections.

4.2 ALTERNATIVE 1 – NO ACTION

No further action means no corrective measures would be implemented to reduce the exposure to contaminated groundwater at CSSA, and would involve continued use of the site in its current condition. This alternative is provided as a baseline against which other CMAs can be compared. Long-term potential human health and environmental hazards at the site would remain as identified in the baseline risk assessment.

4.3 ALTERNATIVE 2 – POINT-OF-USE TREATMENT, LAND USE CONTROLS, AND LONG-TERM MONITORING

This alternative involves implementing institutional and engineering LUCs to prevent contact with contaminated media. Current off-post point-of-use treatment systems (GAC units) would continue to be operated and monitored, and new GAC units would be installed at additional off-post drinking water wells if necessary. The process and rationale for determining when a GAC unit is installed on a wellhead is outlined in the *Off-Post Monitoring Program Response Plan* (Parsons, 2002) in **Appendix A**.

Administrative controls are already in place at the site and include industrial zoning, security guards, and intrusive activity permits. Intrusive activity permits ensure that anyone conducting subsurface activities at the site in the future consider the appropriate health and safety protection. Currently, CSSA is surrounded by a fence and manned with security guards.

Institutional engineering and administrative controls are capable of attaining the remedial action objective of limiting human access to impacted soil and groundwater on-post. However, because groundwater may contact impacted soil at SWMUs and AOCs, this alternative does not prevent or control the leaching of contaminants from soil to groundwater. Also, institutional engineering and administrative controls do not limit access to impacted groundwater off-post.

Routine off-post groundwater sampling began in 2001 and would continue into the foreseeable future. Current data quality objectives (DQOs) (Parsons 2009) that provide the basis for frequency of drinking water well sampling and remedial actions taken will remain in place. After each groundwater sampling event, CSSA will mail the well owners their specific results from the sampling event. On-post drinking water is monitored on a quarterly basis. Current on- and off-post LTM programs would continue under Alternative 2.

Any reduction in plume or source area contaminant concentrations would occur only through natural attenuation processes and would be monitored as part of the LTM program.

4.4 ALTERNATIVE 3 – SOURCE AREA TREATMENT, ALTERNATIVE DRINKING WATER SOURCE, LAND USE CONTROLS, AND LONG-TERM MONITORING

This alternative includes the LUC and LTM components described above in Alternative 2 with the addition of bioremediation to treat source area contamination at SWMU B-3 and ISCO to treat source area contamination at AOC-65. However, rather than continuing current and off-post drinking water treatment (GAC) and monitoring, all six off-post groundwater users would be provided with drinking water from the San Antonio Water System (SAWS) to eliminate their exposure to contaminated groundwater.

Source area treatment via bioremediation is capable of complete reduction of chlorinated ethenes (e.g., PCE) as evidenced by results of a multi-year-long bioreactor treatability study at SWMU B-3. The efficacy of bioremediation treatment is limited by the successful distribution of carbon and the establishment and maintenance of conditions within the subsurface supportive of reductive dechlorination. Although the intermediate dechlorination product vinyl chloride, generated during sequential reductive dechlorination, is more hazardous than the parent PCE due to its inherent toxicity, the absence of potential receptors at SWMU B-3 mitigates potential exposure. However, source treatment utilizing a bioreactor and bioremediation at AOC-65 is not recommended, due to the potential for vinyl chloride generation and proximity of this source area to potential receptors.

Source area treatment via ISCO is capable of complete destruction of chlorinated ethenes. The efficiency of ISCO treatment is limited by successful distribution of the oxidant and oxidant contact time with contaminants. Sodium persulfate is denser than water; thus, when injected into the subsurface, it is thought to follow the same flow paths as released contaminants. Additionally, sodium persulfate has a relatively long reaction time, potentially increasing the time in contact with source area contaminants.

4.5 ALTERNATIVE 4 – SOURCE AREA TREATMENT, POINT-OF-USE TREATMENT, LAND USE CONTROLS, AND LONG-TERM MONITORING

This alternative includes GAC treatment, LUC, and LTM components described above in Alternative 2 with the addition of bioremediation to treat source area contamination at SWMU B-3 and ISCO to treat source area contamination at AOC-65 as described in Alternative 3.

SECTION 5
EVALUATION OF CORRECTIVE MEASURE ALTERNATIVES

This chapter contains detailed evaluations of the CMAs that address the CMOs for groundwater contamination at CSSA. In compliance with the Order, each alternative is evaluated according to the following criteria (USEPA, 1994 and 1999):

- **Protective of Human Health and the Environment**. This standard for protection of human health and the environment is a general mandate of the RCRA statute. The standard requires that remedies include any measures needed to be protective. These measures may or may not be directly related to media cleanup, source control, or management of waste. An example would be a requirement to provide alternative drinking water supplies to prevent exposures to a contaminated drinking water supply.
- **Attain Media Cleanup Standards**. Corrective measures are required to attain media cleanup standards set by State or federal regulations (e.g., groundwater standards). The media cleanup standards for a corrective measure will often play a large role in determining the approach of implementing the remedy.
- **Control the Sources of Releases**. This criterion address the issue of whether source control measures are necessary, and if so, the type of actions that would be appropriate. Any source control measure proposed should include a discussion on how well the method is anticipated to work given the particular situation at the facility and the known track record of the specific technology.
- **Comply with Any Applicable Standards for Management of Waste**. This includes a discussion of how the specific waste management activities will be conducted to comply with all applicable state or federal regulations (e.g., closure requirements, land disposal restrictions).
- **Long-Term Reliability and Effectiveness**. In evaluating the long-term reliability and effectiveness of a corrective measure, USEPA will place an emphasis on its ability to provide adequate protection of human health and the environment over the long term. It should be considered whether the technology, or combination of technologies, has been used effectively together under analogous site conditions, whether failure of any one technology in the alternative will have an immediate impact on receptors, and whether the alternative will have the flexibility to deal with uncontrollable changes at the site (e.g., heavy precipitation, high winds, etc.) or the projected useful life of the overall alternative and of its component technologies. Useful life is defined as the length of time the level of effectiveness can be maintained.
- **Reduction in the Toxicity, Mobility, or Volume (TMV) of Waste**. As a general goal, remedies preferred by USEPA employ treatment technologies capable of eliminating or substantially reducing the inherent potential for waste to cause future environmental releases or other risks to human health and the environment. Estimates of how much the corrective measures alternatives will reduce the waste

toxicity, volume, and/or mobility may be helpful in applying this factor. This may be done through a comparison of initial site conditions to expected post-corrective measure conditions.

- **Short-Term Effectiveness**. Short-term effectiveness may be particularly relevant when remedial activities will be conducted in densely populated areas, or where waste characteristics are such that risks to workers or to the environment are high and special protective measures are needed. Possible factors to consider include fire, explosion, exposure to hazardous substances, and potential threats associated with treatment, excavation, transportation, and redisposal of containment of waste material.
- **Implementability**. Implementability will often be a determining variable in shaping remedies. Some technologies will require state or local approvals prior to construction, which may increase the time necessary to implement the remedy. In some cases, state or local restrictions or concerns may necessitate eliminating or deferring certain technologies or remedial approaches from consideration. Information to consider when assessing implementability may include:
    1. Administrative activities needed to implement the corrective measure alternative (e.g., permits, rights-of-way, off-site approvals) and the length of time these activities will take;
    2. Constructability, time for implementation, and time for beneficial results;
    3. Availability of adequate off-site treatment, storage capacity, disposal services, needed technical services, and materials; and
    4. Availability of prospective technologies for each CMA.
- **Cost Estimate**. The relative cost of a remedy may be an appropriate consideration in situations where several different technical alternatives to remediation will offer equivalent protection of human health and the environment, but may vary widely in cost. Cost estimates may include costs for: engineering, site preparation, construction, materials, labor, sampling/analysis, waste management/disposal, permitting, health and safety measures, training, and operation and maintenance.

A present value analysis is used to evaluate costs (capital costs and costs for operations and maintenance) that occur over different time periods. The total present value (TPV) is the amount needed to be set aside at the initial point in time (base year) to assure that funds will be available in the future as they are needed. The discount rate of 7% per the USEPA guidance, *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study,* (USEPA, 2000) was used to estimate TPV. Contingency costs also were determined using this guidance.

- **Public Involvement.** After the CMS is performed and USEPA selects a preferred alternative for proposal in the Statement of Basis, it is the agency's policy to request public comment on the Administrative Record and the proposed corrective measure(s). Changes to the proposed corrective measure(s) may be made after consideration of public comment. After consideration of the public's comments on the proposed corrective measure, the agency develops the Final Decision and Response to Comments to document the selected corrective measure, the agency's justification for such selection, and the response to the public's comment. The public involvement criterion is based on the degree of assumed acceptance from the public regarding the implementation of alternatives, and therefore, cannot be fully evaluated and assessed until comments on the Statement of Basis are received.

- **Sustainability**. The "Sustainability" criterion was not originally included in the Order, but was added to this CMS to keep in step with CSSA's goal of utilizing "**Green"** environmental remediation practices**.** During the evaluation of CMAs**,** sustainable practices, as outlined in USEPA's *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites* (USEPA, 2008) were considered as part of the CMS. Specifically, certain Best Management Practices of USEPA's defined core elements of Green remediation for integration into the CMS were considered:

  Land and Ecosystem Impacts:

  - Use minimally invasive technologies;
  - Use passive energy technologies such as bioremediation as primary remedies or "finishing steps," where possible and effective;
  - Minimize soil and habitat disturbance;
  - Minimize bioavailability of contaminants through adequate contaminant source and plume controls; and,
  - Reduce noise and lighting disturbance.

  Air Emissions:

  - Minimize use of heavy equipment to reduce fuel consumption, and particulate and dust emissions;
  - Use cleaner fuels and retrofit diesel engines to operate heavy equipment, when possible;
  - Minimize land disturbance and excavations to reduce overall dust emissions;
  - Reduce atmospheric release of toxic or priority pollutants (ozone, particulate matter, carbon monoxide, nitrogen dioxide, sulfur dioxide, and lead); and
  - Minimize dust export of contaminants.

  Water Consumption and Water Quality Protection:

  - Minimize fresh water consumption and maximize water reuse during daily operations and treatment processes;
  - Reclaim treated water for beneficial use such as irrigation;
  - Avoid disturbance to existing vegetation and use native vegetation where needed to reduce need for irrigation; and,

- o Prevent impacts such as nutrient loading on water quality in nearby water bodies.

Material Consumption and Waste Generation:

- o Use technologies designed to minimize waste generation;
- o Re-use materials whenever possible;
- o Recycle materials generated at or removed from the site whenever possible;
- o Minimize natural resource extraction and disposal; and
- o Use passive sampling devices producing minimal waste, where feasible.

Energy Requirements:

- o Consider use of optimized passive-energy technologies (with little or no demand for external utility power) that enable all remediation objectives to be met;
- o Look for energy efficient equipment and maintain equipment at peak performance to maximize efficiency;
- o Periodically evaluate and optimize energy efficiency of equipment with high energy demands; and
- o Consider installing renewable energy systems to replace or offset electricity requirements otherwise met by the utility.

Long-Term Monitoring and Environmental Stewardship:

- o Reduce emission of greenhouse gases contributing to climate change;
- o Integrate an adaptive management approach into long-term controls for a site;
- o Install renewable energy systems to power long-term cleanup and future activities on redeveloped land;
- o Use passive sampling devices for LTM, where feasible; and
- o Solicit community involvement to increase public acceptance.

5.1 ALTERNATIVE 1 - NO ACTION

A detailed description of this CMA is provided in Section 4.2. No Action is included as a baseline for comparison purposes only. It contains no remedial measures, engineering or administrative controls, or monitoring of contaminated groundwater. Alternative 1 provides a description of current conditions to compare to the potential effects of the proposed Alternative 2, 3, and 4. The RFI Report (Parsons, 2014) provides an overall description of the general site conditions. These conditions would not substantially change under this alternative.

5.1.1 Protective of Human Health and the Environment

The No Action alternative would allow contamination to remain in place and have no effect on the migrating contaminant mass within the aquifer. This alternative would not accelerate restoration of the aquifer or be able to monitor potential threats to groundwater users. No additional protection of human health and the environment would result from implementing Alternative 1.

5.1.2 Attain Media Cleanup Standards

No treatment or remediation would be performed under this alternative, and no applicable cleanup standards would be required or attained with implementation of the No Action alternative. Contaminated groundwater that currently exceeds cleanup standards would continue to do so under Alternative 1.

5.1.3 Control the Sources of Release

No source area treatment or remediation would be performed under Alternative 1. This alternative does not include any measures to mitigate further migration of contaminants.

5.1.4 Comply with Any Applicable Standards for Management of Waste

No applicable standards for the management of waste would be triggered with implementation of the No Action alternative.

5.1.5 Long-term Reliability and Effectiveness

Alternative 1 would not entail any active removal, treatment, or containment technologies, nor any LTM of the site. Eventually, natural attenuation processes will remediate the site, but there would be no controls in place to verify that this is occurring and that receptors are protected. Therefore, this alternative would not be reliable or effective in the long term. Residual risk to human health and the environment under future conditions would remain under the No Action alternative since no monitoring or treatment of on- or off-post wells would occur.

5.1.6 Reduction in Toxicity, Mobility, or Volume of Waste

Since contaminated groundwater would remain in place and untreated under Alternative 1, no reduction in the TMV of waste would occur other than that which would result from natural attenuation processes.

5.1.7 Short-Term Effectiveness

The short-term effectiveness describes the risk to human health and the environment until CMOs are attained. Since this alternative does not include monitoring of or point-of-use treatment for on- or off-post drinking water wells, a significant human health risk would exist for consumers of contaminated groundwater.

5.1.8 Implementability

The No Action alternative would be technically feasible but may not be administratively implementable given the unacceptable impacts to human health and the environment.

5.1.9 Cost Estimate

There are no costs associated with this alternative.

5.1.10 Sustainability

No action would be taken under this alternative; therefore, sustainability is not applicable.

5.2 ALTERNATIVE 2 – POINT-OF-USE TREATMENT, LAND USE CONTROLS, AND LONG-TERM MONITORING

A detailed description of this CMA is provided in Section 4.3.

5.2.1 Protective of Human Health and the Environment

Alternative 2 is protective of human health since the current on- and off-post drinking water treatment and LTM programs would remain in place. Current LUCs would be maintained to prevent unauthorized access to and use of contaminated groundwater by human receptors.

5.2.2 Attain Media Cleanup Standards

No active treatment or remediation of the plume or source area would be performed under this alternative, and contaminated groundwater that currently exceeds cleanup standards would continue to do so under Alternative 2. The LTM program could be used to determine if and when groundwater contamination was decreased due to natural attenuation processes. Drinking water standards (MCLs) would be attained at the point-of-use through GAC filtration of contaminated groundwater.

5.2.3 Control the Sources of Release

No active source area treatment or remediation would be performed under Alternative 2. This alternative does not include any measures to mitigate further migration of contaminants.

5.2.4 Comply with Any Applicable Standards for Management of Waste

No applicable standards for the management of waste would be triggered with the implementation of the Alternative 2.

5.2.5 Long-term Reliability and Effectiveness

This alternative is permanent and would be effective over the long-term because it removes the risk to human receptors from exposure to contaminated groundwater. However, the amount of time it would take to obtain an acceptable risk to human receptors is unacceptable.

5.2.6 Reduction in Toxicity, Mobility, or Volume of Waste

Since contaminated groundwater would remain in place and untreated under Alternative 2, no reduction in the TMV of waste would occur other than that which would result from natural attenuation.

5.2.7 Short-Term Effectiveness

Alternative 2 provides immediate short-term effectiveness to protect human health since current treatment and monitoring programs will remain in place.

5.2.8 Implementability

Alternative 2 is easily implementable since current monitoring programs would remain in place.

5.2.9 Cost Estimate

The costs associated with implementing this alternative are:

	Alternative 2
Capital Cost	$1,300
30-Year O&M Cost	$16M
30-Year Total Cost	$22.1M
30-Year Total Present Value	$9.7M

Capital costs associated with this alternative include the cost to file a deed notice and update the Master Plan to restrict AOC-65 and SWMU B-3 to commercial/industrial land use. Periodic costs include one additional or replacement GAC unit (i.e., the entire GAC system and not just the filters) every other year for a total of 15 additional or replacement units over a 30-year period. Additional periodic costs assume $450,000 every other year for new or replacement wells and general well maintenance. Operation and maintenance costs include maintenance and replacement of GAC filters, and labor and laboratory costs related to sampling and project management of LTM for on- and off-post groundwater.

5.2.10 Sustainability

Alternative 2 essentially relies on long-term MNA to reduce groundwater contamination. In terms of sustainability, MNA, in general, has the following advantages:

- Less remediation-generated waste, reduced potential for cross-media transfer of contaminants, and reduced risk of onsite worker exposure to contaminants;
- Less environmental intrusion and smaller treatment-process footprints on the environment, and
- Potentially lower remediation costs compared to aggressive treatment technologies.

When compared to aggressive treatment systems, potential disadvantages of MNA include:

- More complex and costly site characterization, longer periods needed to achieve remediation objectives, and more extensive performance monitoring (with associated energy consumption);
- Continued contamination migration or renewed contaminant mobility caused by hydrologic or geochemical changes;
- Longer-term institutional controls to ensure long-term protectiveness; and
- More public outreach to gain acceptance.

Solar energy will be implemented to power environmental systems at SWMU B-3 in 2015.

5.3 ALTERNATIVE 3 – SOURCE AREA TREATMENT, ALTERNATIVE DRINKING WATER SOURCE, LAND USE CONTROLS, AND LONG-TERM MONITORING

A detailed description of this CMA is provided in Section 4.4.

5.3.1 Protective of Human Health and the Environment

Alternative 3 would effectively reduce or eliminate risks to human health by providing all six off-post groundwater consumers utilizing wellhead GAC units with drinking water from SAWS. Current LUCs would be maintained to prevent access to and use of contaminated groundwater on-post by human receptors. This alternative does not provide specific protection for ecological receptors. Additionally, source area treatment via bioremediation (SWMU B-3) or ISCO (AOC-65) removes or reduces sources of contamination; and LTM tracks changes in contaminant concentration and distribution, as well as evaluates effectiveness of the treatment systems.

5.3.2 Attain Media Cleanup Standards

Alternative 3 is able to attain cleanup standards for groundwater contamination at CSSA (USEPA drinking water standards). Sequential reductive dechlorination and chemical oxidation will achieve transformation or destruction of contaminants to levels at or below these standards given appropriate timeframes. At SWMU B-3, achieving the cleanup standard are anticipated to require between 20 and 30 years of bioreactor operation in its current configuration. Timeframes for achieving cleanup standards at AOC-65 are still being evaluated.

5.3.3 Control the Sources of Release

There are no active disposal operations at SWMU B-3 or AOC-65 and contaminants are no longer being released at the site. Source areas have been removed to the extent possible. However, existing contamination in the soil under Building 90 and fractured bedrock within the vadose zone present an ongoing source of contamination to groundwater. Bioremediation has proven to be effective in reducing contaminant mass in the vadose zone and subsequently within the main aquifer body at SWMU B-3.

5.3.4 Comply with Any Applicable Standards for Management of Waste

Waste generated would include contaminated soil from bioreactor or infiltration gallery construction and well installation, purge water, bailers, decontamination water, bag filters, and personal protective equipment. Waste derived from activities associated with implementation of this alternative would be analyzed and disposed in accordance with appropriate waste management standards and practices as specified in CSSA's waste management plan.

5.3.5 Long-term Reliability and Effectiveness

This alternative is permanent and would be effective over the long-term because it removes the risk to human receptors from exposure to contaminated groundwater. Off-post groundwater users currently utilizing wellhead GAC units would no longer have access to contaminated groundwater as a drinking water source.

The operation of a bioreactor and application of sodium persulfate should have a significant and permanent effect on the mass and concentration of chlorinated hydrocarbons at SWMU B-3 and AOC-65 sites. Both of these treatment technologies will eliminate contaminants in the vadose zone that drive the NAPL contamination found within the aquifer. LTM of groundwater will be conducted to evaluate treatment progress and provide information for future optimization of treatment systems in the event that further treatment is required.

5.3.6 Reduction in Toxicity, Mobility, or Volume of Waste

Alternative 3 would reduce the TMV of waste through bioremediation of VOCs via reductive dechlorination and chemical oxidation of chlorinated hydrocarbons within the SWMU B-3 and AOC-65 source areas, respectively. Additionally, natural attenuation processes reduce TMV of waste elsewhere within the plume.

5.3.7 Short-Term Effectiveness

Current treatment and monitoring programs would remain in place until users were provided with drinking water from SAWS. Therefore, Alternative 3 provides immediate short-term effectiveness to protect human health.

Bioremediation requires several months of bioreactor operations initially to generate the anaerobic and reducing conditions required to support reductive dechlorination in the treatment area. Once these conditions are generated, biodegradation will sequentially reduce PCE to TCE to DCE to vinyl chloride ending in innocuous ethene. ISCO requires less time to affect source area contaminants. Once an oxidant is activated, the oxidation reaction will proceed until the reactants (persulfate and contaminant or naturally occurring organic material) are consumed. Depending on the type of oxidant and activation method, the reaction process may be as short as a few minutes or as long as a few weeks. Following application, the activated oxidant will completely destroy any chlorinated hydrocarbons upon contact. Contaminant rebound is anticipated in the months following ISCO application, which may necessitate additional ISCO injections.

5.3.8 Implementability

This alternative is difficult to implement due to accessibility and ownership of easements, off-post construction obstacles, well-owner rights/access to their water, and managing existing and new infrastructure. Additionally, the U.S. Government cannot legally force private well owners to abandon their wells. Their current private on-site well provides them with a free water source. Therefore, a connection to SAWS would require that the water be paid for. The U.S. Government would also retain financial liability for any ingestion or dermal contact that results in health effects to residents or their animals.

The cost estimate below assumes the U.S. Government would pay for this water, but administratively, this may be difficult and may result in an adversarial relationship between the U.S. Government and the former well owner regarding the amount of water used, water conservation measures in the home, etc. Additionally, a deed notice or restrictive covenant would be required to prevent the use of groundwater at each residence. It is unlikely that the well owners would support such a measure due to potential negative impacts on property values.

5.3.9 Cost Estimate

Costs associated with implementing this alternative are:

	Alternative 3
Capital Cost	$4.6M
30-Year O&M Cost	$37.9M
30-Year Total Cost	$55.8M
30-Year Total Present Value	$26.3M

Capital costs associated with this alternative include those associated with connecting six off-post drinking water consumers to SAWS, the cost to file a deed notice and update the Master Plan to restrict AOC-65 and SWMU B-3 to commercial/industrial land use, the cost to prepare a deed notice or restrictive covenant for each residence converted to SAWS, and one initial ISCO injection at AOC-65. Periodic costs for this alternative include ISCO injections every 5 years on average for the next 30 years, and assume $450,000 every other year for new or replacement wells and general well maintenance. Operation and maintenance costs include maintenance and replacement of GAC filters; labor and laboratory costs related to sampling and project management of LTM for on- and off-post groundwater; and labor and laboratory costs related to LTM of the bioreactor (SWMU B-3) and the ISCO treatment area (AOC-65) for the next 30 years.

In order to develop the most conservative estimate possible for this alternative, the estimated cost of water to the six off-post users that would be converted to SAWS is included in the O&M costs. Off-post water usage costs were determined based on the average monthly water usage per well for all six off-post users from 2001 to present with the exception of Well LS-5 which has only been tracked since 2011. Average monthly usage during these time periods varied significantly depending on the well and ranged from an average 962 gallons per month at LS-5 to 21,420 gallons per month at RFR-11. Because residential monthly volume charges vary based on the amount of water used, an annual water usage cost was calculated for each off-post well that would be converted to SAWS, and the total annual water usage cost on SAWS for all six users was estimated to be approximately $30,000 per year (2014 SAWS Rate Schedules: http://www.saws.org/service/rates/).

A contingency of 40% was applied to the total capital and O&M costs to cover unknown costs due to scope changes and costs associated with construction or implementing this alternative. Even with the contingency factored in, the true cost for Alternative 3 is likely much lower than it would ultimately cost due to unknown or unexpected expenses related to the conversion of off-post residents to SAWS (e.g., lawyer fees, unknown construction obstacles, changes to residents' water usage, changes to SAWS water usage fees, etc).

5.3.10 Sustainability

Alternative 3 does not utilize best management practices of Green Remediation (USEPA, 2008) because the area disturbed for the SAWS conversion is extensive, and significant resources are utilized.

5.4 ALTERNATIVE 4 – SOURCE AREA TREATMENT, POINT-OF-USE TREATMENT, LAND USE CONTROLS, AND LONG-TERM MONITORING

A detailed description of this CMA is provided in Section 4.5.

5.4.1 Protective of Human Health and the Environment

This alternative is protective of human health since the current on- and off-post drinking water treatment and LTM programs would continue. Current LUCs would be maintained to prevent access to and use of contaminated groundwater by human receptors. This alternative does not provide specific protection for groundwater ecological receptors.

Additionally, source area treatment via bioremediation (SWMU B-3) or ISCO (AOC-65) removes or reduces sources of contamination; and LTM tracks changes in contaminant concentration and distribution, as well as evaluates effectiveness of the treatment systems.

5.4.2 Attain Media Cleanup Standards

Alternative 4 is able to attain cleanup standards for groundwater contamination at CSSA (USEPA drinking water standards). Sequential reductive dechlorination and chemical oxidation will achieve transformation or destruction of contaminants to levels at or below these standards given appropriate timeframes. At SWMU B-3, achieving the cleanup standard will require between 20 and 30 years of bioreactor operation in its current configuration. Timeframes for achieving cleanup standards at AOC-65 are still being evaluated.

5.4.3 Control the Sources of Release

There are no active disposal operations at SWMU B-3 or AOC-65 and contaminants are no longer being released at the site. Source areas have been removed to the extent possible. However, existing contamination in the soil under Building 90 and fractured bedrock within the vadose zone present an ongoing source of contamination to groundwater. Bioremediation has proven to be effective in reducing contaminant mass in the vadose zone and subsequently within the main aquifer body at SWMU B-3.

5.4.4 Comply with Any Applicable Standards for Management of Waste

Waste generated would include contaminated soil from bioreactor or infiltration gallery construction and well installation, purge water, bailers, decontamination water, bag filters, and personal protective equipment. Waste derived from activities associated with implementation of this alternative would be analyzed and disposed in accordance with appropriate waste management standards and practices as specified in CSSA's waste management plan.

5.4.5 Long-term Reliability and Effectiveness

The operation of a bioreactor and application of sodium persulfate should have a significant and permanent effect on the mass and concentration of chlorinated hydrocarbons at SWMU B-3 and AOC-65 sites. Both of these treatment technologies will eliminate contaminants in the vadose zone that drive the NAPL contamination found within the aquifer. LTM of groundwater will be conducted to evaluate treatment progress and provide information for future optimization of treatment systems in the event that further treatment is required.

5.4.6 Reduction in Toxicity, Mobility, or Volume of Wastes

Alternative 4 would reduce the TMV of waste through bioremediation of VOCs via reductive dechlorination and chemical oxidation of chlorinated hydrocarbons within the SWMU B-3 and AOC-65 source areas, respectively. Additionally, natural attenuation processes reduce TMV of waste elsewhere within the plume.

5.4.7 Short-Term Effectiveness

Bioremediation requires several months of bioreactor operations initially to generate the anaerobic and reducing conditions required to support reductive dechlorination in the treatment area. Once these conditions are generated, biodegradation will sequentially reduce PCE to TCE to DCE to vinyl chloride ending in innocuous ethene. ISCO requires less time to affect source area contaminants. Once an oxidant is activated, the oxidation reaction will proceed until the reactants (persulfate and contaminant or naturally occurring organic material) are consumed. Depending on the type of oxidant and activation method, the reaction process may be as short as a few minutes or as long as a few weeks. Following application, the activated oxidant will completely destroy any chlorinated hydrocarbons upon contact. Contaminant rebound is anticipated in the months following ISCO application, which may necessitate additional ISCO injections.

5.4.8 Implementability

An Underground Injection Control permit is required for both bioreactor operation and ISCO application. Underground Injection Control permits should be acquired prior to operation/injection and maintained for the duration of treatment. The permitting process may take 60 days, while construction of a bioreactor or infiltration gallery for ISCO may take a month or more. Additionally, it may take several months to generate conditions favorable for reductive dechlorination to occur before any beneficial results are observed within a bioreactor. With ISCO, positive results may be observed in a few weeks following application; however, contaminant rebound may take a year or more to fully peak before an evaluation can be made regarding effectiveness.

5.4.9 Cost Estimate

Costs associated with implementing this alternative are:

	Alternative 4
Capital Cost	$693,500
30-Year O&M Cost	$38.8M
30-Year Total Cost	$52.8M
30- Year Total Present Value	$23.5M

Capital costs associated with this alternative include the cost to file a deed notice and update the Master Plan to restrict AOC-65 and SWMU B-3 to commercial/industrial land use. Also included in the capital cost estimate is one initial ISCO injection at AOC-65. Periodic costs include one additional or replacement GAC unit (i.e., the entire GAC system and not just the filters) every other year for a total of 15 additional or replacement units over a 30-year period. Periodic costs include ISCO injections every 5 years on average for the next 30 years, and assume $450,000 every other year for new or replacement wells and general well maintenance. Operation and maintenance costs include maintenance and replacement of GAC filters; labor and laboratory costs related to sampling and project management of LTM for on- and off-post groundwater; and labor and laboratory costs related to LTM of the bioreactor (SWMU B-3) and the ISCO treatment area (AOC-65).

5.4.10 Sustainability

Both the enhanced bioremediation occurring within the SWMU B-3 bioreactor and the ISCO treatment at AOC-65 rely on naturally occurring microorganisms to consume chemical contaminants and break them down through metabolic processes. This phenomenon has been well documented and is effective in addressing a wide range of contaminants. *In situ* bioremediation at SWMU B-3 and AOC-65 incorporates several key elements of sustainable remediation:

- Eliminates transfer of contamination employed in other approaches;
- Utilizes natural processes, minimizes human intervention, and excessive energy use;
- Is safe, reduces environmental stress, minimizes ground disturbances;
- Reduces construction, materials used, and waste generated; and
- Can be effectively used as the primary treatment method or in conjunction with other remediation approaches in a very cost-effective manner.

The natural processes that drive bioremediation can be enhanced to increase the effectiveness and reduce time required to meet cleanup objectives by:

- Adjusting/optimizing *in situ* conditions through addition/manipulation of oxygen and nutrients and introduction of additional microbes; and
- Extending residence time through recirculation of contaminated groundwater.

Solar energy will be implemented to power environmental systems at SWMU B-3 in 2015.

SECTION 6
RECOMMENDATIONS

This section summarizes the recommendations of the CMS, which are based on the evaluation of CMAs conducted in the previous chapters. CMAs considered for the former Permitted OB/OD Areas included:

- Alternative 1: No Action
- Alternative 2: Point-of-Use Treatment, LUCs, and LTM
- Alternative 3: Source Area Treatment, Alternative Drinking Water Source, LUCs, and LTM
- Alternative 4: Source Area Treatment, Point-of-Use Treatment, LUCs, and LTM

Alternative 1 is not protective of human health, does not achieve the CAO, is not effective over the long-term, and does not reduce the TMV of wastes. Alternatives 2 through 4 all protect human health and the environment and comply with applicable waste management standards, and provide both short- and long-term effectiveness for the protection of human health. Alternatives 2 through 4 would all attain media cleanup standards; however, Alternatives 2 relies only on natural attenuation to degrade contamination in the groundwater, and therefore would take an unacceptably long time to achieve those standards. Reduction of TMV is similar to attainment of cleanup standards in that Alternative 2 would take an unacceptably long time to reduce TMV in groundwater. The remedial methods employed by Alternatives 3 and 4 (bioremediation and ISCO) are already reducing TMV at SWMU B-3 and AOC-65 at CSSA, and would continue to do so effectively in the future. Alternatives 2 and 4 are both easily implementable since all of the elements for these alternatives are already in place at CSSA. Alternative 3 is difficult to implement both technically, logistically, and administratively. Both Alternatives 2 and 4 address CSSA's desire to choose environmentally sustainable remedial alternatives in that they utilize several BMPs of Green Remediation (USEPA 2008).

There would be no cost involved with implementing Alternative 1 at CSSA. The TPV of implementing Alternative 2 (Point-of-Use Treatment, LUCs, and LTM) would be $11.5M, the TPV for implementing Alternative 3 (Source Area Treatment, Alternative Drinking Water Source, LUCs, and LRM) would be $26.3M, and the TPV for implementing Alternative 4 would be $23.5 million.

Alternative 2 achieves two of the CAOs (prevent human ingestion and control on-post exposure to contaminated groundwater); however, it does not directly achieve the CAO of controlling the source areas and preventing migration of groundwater contamination within a reasonable timeframe. While natural attenuation would eventually degrade groundwater contamination, the risk to human health in the time it would take to achieve meet this CAO is likely unacceptable. Alternative 4 achieves all CAOs, provides the highest reduction in TMV, and is the most environmentally sustainable option; however, it is the most costly of the alternatives. A summary of the CMA evaluation is included in **Table 6.1**.

Alternative 4 (Source Area Treatment, Point-of-Use Treatment, LUCs, and LTM) is recommended for implementation because it achieves the CAOs, achieves the highest reduction in TMV, and is effective over the short- and long-term. While Alternative 2 is estimated to be less costly, it does not meet all of the CAOs within a reasonable timeframe. Alternative 3 is difficult to implement both technically, logistically (as the U.S. government cannot force private well owners to abandon their wells), and administratively. For these reasons, the extra cost of Alternative 4 is weighed against the lack of TMV reduction and inability to reasonably achieve all three CAOs under Alternatives 2, and the extreme logistical difficulties under Alternative 3.

Table 6.1
Summary of Corrective Measure Alternative Evaluation
Corrective Measures Study
Camp Stanley Storage Activity, Boerne, TX

Criteria	Alternative 1 No Action	Alternative 2 Point-of-Use Treatment, Land Use Controls, and Long-Term Monitoring	Alternative 3 Source Area Treatment, Alternative Drinking Water Source, Land Use Controls, and Long-Term Monitoring	Alternative 4 Source Area Treatment, Point-of-Use Treatment, Land Use Controls, and Long-Term Monitoring
1. Protective of Human Health and the Environment	No	Yes	Yes	Yes
2. Attain Media Cleanup Standards	Yes, but will take an unacceptably long time.	Yes, but will take an unacceptably long time.	Yes, but will take an unacceptably long time.	Yes
3. Control the Sources of Releases	No	No	No	Yes
4. Comply with Any Applicable Standards for Management of Wastes	Not applicable, no waste generated.	Not applicable, no waste generated.	Yes	Yes
5. Long-Term Reliability and Effectiveness	No	Yes	Yes	Yes
6. Reduction in the Toxicity, Mobility, or Volume of Wastes	No	No	No	Yes
7. Short-Term Effectiveness	No	Yes	Yes	Yes
8. Implementability	Technically feasible, but may not be administratively implementable given potential unacceptable risks.	Easily implementable as all elements of this alternative are already in place.	Difficult to implement both technically and administratively. Requires extensive off-post work including concurrence with multiple landowners, municipalities, and agencies.	Easily implementable as all elements of this alternative are already in place.
9. Cost Estimate				
Capital	$0	$1,300	$4,594,915	$693,559
30-Year Annual O&M	$0	$16,443,984	$37,927,568	$38,804,837
Total Present Value	$0	$11,497,901	$26,273,737	$23,489,660

Table 6.1
Summary of Corrective Measure Alternative Evaluation
Corrective Measures Study
Camp Stanley Storage Activity, Boerne, TX

Criteria	Alternative 1 No Action	Alternative 2 Point-of-Use Treatment, Land Use Controls, and Long-Term Monitoring	Alternative 3 Source Area Treatment, Alternative Drinking Water Source, Land Use Controls, and Long-Term Monitoring	Alternative 4 Source Area Treatment, Point-of-Use Treatment, Land Use Controls, and Long-Term Monitoring
10. Sustainability	Not applicable.	Utilizes Best Management Practices (BMPs) of Green Remediation*: • Uses minimally invasive technologies • Minimizes soil and habitat disturbance • Minimizes use of heavy equipment • Minimizes land disturbance • Avoids disturbance to existing vegetation • Minimizes resource extraction/disposal	Does not utilize BMPs of Green Remediation because the area disturbed is extensive and significant resources are utilized.	Utilizes BMPs of Green Remediation: • Uses minimally invasive technologies • Minimizes soil and habitat disturbance • Minimizes use of heavy equipment • Minimizes land disturbance • Avoids disturbance to existing vegetation • Prevents impacts to water bodies • Uses technologies to minimize waste • Minimizes resource extraction/disposal

*BMPs as outlined in *USEPA's Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites* (USEPA, 2008)

SECTION 7
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APPENDIX A

OFF-POST MONITORING PROGRAM RESPONSE PLAN

Camp Stanley Storage Activity
Off-Post Monitoring Program Response Plan

Prepared by
Camp Stanley Storage Activity

Revised June 6, 2002

Table of Contents

Introduction

Camp Stanley Storage Activity (CSSA) is an U.S. Army facility located in northwestern Bexar County, about 19 miles northwest of downtown San Antonio. The installation consists of 4,004 acres situated immediately east of State Highway 3351 (Ralph Fair Road) and approximately 0.5 miles east of Interstate Highway 10. Camp Bullis, a separate Army installation, is located adjacent to the east, north, and south boundaries of CSSA. Vacant land and residential subdivisions border the remainder of the base. A CSSA Location Map that highlights adjacent subdivisions, roads, and other significant landmarks is provided in Attachment A.

Ground water contamination was discovered at CSSA in 1991, when the Texas Department of Health found volatile organic compounds (VOCs) in two on-post water wells. Since 1991, the ground water contamination plume has been monitored using on-post and selected off-post wells. In December 1999, low levels of VOCs, below the maximum contaminant level (MCL) allowed in drinking water, were found in one off-post well. Since that time, off-post sampling has identified additional wells impacted by VOCs.

Several maps and summary tables referenced in this document can be found in the CSSA Environmental Encyclopedia. The Encyclopedia is the Administrative Record for the CSSA Environmental Program and can be found at the San Antonio Public Library, located at 600 Soledad Street in downtown San Antonio. The Encyclopedia is updated on a periodic basis and includes the most current information available.

Purpose

The purposes of the CSSA Off-Post Monitoring Program Response Plan are to (1) confirm area drinking water meets United States Environmental Protection Agency (EPA) and Texas Natural Resource Conservation Commission (TNRCC) standards, (2) determine the lateral and vertical extent of VOC contamination (3) determine if there any potential off-post VOC source areas, (4) provide the framework to monitor off-post water wells that are located downgradient of known VOC source areas and within close proximity of CSSA, and (5) provide action levels and Army response guidance if additional off-post ground water contamination is encountered.

Background

The land on which CSSA is located was used for ranching and agriculture until the 1900s. During 1906 and 1907, six tracts of land were purchased by the U.S. Government and designated the Leon Springs Military Reservation. In 1917, the Reservation was renamed CSSA and hosted the First Officers' Training Camp. In 1925, the installation was selected as an ammunition depot under the jurisdiction of the San Antonio Arsenal. The Works Progress Administration began construction of earthen-covered and aboveground magazines to adequately house ordnance materiel circa 1938. In 1949, CSSA was transferred to the jurisdiction of Red River Army Depot. Since the early 1950s, federal and private land transfers and acquisitions have increased the installation to approximately 4,000 acres. The primary mission of CSSA is receipt, storage, and issuance of ordnance materiel as well as quality assurance testing and maintenance of military weapons and ammunition.

Geology and Aquifers

CSSA is located along a large regional fault trend known as the Balcones Escarpment. Movement along the fault trend ended many million years ago, but evidence of movement can still be seen on the Hill Country topography. Geologic investigations at CSSA have identified two local fault trends running across CSSA. The approximate locations of these faults are shown on Figure 1 below. The upper and lower members of the Glen Rose formation underlie CSSA. The Glen Rose consists of alternating layers of dolomite, limestone, and marl of varying thickness and hardness. In general, CSSA soils are very thin and outcrops of the Glen Rose, exposed fractured rock, and scattered karst features are common.

The Middle Trinity Aquifer supplies drinking water for CSSA, and most of the surrounding area. The Middle Trinity includes the Lower Glen Rose, Bexar Shale, and Cow Creek Limestone. During periods of heavy precipitation, water levels have reached as high as 45 feet below ground surface (October 1998 flood). During drought conditions water levels are as deep as 375 feet. Residential development surrounding CSSA over the last decades has greatly increased the demand for ground water locally. As of February 2002, there are a total of 35 wells at CSSA. Three are used for drinking water supply; and the remainders are used for agricultural and or monitoring purposes.

Groundwater Contamination

Ground water contamination has been a concern at CSSA since 1991 when the Texas Department of Health found elevated levels of tetrachloroethene (PCE), trichloroethene (TCE), and other volatile organic compounds (VOCs) in a water sample from Well 16. Follow up sampling confirmed VOC contamination was also present in Well D, an agricultural well located approximately 300 feet west of Well 16. After the initial contamination discovery, CSSA removed Well 16 from the water supply distribution. Based on the 1991 ground water contamination findings, CSSA initiated a program of periodic monitoring of all CSSA water wells. In 1996 a selected group of off-post wells were included in the sampling/analyses program. In general, contamination levels in the on-post wells have fluctuated over time. PCE levels in Well 16 have ranged from 24 up to 212 parts per billion (ppb) PCE and from 21 up to 509 ppb TCE. A historical summary of all VOC data from both on and off-post wells tested by CSSA can be found in the Environmental Encyclopedia, Volume 5-1, Introduction to Quarterly Monitoring Program, Table 6.

Since 1991, CSSA has identified three source areas for the VOC contamination. These known source areas include solid waste management unit (SWMU) B-3SWMU O-1, and an area located in the vicinity of Building 90, area of concern – AOC-65. Remediation at SWMU B-3 began in 1997 when a soil vapor extraction (SVE) system was installed. During the summer of 2000, contaminated soil associated with SWMU O-1 was excavated and taken off-post for proper disposal at a Texas Natural Resource Conservation Commission (TNRCC) authorized landfill. AOC-65 was identified as a VOC source in mid 2000. Further investigation and evaluation of cleanup options for this site is being planned. A map showing the CSSA's well locations and known/potential VOC source areas is provided as part of CSSA Environmental Fact Sheets Numbers 3 and 4, found in the Environmental Encyclopedia, Volume 1-1.1, Community Correspondence.

Review of the ground water monitoring results has suggested that the highest levels of ground water contamination are confined to the central portion of the post, with lower levels of contamination, below the maximum contaminant limit (MCL), found near the southern post perimeter. The initial off-post sampling effort occurred in 1995 when four wells located along the western perimeter of CSSA were sampled. Analyses of these wells, which were cross gradient and downgradient of the SWMU B-3 and O-1 source areas, found no VOC contamination. Three of these wells were re-sampled in September 1999 with similar non-detect results.

In December 1999, a fifth well (LS-7) was added to the off-post sampling program. Analyses of water samples from this well, located less than 0.25 miles southwest of the post boundary, found 2.51 ppb PCE and 0.3 ppb TCE. These levels do not exceed Safe Drinking Water Act MCLs. After data validation was completed, this sampling information was provided to the well owner, TNRCC and the EPA. Follow-up samples have been collected from LS-7 on a quarterly basis since the initial VOC detection. Over the course of sampling, VOC concentrations have fluctuated with the highest levels (4.6 ppb PCE) being found in September 2001

Potential Off-post Wells for Monitoring

Starting in the fall of 1999, CSSA contractors have reviewed water well databases and undertaken visual surveys to identify all water wells within a one-quarter mile radius of the post. Based on the findings of this survey work, CSSA has identified several water wells that are located down gradient of the VOC source areas and within close proximity of LS-7 where low levels of VOCs were detected. This list includes residential wells, commercial wells (located at businesses), and public supply wells. A map depicting the approximate locations of these wells in relation to CSSA is provided in the Environmental Encyclopedia, Volume 5-2, Water Well Survey, Figure 3.1. Of the identified wells, it is anticipated that 20 will be selected for sampling. Summary tables that include the map reference name, addresses for these wells, and available well completion data is also provided in the Well Survey Report.

Well Owner Notification

Owners of wells selected for sampling will be contacted by CSSA or its' representatives to request permission for well sampling. The initial contact will be by mail and include an access agreement with general background information regarding groundwater issues and an invitation to contact CSSA to work out the sampling schedule and to answer any questions.

All analytical data generated by the sampling event will be shared with the well owner. The Right of Entry Access Agreement consent form will state the purpose of the sampling event and that CSSA will deliver the sampling results to the well owner, return the well owner's property to the same condition it existed prior to performing sampling work, and that the well owner will not be liable for any property damage or injuries suffered during the sampling event. CSSA will require the well owner to sign the Right of Entry Access Agreement prior to sampling his or her well. The Right of Entry Access Agreement is included in the Attachment B.

Bexar Metropolitan Water District and Fair Oaks Water Utility Company will be contacted separately to discuss the number of connections they have and for other details related to their water distribution system, including well data (geologic, depth, casing, pump location, etc.) pumping rates, and contaminant history for Leon Springs Villa, Hidden Springs Estate, and City of Fair Oaks water distribution systems.

Well Sampling

All of the above listed wells are to be sampled by CSSA through Parsons Incorporated, or other designated contractors. To assure samples are as representative of aquifer conditions as possible, the samples will be collected as close to the wellhead as possible. Where sampling ports are not available, if feasible, one will be installed with permission of and at no cost to the well owner. All samples will be collected in a preserved 40-milliliter (ml) glass volatile organic analyte container, stored on ice, and shipped immediately to a laboratory contracted by CSSA, Parsons

Engineering Science, or other contractor for analyses using EPA SW-846 Method 8260. Where possible, water levels will be collected during the sampling event and the well location will be surveyed using a geographical positioning system (GPS) device. Further details on CSSA's Field Sampling Procedures and Quality Assurance Project Plan can be found in Volume 1-4 of the Environmental Encyclopedia.

Sample Analyses

During the initial sampling event, all samples will be analyzed for a full suite of volatile organic compounds (VOCs) using EPA Method SW8260. A complete list of analytes covered under SW8260B is provided in the Environmental Encyclopedia, Volume 1-4, under Quality Assurance Project Plan (QAPP), Table 7.2.9-1. For future sampling events, CSSA may elect to reduce the VOC analyte list based on the findings of previous sampling events. Well owners, EPA , and TNRCC will be notified of any proposed reduction in the analyte list. Regulatory approval will be obtained prior to well owner notification.

VOC Action Levels

After the analytical results are returned and data verification/validation is complete, CSSA, in coordination with the EPA, TNRCC, and San Antonio Metropolitan Health District will evaluate the sample results and determine the most appropriate course of action. Letters that include the analytical results, an explanation of the findings, and the next appropriate step will be prepared and sent to each well owner.

For residential and commercial wells the Action Levels and Army responses Off-post are:

- If VOC contaminant levels are within 90% of the MCL (4.5 ppb for PCE and TCE) and the well is used as a potable water source, bottled water will be supplied within 24 hours. A confirmation sample will be collected from the well. The re-sampling will take place within 14 days of the receipt of the final validated analytical report. If the follow-up sampling confirms contaminants of concern above MCLs, the residence or supply well will be evaluated and CSSA will determine an appropriate method for wellhead treatment or connection to an alternative water source will be selected if CSSA deems feasible and the preferred alternative. Cost related to the installation and maintenance of wellhead treatment equipment or connection to an alternative water source will be borne by the US Army.

- If VOC contaminant levels are ≥ 80% of the MCL during any single monitoring event based on preliminary data from the laboratory (4.0 ppb for PCE and TCE) and the well is used as a potable water source, it shall be monitored monthly. If the follow-up sampling confirms contaminants of concern are ≥ 80% of the MCL, it will be re-sampled until the level falls below the 80% value. Should the value be ≥ 90% of the MCL see bullet above.

- If any VOC contaminant of concern (COC) is detected at levels greater than the Method Detection Limit (MDL) for SW846 Method 8260, (historically 0.11 ppb for PCE, 0.14 ppb TCE), the well will be re-sampled on a quarterly basis. This sampling will be completed in concert with on-post sampling events and will be used to develop historical trends in the area. Quarterly sampling will continue for a minimum of one year, after which the sampling frequency will be reviewed and possibly decreased with the concurrence of EPA and TNRCC.

- If VOCs are not detected during the initial sampling event, (i.e. no VOC contaminant levels above the MDL), further sampling of the well would be considered on an as needed basis. Future sampling of such a well may be required to evaluate potential seasonal variation in contaminant trends. The well owner, EPA and TNRCC will be apprised of any re-sampling decisions regarding the non-detect wells.

When off-post public supply systems are adversely impacted, CSSA will cooperate and coordinate solutions to the maximum extent practicable.

Modification of CSSA Off-post Monitoring Program Response Plan

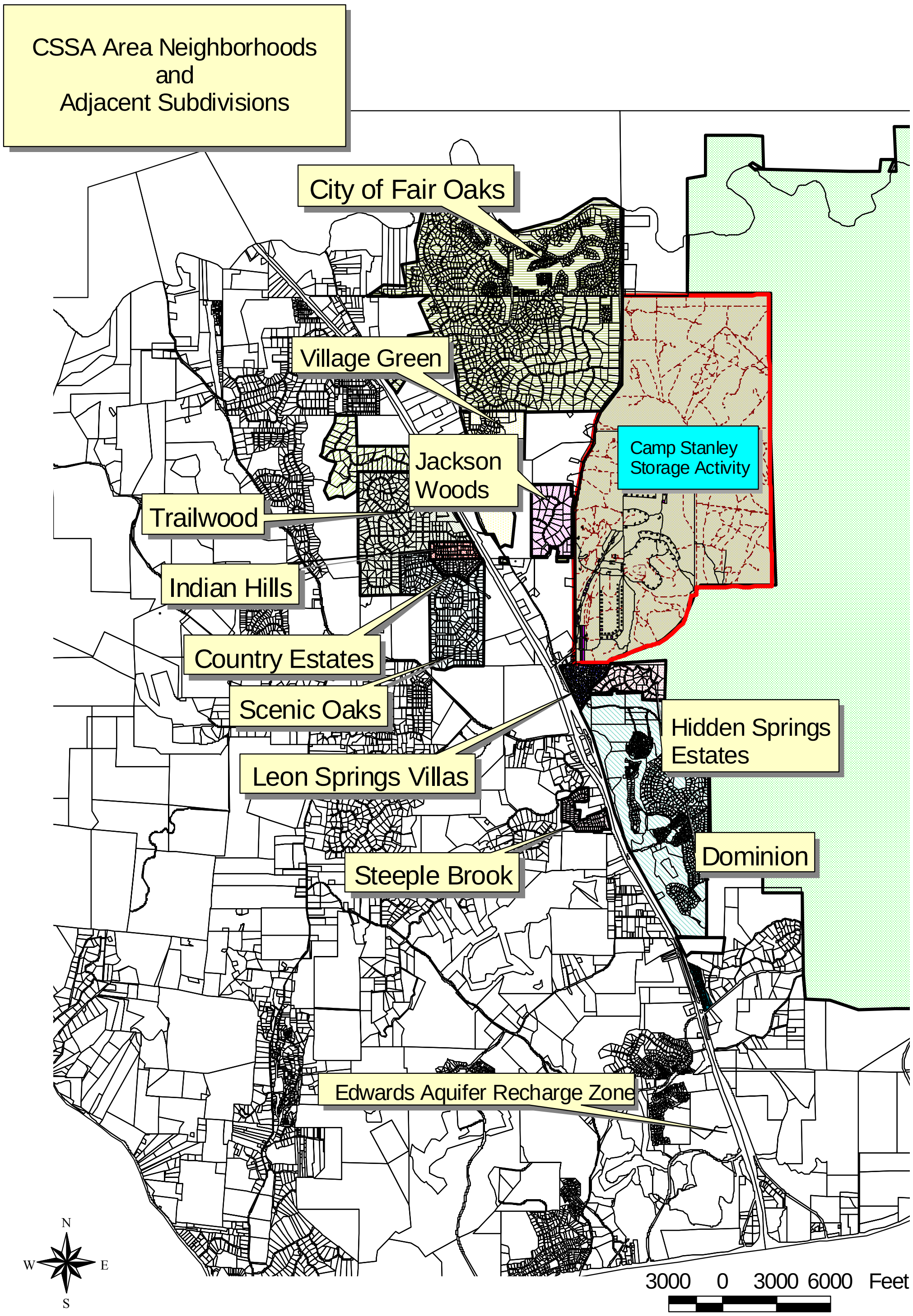
After the initial round of sampling is complete, CSSA, in coordination with EPA and TNRCC, will evaluate the sampling results to determine the need to expand the off-post sampling program. Program expansion would be required to (1) ensure that all impacted wells are identified and appropriate remedial actions are taken, and (2) ensure an accurate assessment of migration of the plume off-post, if at all, has been made. If it is determined that data is needed from additional wells, CSSA will follow the Well Owner Notification procedures as described above to contact the well owner(s) to obtain consent for access.

Comments

Comments can be made to CSSA by writing to the address below or calling Lieutenant Colonel, Jason D. Shirley, CSSA Commander at (210) 295-7416. Comments can also be made to CSSA's EPA Regional Program Manager, Mr. Greg Lyssy at (214) 665-8317, or to U.S. Army, Corps of Engineers, Public Affairs Office, Ms. Anita Horky at (817) 978-3395.

CMDR, CSSA
25800 Ralph Fair Road
Attn: Environmental Office
Boerne, Texas 78015-4800

Attachment A - Area Neighborhoods and Adjacent Subdivisions



Attachment B - Right of Entry Access Agreement

June 6, 2001

Office of the Commander

Name
And Address
of Property Owner

In October 2000, Camp Stanley Storage Activity (CSSA) provided responses to community questions regarding environmental issues at our installation. Included was information regarding our on-going effort to verify groundwater quality on and around our facility. Additional information about the CSSA's Environmental Program and related ground water concerns was recently mailed out to area residents as fact sheets.

As part of our groundwater monitoring efforts, we periodically sample selected on-post and off-post drinking water wells and analyze them for volatile organic compounds (VOCs). This is conducted to confirm that the drinking water well meets United States Environmental Protection Agency (EPA) and Texas Natural Resources Conservation Commission (TNRCC) requirements under the Safe Drinking Water Act. In September 2001, Camp Stanley will expand its' off-post sampling program to include up to 20 off-post wells.

A review of Texas State drilling records indicates a drinking water well is located on your property and within our study area. With your permission, we request access to your property for the purpose of sampling this well. This work will be done at no cost to you and be performed by Parsons Engineering Science, Inc. (Parsons), who has been contracted with by CSSA. In the next few weeks, a Parsons representative will contact you regarding the possibility of sampling your well and also to ask questions about casing depths, pump depths, potential sampling points, and other pertinent well information. If you agree to participate the Parson's representative will provide a summary of what types of information you will receive from the study and an estimate of when you can expect data from the sampling event.

If you have questions or concerns regarding the well sampling, please be sure to discuss your concerns with the Parson's representative when they contact you. Once you and the Parson's representative have discussed the project and sampling details, we strongly encourage you to participate in the study. However, you are under no obligation to participate and the decision is yours.

If you elect to participate in the program, you will be required to sign the enclosed Right of Entry Access Agreement. This agreement releases you from any liability regarding the sampling effort, allows Parson's representatives access to your well for up to three years to collect samples, and holds CSSA responsible for repairs or settlements from damage which occurs from sampling events only. If you wish to participate, please sign the agreement in the block labeled "owner" and send the correspondence back to CSSA at 25800 Ralph Fair Road, Attn: Commander, Boerne, Texas 78015-4800.

If you sign and return the agreement, a Parson's representative will contact you to schedule the sampling. The sampling team will consist of two Parson's employees who will need access to your well to collect the sample. In order to make the sampling as convenient as possible, Parson's representatives will alert you at least 72 hours prior to the sampling day. It is estimated that it will take approximately 0.5 to 1 hour to complete the sample collection.

Although, you are not required to participate in this study, your help and cooperation with this effort would be greatly appreciated. All costs associated with this work will be paid by CSSA, and all analytical results from your well will be provided to you at no expense. If you have any questions, either before or after you speak with a Parson's representative, please contact Lieutenant Colonel Jason Shirley, Commander, CSSA, at 210/295-7416.

Sincerely,

Jason D. Shirley

JASON D. SHIRLEY
Lieutenant Colonel, U.S. Army
Commanding Officer

Department of the Army
Camp Stanley Storage Activity

Right-of-Entry for Water Well Sampling

The undersigned, hereinafter called the "Owner", hereby grants to Camp Stanley Storage Activity, hereinafter called "CSSA", a permit or right-of-entry upon the following terms and conditions:

1. The Owner hereby grants CSSA or its agents, a right to enter upon the land hereinafter described at any time within a period of thirty-six (36) months from the date of this instrument to carry out groundwater sampling of water wells to complete a groundwater investigation of groundwater under said lands by CSSA.
2. The permission/permit includes the right of ingress and egress on other lands of the Owner, not described below, provided such ingress and egress is necessary and not otherwise conveniently available to CSSA.
3. CSSA agrees to be responsible for damages arising from the activity of CSSA, its officers, employees, or representatives on said land in the exercise of rights under this permit or right-of-entry, either by repairing such damage or at the option of CSSA by making an appropriate settlement with the Owner in lieu thereof.
4. CSSA will provide notify you at least 72 hours prior to the sampling event.
5. The land affected by this permit or right-of-entry is located in the State of Texas, County of Bexar, and is described as follows:

PROPERTY OWNER

Name: ______________________________

Address – Street: __________________________

City, State, Zip Code: __________________________

Phone Number: __________________________

Signed this _______day of __________________, 20_____

BY:____

Owner's Name (Printed)

BY:____

Owner's Name (Signature)

CSSA Acknowledgement

United States of America

BY:__________________________________ _________________

Commander Date

*A copy of this Right-of-Entry will be provided to the property owner for their records after all signatures are obtained.

APPENDIX B

COST ESTIMATES

Appendix B
Cost Estimates

Alternative	Activity	Capital Costs	Periodic Costs	Annual Costs
2, 3 (w/o GAC), 4	**Point of Use Treatment**			
	Maintenance and Replacement of GAC Filters			$24,498.00
	Additional GAC Units (every 2 years)		$10,917.00	
	On-Post Water Supply System Operations and Sampling			$144,048.00
	Contingency (20% scope + 10% bid) - Alternatives 2 and 4		$3,275.10	$50,563.80
	Contingency (20% scope + 10% bid) - Alternative 3		*$3,275.10*	*$43,214.40*
	Total - Alternatives 2 and 4	**$0.00**	**$14,192.10**	**$219,109.80**
	Total - Alternative 3	***$0.00***	***$0.00***	***$187,262.40***
2, 3, 4	**Land Use Controls**			
	Deed Notice for Commercial/Industrial Land Use at SWMU B-3 and AOC-65	$500.00		
	Master Plan for Restrictions on Future Well Placement	$500.00		
	Contingency (20% scope + 10% bid)	$300.00		
	Total	**$1,300.00**	**$0.00**	**$0.00**
2, 3, 4	**On- and Off-Post Monitoring (Drinking Water and MNA)**			
	Groundwater Monitoring Plan Updates			$4,244.00
	Quarterly Groundwater Monitoring			$131,414.00
	Quarterly Groundwater Reports			$53,979.00
	New/Replacement Wells and Maintenance		$450,000.00	
	Other GW Monitoring			$40,449.00
	Contingency (20% scope + 10% bid)		$135,000.00	$69,025.80
	Project Management (10% of O&M + Contingency)		$58,500.00	$29,911.18
	Total	**$0.00**	**$643,500.00**	**$329,022.98**
3	**Off-post Conversion to SAWS**			
	Engineering Design	$131,427.00		
	Well Plugging/Abandonment (6 wells)	$45,280.00		
	Water Impact Fees	$51,170.00		
	Water Main Distribution	$1,192,500.00		
	Service Line Connection	$25,316.00		
	Averag water Usage (based on annual usage/well since 2001)			$30,000.00
	Preparation of deed notices or restrictive covenants on groundwater usage	$900,000.00		
	Construction Management (8% of capital costs)	$187,655.44		
	Contingency (20% scope + 20% bid)	$1,013,339.38		$12,000.00
	Project Management (10% of capital costs + contingncy)	$354,668.78		$4,200.00
	Total	**$3,901,356.60**	**$0.00**	**$46,200.00**
4	**Source Area Treatment**			
	SWMU B-3 Bioreactor O&M			$370,000.00
	AOC-65 ISCO O&M (initial, then every 5 years)	$11,500.00	$11,500.00	$140,000.00
	AOC-65 ISCO Materials (initial, then every 5 years)	$472,597.00	$472,597.00	
	Westbay Maintenance			$11,232.00
	Project Management (10% of Total O&M)	$48,409.70	$48,409.70	$52,123.20
	Contingency (20% scope + 10% bid)	$159,752.01	$159,752.01	$172,006.56
	Total	**$692,258.71**	**$692,258.71**	**$745,361.76**

Alternative 2 - Point-of-Use Treatment, Land Use Controls, and Long-Term Monitoring						
Year	Capital Cost ($)	Annual O&M Costs ($)	Periodic Costs ($)	Total Cost + 0% Tax($)	Discount Factor at 7%	Present Value at 7%
0	$1,300	$548,133	$0	$549,433	1.000	$549,433
1	$0	$548,133	$657,692	$1,205,825	0.935	$1,126,940
2	$0	$548,133	$0	$548,133	0.873	$478,761
3	$0	$548,133	$657,692	$1,205,825	0.816	$984,313
4	$0	$548,133	$0	$548,133	0.763	$418,168
5	$0	$548,133	$657,692	$1,205,825	0.713	$859,737
6	$0	$548,133	$0	$548,133	0.666	$365,245
7	$0	$548,133	$657,692	$1,205,825	0.623	$750,928
8	$0	$548,133	$0	$548,133	0.582	$319,019
9	$0	$548,133	$657,692	$1,205,825	0.544	$655,889
10	$0	$548,133	$0	$548,133	0.508	$278,643
11	$0	$548,133	$657,692	$1,205,825	0.475	$572,879
12	$0	$548,133	$0	$548,133	0.444	$243,378
13	$0	$548,133	$657,692	$1,205,825	0.415	$500,375
14	$0	$548,133	$0	$548,133	0.388	$212,576
15	$0	$548,133	$657,692	$1,205,825	0.362	$437,047
16	$0	$548,133	$0	$548,133	0.339	$185,672
17	$0	$548,133	$657,692	$1,205,825	0.317	$381,734
18	$0	$548,133	$0	$548,133	0.296	$162,173
19	$0	$548,133	$657,692	$1,205,825	0.277	$333,421
20	$0	$548,133	$0	$548,133	0.258	$141,648
21	$0	$548,133	$657,692	$1,205,825	0.242	$291,223
22	$0	$548,133	$0	$548,133	0.226	$123,721
23	$0	$548,133	$657,692	$1,205,825	0.211	$254,366
24	$0	$548,133	$0	$548,133	0.197	$108,063
25	$0	$548,133	$657,692	$1,205,825	0.184	$222,173
26	$0	$548,133	$0	$548,133	0.172	$94,386
27	$0	$548,133	$657,692	$1,205,825	0.161	$194,054
28	$0	$548,133	$0	$548,133	0.150	$82,441
29	$0	$548,133	$657,692	$1,205,825	0.141	$169,495
Total	$1,300	$16,443,984	$9,865,382	$26,310,665		**$11,497,901**
				Total Cost + 0% Tax($)		**$26,310,665**
				Lower end of TPV Range		**$7,473,636**
				Upper end of TPV Range		**$17,246,852**

Alternative 3 - Source Area Treatment, Alternative Drinking Water Source, Land Use Controls, and Long-Term Monitoring						
Year	Capital Cost ($)	Annual O&M Costs ($)	Periodic Costs ($)	Total Cost + 0% Tax($)	Discount Factor at 7%	Present Value at 7%
0	$ 4,594,915.31		$0	$4,594,915	1.000	$4,594,916
1	$0	$1,307,847	$657,692	$1,965,539	0.935	$1,836,953
2	$0	$1,307,847	$0	$1,307,847	0.873	$1,142,325
3	$0	$1,307,847	$657,692	$1,965,539	0.816	$1,604,466
4	$0	$1,307,847	$0	$1,307,847	0.763	$997,751
5	$0	$1,307,847	$1,349,951	$2,657,798	0.713	$1,894,974
6	$0	$1,307,847	$0	$1,307,847	0.666	$871,474
7	$0	$1,307,847	$657,692	$1,965,539	0.623	$1,224,040
8	$0	$1,307,847	$0	$1,307,847	0.582	$761,179
9	$0	$1,307,847	$657,692	$1,965,539	0.544	$1,069,124
10	$0	$1,307,847	$692,259	$2,000,106	0.508	$1,016,753
11	$0	$1,307,847	$657,692	$1,965,539	0.475	$933,814
12	$0	$1,307,847	$0	$1,307,847	0.444	$580,700
13	$0	$1,307,847	$657,692	$1,965,539	0.415	$815,629
14	$0	$1,307,847	$0	$1,307,847	0.388	$507,206
15	$0	$1,307,847	$1,349,951	$2,657,798	0.362	$963,309
16	$0	$1,307,847	$0	$1,307,847	0.339	$443,014
17	$0	$1,307,847	$657,692	$1,965,539	0.317	$622,240
18	$0	$1,307,847	$0	$1,307,847	0.296	$386,945
19	$0	$1,307,847	$657,692	$1,965,539	0.277	$543,488
20	$0	$1,307,847	$692,259	$2,000,106	0.258	$516,866
21	$0	$1,307,847	$657,692	$1,965,539	0.242	$474,704
22	$0	$1,307,847	$0	$1,307,847	0.226	$295,199
23	$0	$1,307,847	$657,692	$1,965,539	0.211	$414,625
24	$0	$1,307,847	$0	$1,307,847	0.197	$257,838
25	$0	$1,307,847	$1,349,951	$2,657,798	0.184	$489,698
26	$0	$1,307,847	$0	$1,307,847	0.172	$225,206
27	$0	$1,307,847	$657,692	$1,965,539	0.161	$316,315
28	$0	$1,307,847	$0	$1,307,847	0.150	$196,704
29	$0	$1,307,847	$657,692	$1,965,539	0.141	$276,282
Total	$4,594,916	$37,927,568	$13,326,676	$55,849,157		**$26,273,737**
				Total Cost + 0% Tax($)		**$55,849,157**
				Lower end of TPV Range		**$17,077,929**
				Upper end of TPV Range		**$39,410,606**

Alternative 4 - Source Area Treatment, Point-of-Use Treatment, Land Use Controls, and Long-Term Monitoring						
Year	Capital Cost ($)	Annual O&M Costs ($)	Periodic Costs ($)	Total Cost + 0% Tax($)	Discount Factor at 7%	Present Value at 7%
0	$693,559	$1,293,495	$0	$1,987,053	1.000	$1,987,054
1	$0	$1,293,495	$657,692	$1,951,187	0.935	$1,823,539
2	$0	$1,293,495	$0	$1,293,495	0.873	$1,129,789
3	$0	$1,293,495	$657,692	$1,951,187	0.816	$1,592,750
4	$0	$1,293,495	$0	$1,293,495	0.763	$986,801
5	$0	$1,293,495	$1,349,951	$2,643,445	0.713	$1,884,741
6	$0	$1,293,495	$0	$1,293,495	0.666	$861,911
7	$0	$1,293,495	$657,692	$1,951,187	0.623	$1,215,101
8	$0	$1,293,495	$0	$1,293,495	0.582	$752,826
9	$0	$1,293,495	$657,692	$1,951,187	0.544	$1,061,317
10	$0	$1,293,495	$692,259	$1,985,753	0.508	$1,009,457
11	$0	$1,293,495	$657,692	$1,951,187	0.475	$926,995
12	$0	$1,293,495	$0	$1,293,495	0.444	$574,328
13	$0	$1,293,495	$657,692	$1,951,187	0.415	$809,674
14	$0	$1,293,495	$0	$1,293,495	0.388	$501,640
15	$0	$1,293,495	$1,349,951	$2,643,445	0.362	$958,107
16	$0	$1,293,495	$0	$1,293,495	0.339	$438,152
17	$0	$1,293,495	$657,692	$1,951,187	0.317	$617,696
18	$0	$1,293,495	$0	$1,293,495	0.296	$382,699
19	$0	$1,293,495	$657,692	$1,951,187	0.277	$539,520
20	$0	$1,293,495	$692,259	$1,985,753	0.258	$513,157
21	$0	$1,293,495	$657,692	$1,951,187	0.242	$471,238
22	$0	$1,293,495	$0	$1,293,495	0.226	$291,959
23	$0	$1,293,495	$657,692	$1,951,187	0.211	$411,597
24	$0	$1,293,495	$0	$1,293,495	0.197	$255,009
25	$0	$1,293,495	$1,349,951	$2,643,445	0.184	$487,053
26	$0	$1,293,495	$0	$1,293,495	0.172	$222,734
27	$0	$1,293,495	$657,692	$1,951,187	0.161	$314,006
28	$0	$1,293,495	$0	$1,293,495	0.150	$194,545
29	$0	$1,293,495	$657,692	$1,951,187	0.141	$274,265
Total	$693,559	$38,804,837	$13,326,676	$52,825,070		**$23,489,660**
				Total Cost + 0% Tax($)		**$52,825,070**
				Lower end of TPV Range		**$15,268,279**
				Upper end of TPV Range		**$35,234,490**