TINKER AFB RCRA PERMIT

ATTACHMENT 8 - RISK EVALUATION AND RISK MANAGEMENT REPORT

(Attached on CD)

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Risk Evaluation and Risk Management Report

For Tinker AFB, Oklahoma City, Oklahoma

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Risk Evaluation Report and Risk Management Report
Tinker Air Force Base
Oklahoma City, Oklahoma Section

Acronyms and Abbreviations

AFB	Air Force Base
AFCEC	Air Force Civil Engineer Center
AFR	Air Force Regulation
AOC	Area of Concern
ASTM	American Standard for Testing Materials
CAO	Corrective Action Objective
CAS	Corrective Action Strategy
CMS	Corrective Measures Study
COA	Central Oklahoma Aquifer
COCs	Contaminants of Concern
CVOC	Chlorinated Volatile Organic Compound
CSM	Conceptual Site Model
ELCR	Excess Lifetime Cancer Risk
EPA	Environmental Protection Agency
ERPIMS	
EVO	Emulsified Vegetable Oil
HQ	Hazard Quotient
HSWA	Hazardous and Solid Waste Amendments
IC	Institutional Control
ICM	Interim Corrective Measure
IRP	Installation Restoration Program
ISCO	In-Situ Chemical Oxidation
LUC	Land Use Control

LSZ	Lower Saturated Zone
MAAC	Maximum Ambient Air Concentration
MCL	Maximum Contaminant Level
NCP	National Contingency Plan
NFA	No Further Action
NPL	National Priorities List
OCC	Oklahoma Corporation Commission
ODEQ	Oklahoma Department of Environmental Quality
OU	Operable Unit
OWRB	Oklahoma Water Resources Board
OWS	Oil Water Separator
PFAS	Per- or Polyfluoroalkyl Substance
POC	Point of Compliance
PVC	Polyvinyl Chloride
PZ	Producing Zone
QA	Quality Assurance
QAPPs	Quality Assurance Project Plans
QC	Quality Control
RBSL	Risk Based Screening Level
RC	Remedy Complete
RCRA	Resource Conservation and Recovery Act
RER	Risk Evaluation Report
RFI	RCRA Facility Investigation
RMP	Risk Management Plan
RSL	Risk Screening Level
SLHHRA	Screening-level Human Health Risk Assessment
SVOC	Semi-volatile Organic Compound
SWMU	Solid Waste Management Unit
SWTP	Sanitary Wastewater Treatment Plant
TAC	Toxic Air Contaminant
TAC1	Tinker Aerospace Complex
TAFB	Tinker Air Force Base
TCE	Trichloroethene
TCLP	Toxicity Leaching Characteristic Procedure
THQ	Target Hazard Quotient
TPH-DRO	Total Petroleum Hydrocarbon-Diesel Range
TPH-GRO	Total Petroleum Hydrocarbon-Gasoline Range

TRL	Target Risk Level
UFP-QAPP	Uniform Federal Policy for Quality Assurance Project Plans
USAF	United States Air Force
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
USZ	Upper Saturated Zone
UU/UE	Unrestricted Use/Unrestricted Exposure
VC	Vinyl Chloride
VEP	Vacuum Enhanced Pumping
VI	Vapor Intrusion
VOC	Volatile Organic Compound
WBZ	Water Bearing Zone

Executive Summary

Tinker Air Force Base (Tinker AFB or TAFB) has been and remains a major industrial complex for overhauling, modifying, and repairing military aircraft, aircraft engines, and accessory items. Base operations began in 1942 and certain activities employing hazardous materials resulted in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludge, electroplating wastewater and sludge, alkaline cleaners, acids, jet fuels, and radium paints. Wastes that currently are generated are managed at two permitted hazardous waste storage facilities. Tinker AFB is operating under the RCRA Permit #OK1571724391 issued by the Oklahoma Department of Environmental Quality (ODEQ) in 2002. The current RCRA permit contains provisions required under 40 CFR 264 Subpart F for releases from Solid Waste Management Units (SWMUs) and Areas of Concern (AOCs). The RCRA permit renewal application identifies the notice of intent to implement the Corrective Action Strategy (CAS) approach for future corrective action activities for the non-NPL sites identified under the RCRA permit.

The northeast 'quadrant' of Tinker AFB is on the National Priorities List (NPL) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The NPL site at Tinker AFB is administered by USEPA Region 6 under CERCLA of 1980. The Soldier Creek/Building 3001 (B3001) site at Tinker AFB was placed on the NPL in July 1987. A Federal Facility Agreement was signed by the United States Air Force (USAF), Environmental Protection Agency (EPA) Region 6 and ODEQ in December 1988. Any contaminated sites outside of the NPL are deemed non-NPL sites and thus are included in the RCRA Operating Permit issued by ODEQ.

Work completed between 1981 through 2017 includes:

- Preparation and submittal of a Current Conditions Report;
- Completion of several RCRA facility individual site investigations;
- Identifying, implementation and operating various interim corrective measures;
- Capping and maintaining six closed/historical landfills;
- Conducting individual site investigations and corrective measure studies;
- Achieved No Further Action Status at numerous sites;
- Established a comprehensive basewide groundwater monitoring program.

The above work has been performed under the USAF Environmental Restoration Program with oversight by, and input from, EPA Region 6 (pre-2000's) and ODEQ (since 2000). The activities and results are documented in the information repository for Tinker AFB.

Upon re-issuance of the RCRA Operating Permit and CAS guidelines, the following additional work is scheduled to be performed for the following Solid Waste Management units (SWMUs) and Areas of Concern (AOCs), summarized below:

- Long Term Management/Monitoring for all six closed landfill SWMUs;
- No Further Action Statement of Basis for the IWTP soils SWMU;
- Complete RCRA Facility Investigation (RFI) Reports for six AOCs sites;

- Complete Corrective Measures Study (CMS) Reports for three AOCs sites;
- Operate and Maintain Corrective Measures activities for three AOCs sites;
- Conduct and submit reports for the Basewide Groundwater Monitoring program.

The purpose of this Risk Evaluation/Risk Management Plan is to document that work performed under the CAS guidelines results in site conditions that are fully protective of human health and the environment and that, therefore, no additional work is warranted at the site except for post-closure (where applicable) and long term monitoring /management.

ODEQ has issued a "Ready for Reuse" determination for the six historical landfills within the installation property in recognition that the landfills are protective of human health and the environment for recreational use.

For the ongoing seven SWMU sites and 13 AOC sites, Tinker AFB will document that there are no ongoing releases to the environment such that the nature and extent of any contamination is fully delineated, and will identify and secure any completed pathway via a corrective measure and/or land use controls and institutional controls. Tinker AFB will also implement any interim corrective measure as necessary or implement and operate any long term remedy at a site in order to ensure immediate protectiveness to human health and environment should a release occur.

Identified exposure pathways will be mitigated or eliminated as follows:

• **Surface water**
- There are no discharges from a site source except for storm water runoff.
• **Surface soil**
- All affected surface soils are isolated or have been removed, thus eliminating the potential for contact with storm water.
• **Subsurface soil**
- Restrictions on subsurface work (e.g., excavation, drilling, pile driving) have been designated near any of the ongoing SWMUs and AOCs and any No Further Action (NFA) sites with Land Use Controls (LUCs) and Institutional Controls (ICs).
• **Ground Water**
- Ground water monitoring will be performed to demonstrate that the extent of all contaminant plumes is at steady state or demonstrates declining conditions (aka monitored natural attenuation) and that no groundwater contamination exceeds Maximum Contaminant Levels (MCLs) at the installation boundary.

1.0 Introduction

Tinker AFB is situated on a relatively flat expense of grassland. Prior to the development of the base, the area was characterized by large tracts of private agricultural land. The Base currently occupies approximately 4,277 acres of semi-improved and unimproved grounds that are used for the airfield, golf course, housing area, offices, shops, and other uses characteristic of military installations. Tinker AFB's mission is dedicated to providing worldwide technical logistics support to Air Force aerospace weapon systems, equipment, and commodity items, and encompasses a myriad of responsibilities. The logistics center manages or maintains the B-1B, B-2, B-52, E-3, and the C/KC-135 series aircraft. It performs annual depot-level maintenance on more than 120 aircraft and overhauls and maintains more than 1,100 engines from 11 major commands, as well as the Army, Navy, and numerous foreign countries. The center also manages various missile systems. Tinker AFB also accommodates a large family of associate organizations representing several major commands. Two large Air Combat Command support units add to the complex mission of the Base. Tinker AFB is the home operating base for the 552nd Air Control Wing flying the E-3 Sentry, and the Air Force Reserve's 507th Air Refueling Wing. Tinker AFB is also home of the Navy's E-6A Strategic Communications Wing One and will soon be the depot for the new refueling tanker, the KC-46A. Tinker AFB is operating under the RCRA Permit #OK1571724391 issued by the Oklahoma Department of Environmental Quality in 2002. The efforts to identify, investigate, and remediate any actionable releases and/or migration of hazardous constituents to the environment in order to protect human health and the environment is performed under USAF Environmental Restoration Program.

Upon ODEQ re-issuance of the RCRA Operating Permit, Tinker AFB will conduct upcoming corrective action activities per EPA Region 6 2015 Corrective Action Strategy guidelines. In order to achieve the AF and RCRA cleanup milestone goals, Tinker has prepared both a Corrective Action Strategy Workplan and this Risk Evaluation and Risk Management Plan. This report includes the following information:

- Release characterization activities and results;
- Documentation of interim measures implemented to address historical releases;
- An exposure scenario evaluation (i.e., excerpts of the Base Conceptual Site Model, or CSM);
- A demonstration that remedial activities already completed at the site have reduced risks to acceptable levels or allow potential risks to be managed; and
- A discussion of institutional controls which have been implemented to restrict land and ground water use and to prevent or reduce exposure to site contaminants.

1.1 Objectives of Document

According to the Region 6 2105 CAS guidance document, the primary objective of a Risk Evaluation Report (RER) is to document whether site releases are "actionable." The CAS guidance document indicates that a Risk Management Plan (RMP) should be prepared to describe and justify the facility's intended actions to ensure the protection of human health and the environment.

1.2 Site Description and Background

Tinker AFB is located in central Oklahoma, approximately five miles southeast of downtown Oklahoma City. The Base is bounded on the west by Sooner Road, on the east by Douglas Boulevard, on the north by Interstate 40, and on the south by Southeast 74th Street. The Base currently occupies approximately 4,277 acres of semi-improved and unimproved grounds that are used for the airfield, golf course, housing area, offices, shops, and other uses characteristic of military installations. Since 1942, Tinker AFB's mission has been dedicated to providing worldwide technical logistics support to Air Force aerospace weapon systems, equipment, and commodity items, and encompasses a myriad of responsibilities.

As currently configured, the western portion of the base is reserved for various forms of housing as well as community and retail structures; thus the 7 SWMUs and 13 AOCs sites are primarily located in the central and eastern portion of the installation where the industrial operations facilities are located.

1.3 Document Organization

This report is organized as follows:

- Section 1 – Introduction with document objectives, site description and background, as As document organization;
- Section 2 – Summary of RCRA Corrective Action activities and results to date;
- Section 3 – Conceptual Site Model;
- Section 4 – Risk reduction/risk management demonstration; and
- Section 5 – Ongoing Sites Remediation Cleanup goals and Monitoring; and
- Section 6 – Corrective Action Objectives (CAO), CAO endpoints, Risk Management Sites.

1.4 Corrective Action Objectives, End Points, Risk Management Sites

1.4.1 Corrective Action Objectives

Corrective action is a requirement under the 1976 Resource Conservation and Recovery Act (RCRA) that facilities that treat, store, or dispose of hazardous wastes investigate and clean up hazardous releases to soil, groundwater, surface water, and air. Congress passed the Hazardous and Solid Waste Amendments in 1984, which granted the Environmental Protection Agency (EPA) authority to require corrective action at permitted and non-permitted treatment, disposal, and disposal facilities. Tinker Air Force Base (Tinker AFB) is one such permitted facility and therefore corrective action at release sites is required. Wastes that currently are generated are managed at two permitted hazardous waste storage facilities. However, prior to enactment of the Resource Conservation and Recovery Act of 1976 (RCRA), industrial wastes were discharged into unlined landfills and waste pits, streams, sewers, and ponds. Past releases from these areas and from underground storage tanks (USTs) have occurred, resulting in soil, groundwater, and surface water contamination. Corrective action is principally implemented through RCRA permits and orders. On July 1, 1991, OSDH (now ODEQ) and USEPA Region 6 issued the RCRA Part B Hazardous Waste Management Permit (No.OK1571724391), which formally authorized Tinker AFB to operate as a hazardous waste storage facility.

The Tinker Air Force Base (Tinker AFB) remediation strategy, as executed under the Air Force Environmental Restoration Program (ERP) is consistent with the corrective action requirements set out in the U.S. EPA *Region 6 Corrective Action Strategy (CAS)* dated February 2015. This serves as notice to the State of Oklahoma Department of Environmental Quality of Tinker Air Force Base's intent to continue to conduct corrective action using the CAS.

Corrective Action at Tinker AFB will be performed in accordance with the 2015 United States Environmental Protection Agency (USEPA) Region 6 Corrective Action Strategy (CAS) guideline (February 2015), that has been approved and adopted by the ODEQ Land Protection Division. The proposed CAS for Tinker AFB will be a holistic approach to all of the solid waste management units (SWMUs), areas of concern (AOCs), and other recognized release areas. The CAS will be conducted in accordance with § 264.90 and 264.101, ensuring that the requirements of a corrective action program are implemented and maintained. The emphasis will be on streamlining the process of corrective action to achieve results that satisfy all of the stakeholders. The ultimate goal of corrective action at the Base is to ensure groundwater MCLs for all constituents at the installation boundary, site source goals with agreement reached with regulatory agencies for alternate standards as appropriate for foreseeable land use.

The description of the CAS Performance Standards applying to Tinker AFB is provided below:

- **Source Control Performance Standard:** Tinker AFB will use CAS procedures to determine the most effective source control standard utilizing historical and current information.
- **Statutory and Regulatory Performance Standard:** Tinker AFB will utilize the risk based stator and regulatory standards for the facility. Applicable and Relevant Federal, state and local laws and regulations will be adhered to during this process
- **Final Risk Goal Performance Standard:** The risk goal for Tinker AFB will be for industrial land use unless otherwise specified goal for complete site closeout at residential standards.

Tinker AFB proposes to continue to use the February 2015 U.S. EPA *Region 6 Corrective Action Strategy (CAS)* Guidance Document to the fullest extent practicable for planning and implementing corrective action without superseding existing Federal, State, and local regulations. Current groundwater corrective action objectives for Tinker AFB are outlined below.

a. To ensure that in the future contaminants do not migrate off-site at levels above their respective drinking water MCL.

b. To monitor and provide sampling analytical data that reports the concentrations of COCs in groundwater collected from performance wells, as defined in Section 10.5.4.2, at each groundwater management unit or other named RCRA site.

c. To mitigate potential indoor air exposure in buildings located over existing groundwater plumes for which there is the potential for vapor intrusion and contamination of indoor air from volatile contaminants.

d. To remove or treat source material in groundwater to the extent practicable to reduce potential for future migration beyond the base perimeter and enhance the attainment of performance metrics. The goal includes removal or treatment of surface/subsurface sources in soils to the extent practicable since soil sources could subsequently migrate to groundwater.

e. To maintain existing on-site institutional and land use controls that protect workers from contact with contaminated groundwater and soils. Restricted access to the base by the general public, required digging permit approval for any excavation below six inches, and appropriate fencing are examples of existing institutional controls.

Current remediation activities and planned remedial actions are designed to meet the objectives listed above. Continuing efforts to remediate groundwater contamination satisfy the groundwater protection intent of regulations stated in 40 CFR 264.90 and 40 CFR 264.101. Tinker AFB will continue both the present groundwater monitoring program and the present groundwater remediation program and will submit to the ODEQ all status reports detailing progress and changes in the program.

1.4.2 Corrective Action End Points

According to the February 2015 CAS guidance, "For RCRA-regulated units, the point of compliance is described as the location closest to the waste management area (which can be one or more SWMUs) where the cleanup standard must be met. For risk-based corrective action, the POC is the point at which the risk-based cleanup standard must be met. In groundwater corrective action, the POC is often described as the point at which the facility must meet MCLs – which may be at the facility boundary or at another defined point of exposure. In these cases, an ACL (or other risk-based number) is met at the closest location to the waste management area." For Tinker, the point of compliance (POC) is the location where the groundwater protection standard applies. This location lies at the on-base "hydraulically down-gradient limit" of the waste management area, or down-gradient of a collection of waste management areas. The complex facility hydrogeology and 70-year history of site operations, waste management, and corrective action necessitate a POC approach where the POC consists of all those portions of the site boundary that are hydraulically down-gradient of identified waste management sites. Groundwater plumes are widespread across the facility, but only certain plumes have reached the base boundary, or are thought to potentially impact the boundary. There are no compliance point issues related to the Hennessey Water Bearing Zone or Producing Zone since any identified contamination in these zones is either below the MCL or is not anticipated to reach the Base boundary.

Although the point of compliance is recognized as the base boundary, additional monitoring wells are located off-site just beyond the base fence line; some within 500 feet or closer. Originally installed to characterize areas where groundwater contamination was thought to have migrated off-site, these points are now monitored to either help evaluate the effectiveness of an existing active remedy where those have been installed, or where concentrations are at MCL or above near the boundary but monitored natural attenuation has been approved for the site, to ascertain whether contaminants have migrated off-site. These wells are labeled as 'sentinel' wells. Sentinel wells are those currently uncontaminated monitoring points or those with concentrations at or near the MCL that are located just outside the base fence line opposite of, and generally down gradient to, an on-base plume with concentrations above the MCL, but where either 1) the plume has not migrated off-base due to site hydro-geologic conditions or 2) remediation activities have reduced off-site concentrations to much lower levels.

The maximum concentration allowed at compliance wells for AF sites is the maximum contaminant limit (MCL). For all other plumes where performance monitoring is in effect, concentration limits will be determined on a site by site basis based on risk, potential for a completed pathway, and demonstration through groundwater modeling or other analysis that the plume is unlikely to reach the Base boundary. For compliance wells with current contaminant concentrations above respective MCLs, the future maximum concentration will be the MCL beginning at such time as corrective actions have reduced levels to MCLs. Note that ongoing remedial activities have been taken as voluntary corrective actions by Tinker when it was recognized that contaminated groundwater had either reached or passed the fence line in those areas.

1.4.3 Risk Management Sites

Sites that are planned for inclusion as risk management sites include those outlined for additional investigation and characterization as well as any with a heightened potential for risk are detailed in the RCRA Permit and Table 3-1 of the Corrective Action Strategy (CAS) Workplan. Ongoing Solid Waste Management Unit sites include Landfill 6 (SWMU 1), Landfill 5 (SWMU 2), Landfill 1 (SWMU 3), Landfill 2 (SWMU 4), Landfill 3 (SWMU 5), Landfill 4 (SWMU 6), Site OTO34 (SWMU 24), Site ST007 (Area of Concern{AOC}1), Site ST008 (AOC 20), Site CG040 (AOC 21), Site CG041 (AOC 22), Site OT058 (AOC 23), Site OT062 (AOC 24), Site OT064 (AOC 25), Site OT065 (AOC 26), Site OT066 (AOC 27), Site OT067 (AOC 28), Site OT068 (AOC 29), Site OT069 (AOC 30), Site ST033 (AOC 31) and Site VI080 (AOC 32). In addition, groundwater has been investigated and continues to be evaluated and monitored under three additional Groundwater Management Areas designated CG037, CG038, and CG039. Additional details regarding SWMUs, AOCs, and groundwater management areas is available in the CAS Workplan and the Tinker Conceptual Site Model (CSM) document. These reports also provide additional information regarding potential human and ecological receptors and migration pathways in support of Section 4.0 of this document.

2.0 Summary of RCRA Corrective Action Activities

The corrective action activities for releases from Solid Waste Management Units at this hazardous waste management facility conducted under the USAF Environmental Restoration Program are pursuant to 40 CFR 264 Subpart F as provided in §§ 264.90 and 264.101. There are no regulated units such as surface impoundments, waste piles, land treatment units, or land disposal units that received hazardous waste after July 26, 1982 at Tinker AFB as defined under § 264.90(a)(2). Therefore the requirements for regulated units under §264.91 through §264.100 are not applicable. Tinker AFB is conducting, or has already conducted, corrective action and remediation at the SWMUs and other release areas identified in Table 1 and Table 2 below (with provisions for any newly discovered releases) in compliance with §264.90 and §264.101. The Tinker AFB corrective action program has similar elements to those required for regulated units.

2.1 Interim Measures

Tinker AFB has conducted several interim measures at various RCRA sites consisting of contaminated ground water recovery and treatment. Interim measure planning activities commenced in the early 1990s; many pump and treat interim measures were shut down by 2012 in order to allow for the groundwater to rebound. All RCRA sites with an interim corrective measure are undergoing an updated RFI effort.

2.1.1 Groundwater Containment, Control and Treatment

Since the early 1990s, Tinker AFB, has installed and operated various 'pump and treat' systems, as interim corrective measures at eight RCRA sites, including addressing groundwater contamination beneath SWMU #s 4, 5 & 6, AOC # 1, and AOC #s 21, 23, 24 & 31. All the systems treating the AOCs were shut down by 2012 in order to conduct and complete the RFI report for each site. These ground water 'pump and treat' systems were installed as a precautionary measure to preclude the potential migration of low-level ground water contamination, while site optimization was undertaken and additional interim measures such as consolidation, capping, or in-situ remedies were implemented. Each system consisted of multiple, 4- or 6-inch, stainless steel or Polyvinyl Chloride (PVC) recovery wells equipped with a submersible pump (sometime dual phase). In addition, nearby piezometers and/or groundwater wells were installed to monitor the cone of depression created by pumping from each recovery well. Each system included an activated carbon filtration system for treating contaminated groundwater. Ground water monitoring data from downgradient wells indicated that at the time the systems were shut down, site constituents in ground water had reached steady-state or declining concentrations. Note that all SWMUs and AOCs are identified in Table 1.

An interim groundwater extraction system was also installed at a site located east of the main part of Tinker AFB. This site is listed as an Air Force Installation Restoration Program (IRP) site that is currently identified as AOC 21. At that site, a solvent plume had migrated off-site; the system was designed to control further migration and to pull back off-site contamination by reversing the groundwater gradient. Currently, monitoring wells indicate that all off-site solvent concentrations are below MCLs at that location.

In addition to various groundwater extraction systems, the Base has installed a permeable reactive barrier across the toe of a plume that extended off-site in the southwest quadrant of the Base from SWMU 5 (all solvent concentrations on the down-gradient side of the plume are now below MCLs), has constructed full RCRA caps on all six landfills to control infiltration of surface water, generation of leachate, and access to trench materials. Several In-Situ Chemical Oxidation (ISCO) pilot studies have also been performed successfully to reduce areas of higher contaminant concentrations ('hot spots'), and additional hot spot areas are undergoing long-term ISCO using either emulsified vegetable oil (EVO) or potassium permanganate (KMNO4). Currently several of these sites include construction of EVO 'walls' along the Base boundary to intercept groundwater contamination before it can migrate off-site.

2.2 RCRA Facility Investigation

Numerous RFIs have been conducted on a site-specific basis over many years at Tinker AFB. Any future RFIs will determine the nature and extent of releases of hazardous waste or constituents from regulated units and subunits and AOCs at the facility and will gather all necessary data to support the Corrective Measures Study (CMS).

2.2.1 RFI Planning

Updated information on the facility background and setting, nature and extent of contamination, and evaluation of corrective measures technologies is provided via Remedial Investigation reports and Feasibility Study Reports for the National Priorities List (NPL) site and via site RCRA Facility Investigation (RFI) reports and CMS reports at appropriate SWMUS and AOCs for non-NPL sites. In addition, data provided in the Basewide Sampling Program reports that are generated at 15-month intervals, which includes both CERCLA and RCRA areas on Base, is used to monitor and evaluate groundwater plumes, data that is used during planning of any future work at any site. Data from both site specific investigation reports and from the basewide program is used to characterize possible source areas of contamination, plan treatability studies/investigations, evaluate the potential for risk, screening of alternatives, selection of corrective measures, and remedial designs etc. Although site specific data is always gathered for any site under investigation or remediation, the Base has taken a holistic approach to planning and data is also gathered on a basewide scale to ensure, for example, that sites with co-mingled plumes or multiple sources to individual plumes are fully characterized and understood before any remedy is applied.

2.2.2 RFI Sampling and Analysis

Data is collected on a site specific basis as appropriate (RFI, CMS etc.), but the primary data collection tool is the Basewide Sampling and Water Level Measurements program. This program takes a holistic approach to sampling and includes a major portion of all base monitoring wells, water supply well, piezometers, wells used for remediation such as groundwater extraction wells, vapor extraction wells (includes dual-phase). Under this program, compliance wells, sentinel wells (described in more detail in the permit and the CAS Workplan), and other wells used to characterize and/or monitor groundwater conditions are sampled, mapped, and evaluated. Reports are generated on a roughly 15-month interval. The Basewide Environmental Well Sampling and Water Level Measurements project is an essential part of the environmental restoration program conducted by the 72 ABW/CEPR at Tinker AFB to comply with the goal of completing environmental restoration of contaminated groundwater sites regulated under the Resource Conservation and Recovery Act of 1976 (RCRA) and the Comprehensive Environmental

Response, Compensation and Liability Act of 1980 (CERCLA). The data collected under this project are used in conjunction with other data at specific sites to meet regulatory requirements for long-term monitoring, site characterization, and site close-out.

All sampling and data analysis follows the August 2012 *Basewide Work Plan* (Versar, 2012), which is also known as the *Base-wide Uniform Federal Policy for Quality Assurance Project Plan* (UFP-QAPP) (Versar and CH2M Hill, 2012b). The UFP-QAPP provides instructions for any environmental data collection operation and is mandated for all government agencies and programs. The document describes necessary quality assurance (QA), quality control (QC), and other technical activities that are implemented to ensure that the results of the work will satisfy stated performance criteria. The Tinker AFB Basewide Workplan has been submitted to the Oklahoma Department of Environmental Quality and the USEPA Region 6 and was approved by both regulatory agencies.

Data review, including assessing the accuracy, precision, and completeness of data, is based on procedures described in guidance document *National Functional Guidelines for Organic Data Review* (USEPA, 2008), including a series of quality assurance (QA)/quality control (QC) procedures such as holding times, initial and continuing calibration accuracy, blank results, matrix spike/matrix spike duplicate precision and accuracy, field duplicate precision, if applicable, completeness etc. Laboratory data and validation reports are typically included with any project where analytical data is collected.

Primary Chemicals of Concern (COCs) include tetrachloroethene, trichloroethene, cis-1,2-dichloroethene, 1,2-dichloroethane, vinyl chloride, and hexavalent chromium, as revised and approved by the ODEQ in 2006 under a class 2 permit modification. However, data for all volatile organic compounds listed under EPA Method SW-846 8260B as well as hexavalent chromium (EPA Method SW-846 7196A and total chromium, are collected and archived into the Air Force's Environmental Resources Program Information Management system (ERPIMS) database, along with measured field parameters and any site specific miscellaneous analytical data. Per ODEQ requirements, total chromium is also collected for comparison with hexavalent chromium. Additional site specific analytes such as BTEX are also collected based on conditions and status at individual environmental sites. It should be noted that pesticides and polychlorinated biphenyls PCBs), included for many years under the basewide sampling program, were approved for deletion from sampling under the 2002 RCRA Permit since there were no documented issues and therefore no risk associated with these classes of contaminants. Fuel compounds continue to be sampled for at specific sites, but these are no longer evaluated on a basewide scale. Per- and polyfluoroalkyl substances (PFASs) are in the early stages of evaluation and are not yet included in the basewide sampling program but are being investigated on a site-by-site basis.

2.2.3 RFI Reporting

Reporting requirements and time lines are set out in the Permit. All reports produced under the auspices of CERCLA and RCRA (PA/SI, RFI, CMS etc. or equivalent) are submitted for review and approval to the appropriated regulatory agency. In addition, basewide sampling reports are provided as they are generated. Supplemental to required reporting, Tinker AFB attempts to keep both EPA Region 6 and the ODEQ apprised of events, concerns, and ongoing activities on a timely basis between submitted reports. Typically information is provided via phone or in face-to-face meetings when requested.

2.3 Assessment and Additional Analysis

Assessment of sites is ongoing and continual. Not only do site specific reports contain information to evaluate site status, but an overall basewide assessment is provided under the basewide sampling program. Isopleth and potentiometric maps provide a good tool to rapidly evaluate plume migration for example, by allowing a visual comparison of plume extent and plotted data. Periodic optimization of the groundwater well network is performed in order to evaluate the need for additional wells or whether wells are no longer needed. Other examples include: 1) soil sources have been, and are, evaluated to determine whether these are continuing to contribute contamination to the groundwater and 2) compliance/sentinel wells are evaluated each time a basewide report is generated to verify that potential risk levels have not increased. Where soil sources are deemed to no longer be a concern at a location with both soil and groundwater issues, that site may be closed but groundwater evaluation and monitoring would continue under one of the groundwater management units. This allows a certain amount of risk management since for example, workers at the site would only need to be concerned if they reach depths where they encounter groundwater.

Additional analysis takes two forms. The first is required by the Permit and relates to sentinel and compliance wells. Additional sampling on specified intervals is required should contaminant concentrations increase above a respective MCL in one of those wells. Secondarily, additional sampling is performed at sites where data is ambiguous and contamination may not be fully characterized or delineated. Several sites at Tinker AFB fall in this category, and RFIs are ongoing.

2.4 Site Groundwater

The following text summarizes important aspects of the saturated intervals at Tinker AFB Additional details are available in the Base Conceptual Model Document.

The most important source of potable groundwater in the Oklahoma City metropolitan area is the Central Oklahoma Aquifer (COA) System. Two of the primary water-bearing units of this system include the Garber Sandstone and the Wellington Formation. Together, they are commonly referred to as the Garber-Wellington Aquifer and are considered to form a single aquifer because the units were deposited under similar conditions and because many of the best producing wells are completed in this zone. Tinker AFB obtains much of its water from this source while local municipalities (Oklahoma City, Del City, Midwest City) have switched primarily to surface water sources. The Base water supply wells (WSWs) are screened or perforated at depths of 200 to 750 feet below ground surface (BGS).

Regional groundwater flow in the Central Oklahoma Aquifer is generally west to east. Structural features, such as the Oklahoma City Anticline located roughly 1.5 miles west of the Base, and regional dip, control regional groundwater flow. In addition, regional groundwater flow is influenced by discharge points such as the Deep Fork River, the Canadian River, and water supply wells.

Recharge of the Garber-Wellington Aquifer is accomplished principally by percolation of surface waters crossing the area of outcrop and by rainfall infiltration in this same area. Because most of Tinker Air Force Base is located in an aquifer outcrop area the base is considered to be situated in a recharge zone; the Garber Sandstone outcrops across a significant portion of Tinker AFB, or is overlain by only a thin veneer of the Hennessey Group, and therefore much of Tinker AFB occurs within the recharge area.

According to Wood and Burton (1968), the quality of ground water derived from the Garber-Wellington Aquifer is generally good, although wide variations in the concentrations of some constituents are known to occur. Wells drilled to excessive depths may encounter a saline zone, generally greater than 900 feet below ground surface. Wells drilled to such depths or those accidentally encountering the saline zone are either grouted over the lowest screens or may be abandoned.

Four primary hydro-stratigraphic units have been defined at Tinker AFB, including the Hennessey Water Bearing Zone (HWBZ), the Upper Saturated Zone (USZ), the Lower Saturated Zone (LSZ) and the Producing Zone (PZ). This terminology is colloquial to Tinker and reflects various hydro-stratigraphic units delineated at the Base. In general, a hydro-stratigraphic unit can be defined as a part of a body of rock that forms a distinct hydrologic unit with respect to the flow of groundwater.

2.4.1 Groundwater Conditions and Flow

The Hennessey Group at Tinker AFB does not have a recognized aquifer but some saturation, identified as the Hennessey Water Bearing Zone (HWBZ) does exist. The HWBZ is absent in the northeastern portion of the Base where the Hennessey strata are thin. Three aquifer zones (in descending order) have been identified for the Garber Sandstone and Wellington Formation (Garber-Wellington Aquifer) under Tinker AFB; these zones are part of the regional Garber-Wellington Aquifer. The zones include the Upper Saturated Zone (USZ), the Lower Saturated Zone (LSZ), and the Producing Zone (PZ). The LSZ has been subdivided into an upper and lower (Lower-Lower Saturated Zone) to address a significant downward component of groundwater flow in the LSZ, which is noted within the aquifer under Tinker AFB. The magnitude of this vertical flow component varies across the Base and is much less under the western one-third of Tinker AFB where the overlying Hennessey Group is thicker. The HWBZ is present in the southwestern portion of Tinker AFB where the Hennessey Group thickens and becomes locally saturated with groundwater. The hydraulic conductivity is low; hydraulic conductivity (slug) test data indicate it is generally less than 0.5 ft/day. The HWBZ is not considered a significant source of drinking water. The unit receives recharge from precipitation where it is exposed at the surface, at localized areas where sandstone outcrops at the surface and in locations of desiccation cracks with higher conductivity. Water levels in wells completed in the HWBZ show significant variation seasonally (as much as 10 feet has been documented) depending on the amount of rainfall, unlike in USZ and LSZ wells where water levels generally fluctuate a few feet at most under unstressed conditions.

Generally, groundwater in the Hennessey Group flows toward lower topographical elevations. In some areas, potentiometric lows mapped in the HWBZ are coincident with potentiometric highs on the USZ surface and suggest that vertical downward flow paths exist between the two zones. Downward vertical flow (and possibly lateral flow) and communication with the USZ are enhanced by the presence of desiccation cracks where the Hennessey Group is 30 ft or less in thickness. The approximate limit of saturation (HWBZ) within this geologic unit is estimated to occur when the unit is less than 20 feet thick and can no longer support a stable aquifer zone. Locally however, where the Hennessey is less than 20 feet thick, some thin, perched saturated zones may exist.

The USZ is the uppermost saturated zone of the Garber-Wellington Aquifer and is delineated from the LSZ by a basal aquitard. The USZ is approximately 50 feet thick, measured from the base of the overlying Hennessey Group to the base of the underlying aquitard, except where portions have been removed by erosion along down-cutting streams such as Crutcho Creek. The saturated portion typically ranges from less than 1 foot to 20 feet thick, and truncates along a line extending from near the Base boundary at CG040 a westward toward Douglas Boulevard north of SE 59th Street, north along Douglas Blvd, to just west of West Soldier Creek in the northeast part of the Base, looping through the old Kimsey Addition located north of Building 3001, and turning northwestward around the north end of Runway 17/35. Truncation of the saturated zone is primarily due to westward geologic dip and stream erosion. Desiccation cracks are also present in the USZ where it is exposed at the surface. Vertical contaminant transport from surface spills may impact deeper portions of the USZ more quickly due to the presence of desiccation cracks. Open desiccation cracks would provide relatively little resistance to water and contaminant infiltration, and movement through the desiccation cracks in the unsaturated USZ could be rapid.

The USZ has a large areal extent and occurs throughout Tinker AFB except in a small part of the northeast quadrant and east of the Base where Soldier Creek has eroded the Garber Sandstone to a point below the basal aquitard. Over much of the Base, the USZ occurs under unconfined conditions. In some areas, such as where fractures in the overlying Hennessey Group extend at depth, it may also be semi-confined. The extent of saturation has been confirmed by monitor well drilling as well as by comparing the elevation of several surface water bodies east of the Base to groundwater elevations in USZ wells located near them.

The USZ becomes confined in the farthest southwestern corner of the Base and to the west of the Base where it is locally confined by the overlying Hennessey Group. The depth to the top of the USZ potentiometric surface ranges from near the land surface in the northeastern portion of the Base where streams have cut deep enough (portions of Crutcho Creek and Kuhlman Creek) to 70 ft BGS in the southwestern portion of the Base. Hydraulic conductivity test data yield values that range from 0.04 to 6.7 ft/day.

Groundwater flow in the USZ under Tinker AFB is generally to the west or southwest due to geologic dip. However, local variations in flow direction exist on the western part of the Base, due either to structural features related to the Oklahoma City Anticline or to the presence of Crutcho Creek, and on the eastern part of the Base due to a leaky aquitard at the base of the USZ or man-made features. Locally, surface discharge of USZ groundwater occurs where creeks have eroded into the top of the Garber Sandstone, such as to Crutcho and Kuhlman Creeks in the northwest part of the Base, but most shallow groundwater leaves Tinker AFB as groundwater in the aquifer flowing southwestward. Eastward shallow groundwater flow off of the Oklahoma City Anticline is identified west of Crutcho Creek and locally at the eastern edge of the Base due to local groundwater mounding under Building 3001.

Numerous mudstone layers, which act as local aquitards, exist within the Garber-Wellington Aquifer saturated units. Most do not extend over great distances; a 1993 *Geostatistical Analysis of Geologic Heterogeneities* report indicates that sandstone and shale (mudstone) strata can be reasonably well correlated in the northeast quadrant over distances of only 500 to 1000 feet in the horizontal plane. However, two mudstone layers occur on a semi-regional basis under Tinker AFB; these are more laterally continuous and actually function as semi-regional aquitards. The uppermost aquitard occurs between the USZ and LSZ and is referred to as the USZ/LSZ aquitard. The second aquitard occurs between the LSZ and PZ and is referred to as the PZ aquitard. These aquitards, however, do not consist of a single continuous mudstone unit. Instead, they are zones composed of interbedded mudstones and fine sandstones and siltstones with a higher proportion of clay relative to sand. They are recognized by significant groundwater pressure head differences (up to 70 ft of head difference across the PZ aquitard for example) at well cluster locations where wells are screened above and below the aquitard layers.

The USZ/LSZ aquitard is composed of overlapping discontinuous mudstone lenses with interbedded thin sand lenses. This aquitard interval varies in thickness from less than 10 feet to greater than 25 ft. A vadose zone exists under the eastern third of Tinker AFB between the base of the USZ/LSZ aquitard and the saturated portion of the LSZ. This vadose zone is roughly 10 to 20 feet thick in the northeastern portion of the Base, but thins to the west and is no longer present west of north- south runway (Runway 17/35) where the LSZ potentiometric surface intersects the aquitard. Head differences of up to 6 feet occur between the USZ and LSZ at the western Base boundary and up to 40 feet on the east side of the Base. The USZ/LSZ aquitard outcrops between 15 and 20 feet above the creek along the west bank of Soldier Creek just south of the IWTP. Based on the distribution of chemical contaminants, the USZ/LSZ aquitard is believed locally to allow some hydraulic communication between the USZ and the LSZ through natural and man-made discontinuities.

The next deeper zone in the Garber-Wellington Aquifer is the LSZ. This saturated interval is approximately 150 feet thick. However, as previously noted, this zone is sub-divided into the LSZ and the LLSZ for modeling and discussion purposes based on the recognition of a vertical component of the flow gradient. Generally, the LSZ consists of the upper third of the section, while the LLSZ is considered, when included, as the lower two-thirds. The LSZ directly underlies the USZ/LSZ aquitard and exists under all of Tinker AFB. Hydraulic conductivity test data show the hydraulic conductivity of the LSZ ranges from 0.25 to 8.7 ft/day. Flow is generally to the west and southwest under the Base but, as with the USZ, local variations exist under the west portion of Tinker AFB due to structural features related to the Oklahoma City Anticline. In addition, a groundwater ridge exists just east of the Base in this aquifer zone, which causes LSZ groundwater east of the Base to flow eastward. Just east and north of Tinker AFB, changes in recharge and interaction with Soldier Creek create variable flow directions. Recharge to the LSZ occurs primarily by precipitation where units outcrop just east of the Base and locally by the downward movement of groundwater through the USZ/LSZ aquitard where the USZ overlies it and discontinuities in the aquitard occur.

Groundwater in the LLSZ generally flows in the same direction as groundwater in the LSZ at any given location on Tinker AFB. Recharge to the LLSZ is by downward leakage from the LSZ and by lateral inflow of groundwater from the area east of the Base. A pumping test was conducted at well cluster 1-91PW in the northeastern corner of the Base in November 1994 as part of the IWTP/Soldier Creek Groundwater OUs RI. The hydraulic conductivity values calculated from the pumping test ranged from 0.78 to 15.6 ft/day. The results from the pumping test indicate that the LLSZ is interconnected with the LSZ. Additional pump tests to evaluate interaction between the HWBZ, the USZ, and the LSZ have been conducted at the Landfill 6 area and near Landfills 2 and 4.

The PZ aquitard occurs at the base of the LSZ (LLSZ) and hydraulically separates the LSZ from the underlying PZ. The isolation of the PZ from the LLSZ is demonstrated by head differences of up to 70 feet across the unit. This aquitard appears to be similar to the USZ/LSZ aquitard, being formed by a series of overlapping mudstones with interbedded more permeable sandstone/siltstone lenses. Well log data suggest that the PZ aquitard is present beneath the entire Base. The aquitard appears to be at least 30 feet thick; however, studies suggest that this aquitard may be up to 80 feet thick locally.

The PZ lies below the PZ aquitard and extends downward approximately another 500 to 600 ft. At around 700 to 800 feet BGS, the PZ grades progressively into saline water, which forms the lower limit of potable water. A physical boundary between the PZ and underlying units (i.e., the Chase, Council Grove, and Admire Formations) occurs somewhat deeper. The natural flow direction in the PZ is difficult to identify due to the influence of water supply wells (WSW) and limited data coverage but is most likely to the west. Data supplied by Wood and Burton (1968) from the Nichols Hills area to the west of the Base and results of the U. S. Army Corps of Engineers pump test involving former Tinker WSW-14, WSW-15, and WSW-16, originally located just east of Building 3001, suggest that there is little vertical communication between the PZ and shallower zones. Several shallow wells in the LSZ were monitored during the pump test and none of the wells exhibited any measurable drawdown. An average hydraulic conductivity of approximately 5 ft/day has been calculated for the Garber-Wellington sandstones and from production well data in the Oklahoma City area. A total of 34 Tinker AFB WSWs have been completed in the PZ; twelve have since been plugged, and one new well (#34) was recently placed in operation. Twenty-one of the wells are currently operational, although this number varies over time.

Shallow aquifers exist temporarily in zones of alluvium that border streams, or where sandy residual soils overly bedrock at shallow depths. Soil aquifers are typically recharged directly by precipitation, gradually running dry seasonally as base flow to local streams and recharging of underlying rock aquifers deplete limited supplies. The significance of shallow aquifers is that they may facilitate the contamination of important lower aquifers or surface waters by generation and mobilization of wastes. Shallow aquifers may not facilitate the detection of developing ground-water contamination problems because of their localized nature and ephemeral character.

The average groundwater flow velocity ranges from 0.5 to 95 feet per year, depending on whether it is calculated for more, or less, permeable layers. Groundwater gradients vary as follows: Hennessey Group, the average is 0.027 ft/ft. USZ ranges between 0.005 and 0.02 ft/ft, and LSZ (inclusive of the LLSZ), ranges 0.002 to 0.005 ft/ft.

2.4.2 Groundwater Monitoring

Basewide groundwater monitoring is an essential part of the environmental restoration program conducted by the Environmental Restoration Office at Tinker AFB. The data collected under this program are used in conjunction with other data at specific sites to meet regulatory requirements for long-term monitoring, site characterization, and site close-out. The long-term goal of the monitoring program is to help complete environmental restoration of contaminated groundwater sites.

Over 1500 groundwater monitoring wells have been installed on and around Tinker AFB since the mid-1980s, although a large number have subsequently been plugged through well optimization programs and approval from the ODEQ. Monitoring wells have generally been installed in clusters or groups that intercept a prescribed portion of the four principal hydrostratigraphic or water-bearing zones (WBZs) of a portion of the Central Oklahoma Aquifer system commonly referred to as the Garber-Wellington Aquifer and a shallow water bearing zone in the Hennessey Group. These zones are designated as the upper saturated zone (USZ), lower saturated zone (LSZ), lower-lower saturated zone (LLSZ) and producing zone (PZ) in the Garber-Wellington Aquifer and the Hennessey water-bearing zone (HWBZ) in the overlying Hennessey Group. Individual wells and groups of wells are spread over the entire Base and some outlying areas. They are identified by their depth and respective aquifer and their surface locations within a particular sampling zone. All monitoring wells, piezometers and most extraction wells have water levels measured during each Basewide sampling event (currently performed on a 15-month basis) and during site specific sampling episodes. All wells constructed by the Air Force on and around the Base and surface completions are designed to collect representative and unbiased groundwater samples and to provide accurate groundwater elevations for long-term monitoring from discrete aquifer zones. Well design criteria such as well type, total depth, surface casing depth and screen interval were developed based upon a review of existing cross sections, well data, topographic maps, etc.

Wells are constructed to minimize the potential for migration of any substance between the surface and subsurface and/or geologic formations. Each new monitoring well borehole was geophysically logged prior to well installation. The logs were reviewed in the field and used to determine surface casing depths, well completion depths, and screen intervals. Proposed well designs were verified or altered in the field based upon the actual conditions encountered at each site. All wells installed on or around Tinker AFB by the Air Force are constructed to meet Oklahoma Water Resources Board (OWRB) Title 785, Chapter 35 requirements.

The basewide groundwater monitoring program began primarily as an annual event (1994) that evolved into a 15-month program via a 2006 modification to the Tinker AFB 2002 Resource Conservation and Recovery Act Part B Renewal Permit. In addition, more frequent site-specific sampling has been included during site specific investigations throughout the years on an as-needed basis. The basewide program includes the collection of water level measurements and groundwater samples from a network of monitoring wells, piezometers, extraction and recovery wells, landfill sumps, and private off-base wells. Data collected during water level measurement events are used to construct potentiometric surface maps and to determine the direction of groundwater flow beneath the entire Base. The maps can also be used to provide an estimate of hydraulic gradient, which controls groundwater velocity. The maps allow insight into patterns of groundwater flow, identification of natural recharge and discharge areas, identification of areas of artificial recharge (such as a leaking subsurface water line), effects of pumping wells, and effects of seasonal influences (such as extended periods of drought or heavy precipitation). In order to map the potentiometric surface at a scale that allows such subsurface features to be delineated and changes identified over time, it is essential to maintain a sufficiently dense network of locations where water level measurements can be reliably and repeatedly obtained. A detailed discussion of the groundwater monitoring program at Tinker AFB is contained in Section 10.5 of the permit renewal application.

2.4.3 Groundwater Delineation Activities

With data from some 1500 monitoring wells, as well as from many temporary wells and borings, groundwater plumes appear well characterized and delineated. However, it should be noted that in a few exceptions, new data from wells installed in the past several years has allowed more precise definition of the extent of plumes at several sites. The delineation of groundwater contamination is not considered to be static; the concept that plumes can migrate at differential rates due to the complex, heterogeneous subsurface geologic framework, is a constant reminder that characterization activities are an ongoing concern. The Base has taken a holistic approach to characterizing groundwater contamination and, in addition to site specific monitoring, has applied a 'basewide' program that allows for all wells to be evaluated in a short time span. Early in the program wells were sampled quarterly. This was changed in the mid-1990s to yearly, and was further revised in 2006 to a 15-month interval with approval from the ODEQ. Both chemical and potentiometric data are generated under each 'basewide' event. Data from this 'basewide' program is used to evaluate compliance issues, general plume dynamics and changes in concentrations over time, as well as any interaction between co-mingled or geographically proximal plumes. The program, continues at present with around 800 monitoring wells being sampled, and all existing monitoring wells (roughly 1175) being measured for depth to groundwater.

2.4.4 Installation and Sampling Plume-defining Wells

See Sections 2.4.2 and 2.4.3. In addition to roughly 1500 wells installed since the mid-1980s, numerous borings and temporary wells from which screening level data have been gathered have helped to define and characterize plume extent. Over 100 hydro-geologic cross-sections have been generated and digitized, which are used to help delineate both geologic and hydraulic subsurface units. These sections also have been instrumental in understanding both the horizontal and vertical extent of plumes as well as potential pathways.

2.4.5 Post-Closure Groundwater Monitoring Program

Groundwater will continue to be monitored at all sites based on regulatory requirements and agreements with regulatory agencies. This includes any sites that have not yet reached closure as defined under RCRA or EPA regulations or requirements. The frequency and duration of sampling, as well as the list of analytes to be reported, will be based on documented agreements approved by the regulatory agencies for each SWMU or AOC.

Table 1: Schedule for Ongoing Solid Waste Management Units

Current SWMU No.	AF Site Number	Original Site Name	Activity History	Current Status
1	LF016	Landfill 6	Listed as a SWMU in the 1991 and 2002 RCRA Permits. Final Phase I RFI report completed September 1994. Final Phase II RFI report completed June 1997. RCRA landfill cap upgrades were completed in 2001. Long term monitoring and care of the RCRA cap was approved as the remedy for this site in a letter from ODEQ dated 6/1/2001.	Recurring: Long Term Monitoring and Care of the RCRA cap. Annual Report: September
2	LF015	Landfill 5	Listed as a SWMU in the 1991 and 2002 RCRA Permits. Final Phase I RFI report completed September 1994. Final Phase II RFI completed September 1995. RCRA landfill cap installed in 1998. Long term monitoring and care of the RCRA cap as the remedy for this site was documented in a letter from ODEQ dated 10/4/2001.	Recurring: Long Term Monitoring and Care of the RCRA cap. Annual Report: September
3	LF011	Landfill 1	Listed as a SWMU in the 1991 and 2002 RCRA Permits. RCRA landfill cap installed in 1991. Final Phase I RFI report completed September 1994. Final Phase II RFI completed April 1999. Long term monitoring and care of the RCRA cap as the remedy for this site was documented in a letter from ODEQ dated 7/25/2001.	Recurring: Long Term Monitoring and Care of the RCRA cap. Annual Report: September
4	LF012	Landfill 2	Listed as a SWMU in the 1991 and 2002 RCRA Permits. Final Phase I RFI report completed September 1994. RCRA landfill cap installed in 1998. Final Phase II RFI completed April 1999. Long term monitoring and care of the RCRA cap as the remedy for this site was documented in a letter from ODEQ dated 7/25/2001.	Recurring: Long Term Monitoring and Care of the RCRA cap. Annual Report: September
5	LF013	Landfill 3	Listed as a SWMU in the 1991 and 2002 RCRA Permits. RCRA landfill cap installed in December 1991. Final Phase I RFI report completed September 1994. Final Phase II RFI completed April 1999. Long term monitoring and care of the RCRA cap as the remedy for this site was documented in a letter from ODEQ dated 7/11/2001.	Recurring: Long Term Monitoring and Care of the RCRA cap. Annual Report: September
6	LF014	Landfill 4	Listed as a SWMU in the 1991 and 2002 RCRA Permits. RCRA landfill cap installed in December 1991. Final Phase I RFI report completed September 1994. RCRA landfill cap installed in 1998. Final Phase II RFI completed April 1999. Long term monitoring and care of the RCRA cap as the remedy for this site was documented in a letter from ODEQ dated 10/29/2001.	Recurring: Long Term Monitoring and Care of the RCRA cap. Annual Report: September
24	OT034	IWTP - Industrial Wastewat er Treatment Plant Soils	Identified as a RCRA SWMU in the 1991 and 2002 RCRA Permits. Phase I RFI report completed April 1994, Phase II RFI report completed July 1996. CMS report completed June 2003. The Air Force submitted a decision document to ODEQ (April 23, 2004) proposing the selected remedy be vapor extraction from the soils. The ODEQ concurred with the Air Force in a letter dated May 5, 2004. In 2016, an additional non-time critical removal was performed to remove soil hot spots discovered to be slightly above industrial levels. A Corrective Action Completion report for soils was completed and approved by DEQ on 1/25/2019.	Corrective Action complete - soil removal Construction Completion Report: January 2019

Table 2: Schedule for Ongoing Areas Of Concern Sites

Current AOC No.	AF Site Number	Site Name	Activity History	Current Status
1	ST007	Fuel Farm (290 POL Facility)	AOC 1 was identified in the 6/15/89 USEPA Region 6 RFA, but was not listed as an AOC in the 1991 RCRA Permit. As required by the 1991 RCRA Permit, a summary of previous studies was documented in the December 1992 Description Of Current Conditions for Tinker AFB. This AOC was not listed in the 2002 RCRA Permit. However, a RFI report was completed in 1995, and an additional Draft Site Investigation Report was completed in December 1996. Two vacuum enhanced pumping (VEP) systems were installed at the site between 1998 and 2000 as interim corrective measures. Collectively, the two systems extract groundwater and soil vapor from 34 recovery wells around Building 214, the former Building 210, near Tank 349, and near Building 117. The two systems where shut down in April 2012.	ICM – completed in 2012. New RFI underway RFI Report: July 2018
20	ST008	Building 201 Vapor Intrusion	A potential vapor intrusion condition was identified at Building 201 during a base-wide vapor intrusion survey (inventory) in 2010.	RFA completed for soil vapors RFI effort: FY2022
21	CG040	Gator Groundwater Management Unit	CG040 encompasses chlorinated solvent impacted groundwater underneath an adjunct facility approximately one mile east of the eastern boundary of Tinker AFB near the intersection of SE 59th St. and Post Road. The facility is non-industrial; only one building used for administrative purposes was found at the site. No unique source has been identified for this contamination. A groundwater extraction and treatment system began operation as an interim action in October 1999. The RFI report was completed in December 2003 and the CMS report was completed in July 2006. A Statement of Basis was completed as a decision document between Tinker AFB and the ODEQ, and was signed by ODEQ on July 31, 2006. Ultimate goal is to achieve UU/UE site close out.	Corrective Actoin - GW extraction system and bioreactor with insitu remediation Construction Completion Report (for RC): December 2017
22	CG041	AWACS Sector	CG041 encompasses impacted groundwater beneath the tarmac and taxiways south of Building 230. This site was introduced to ODEQ at the October 2009 RAB meeting.	RFI Report completed in December 2015 CMS underway CMS Report: September 2018
23	OT058	Jet Engine Test Cells (Bldg. 3703)	A site investigation report was completed in July 2002; Interim Corrective action using soil gas vapor and groundwater extraction was initiated in 2002 with the report issued in May 2003. A CMS was completed in May 2005. The VEP system continues to operate until the interim remedy in place (RIP) is either adopted or an improved remedy is selected.	RFI underway RFI Report: March 2018
24	OT062	Building 230	A RFI report was completed in March 2004. A VEP system was installed as an interim corrective measure to mitigate the potential risk posed by subsurface contaminants along the north and west sides of Building 230. A Phase I CMS was completed in April 2007 and a draft Phase II CMS was completed in May 2011. The VEP system continues to operate until the interim RIP is either adopted or an improved remedy is selected.	RFI underway
25	OT064	Building 210	A Draft Final RFA was completed in July 2008. A potential vapor intrusion condition was identified.	RFI underway
26	OT065	Building 283, Building 284, Building 296	A potential vapor intrusion condition was identified at Buildings 283, 284, and 296 during a base-wide vapor intrusion survey (inventory) in 2010.	RFI Report completed in December 2015 CMS underway CMS Report: September 2018
27	OT066	Building 2110 Oil Water Separator	Same Location as the Fuel Truck Maintenance Area AOC (see Table 10-1). The ODEQ approved the Air Force's NFA request in the 8/12/2002 RCRA Operations Permit Renewal. However, a fuel leak from the oil water separator to the oil was noticed in 2004. The RFI report was completed in 2016. Ultimate goal is to achieve UU/UE site close out.	Corrective Action - Non-time critical OWS removal work plan underway
28	OT067	Building 2101	This building is the former motor pool which has been demolished and will not be replaced. Due to the nature of the motor pool operations, solvent and fuel leaks are suspected. The RFI report was completed in June 2015. The CMA	Corrective Action – is scheduled for late 2017.

Current AOC No.	AF Site Number	Site Name	Activity History	Current Status
			workplan completed in March 2017. A non-time critical soil removal action is planned for late 2017. Ultimate goal is to achieve UU/UE site close out.	
29	OT068	Replaced" Fuel Hydrant System	In 1992, fuel releases from the hydrant system were detected when fuel would seep to the surface between the joints in the concrete of the tarmac. .	RFI Report completed in December 2015 CMS underway CMS Report: September 2018
30	OT069	Building 2121 and Building 2122	A RFA/RFI report was completed in March 2001 followed by a supplemental SI/RFI report in September 2001 and a CMS Report in October 2001 at Building 2122. Soil contamination was identified, but concluded that it was not impacting the groundwater. Similar process activities occurred at Building 2121 in the past, though no investigations have been performed at building 2121. Results for sub slab soil gas sampling beneath Building 2121 and 2122 were reported in a Vapor Intrusion Assessment that was completed in August 2011.	RFI underway RFI Report: January 2018
31	ST033	Area A Service (Fuel) Station	Soil and groundwater investigations conducted in 1990 and 1992 showed the presence of motor vehicle gas contamination. A product recovery system was installed in 1992 to pump fuel from the groundwater. By 1996, the extent of soil contamination was delineated, the USTs were removed and the product recovery system expanded. VEP remediation began June 1997, and fuel product recovery was completed by 1999. The OCC approved site closure on December 18, 2000; however, this is limited to only petroleum hydrocarbons in soil and groundwater. A TCE plume (along with other chlorinated compounds) has been identified in the groundwater beneath the site. The VEP system was shut down in November, 2012 and replaced with an Emulsified vegetable oil mixture injection – In Situ.	Corrective Action – In Situ Remediation for CVOCs ongoing.
32	VI080	Building 3105	Suspected releases of solvents from drain lines beneath Building 3105 were reported at this site in August 2009.	RFI underway RFI Report: September 2018

3.0 Conceptual Site Model

The conceptual site model information can be found in the companion document "Conceptual Site Model Tinker Air Force Base, Oklahoma" that was updated October 2017 by the Base geologist, Tinker AFB Installation Support Section.

4.0 Risk Reduction/Risk management demonstration

4.1 General Media Risk Management

There is only one complete exposure pathway that may exist; at site, AOC #1 – 290 Fuel Farm. All other exposure pathways have been mitigated or eliminated as follows:

• **Surface water**

- There are no known current ongoing discharges from any site except for storm water runoff.

• **Surface soil**

- Impacted surface soils at NPL Operable Unit #2 have been consolidated and removed, eliminating the potential for contact with storm water. NPL Operable Unit #2 has achieved a Certificate of Completion from EPA.

• **Sediment**
- The NPL Operable Unit #2 affected surface soils and stream sediments have been consolidated and removed, eliminating the potential for contact with storm water. NPL Operable Unit #2 has achieved a Certificate of Completion from EPA.

• **Subsurface soil (Engineered Controls/Institutional Controls)**

- Restrictions on subsurface work (e.g., excavation, drilling, pile driving) have been placed on all sites with an approved Decision Document; TAFB does not have land use controls with surrounding landowners as no plumes are off-the facility.
- No significant subsurface work, at any of the sites, will be allowed without proper coordination with EPA and ODEQ. Appropriate testing and management of soils required as applicable.

• **Ground Water (Monitored Natural Attenuation/Land Use Controls/Institutional Controls)**

- Ground water monitoring will be performed to demonstrate that the extent of all contaminant plumes is at steady state or concentrations are declining (Natural Attenuation) and that no further migration of ground water constituents is occurring.
- Ground water In-Situ treatment of 'hot spots' was implemented at several sites to reduce long term life cycle costs and to ensure compliance at the installation boundary.

4.2 Screening-level Risk Assessment

A screening-level human health risk assessment (HHRA aka SLHHRA) will be performed during each new site RCRA Facility Investigation to assess potential risk associated with human exposure to contaminants in indoor air, soil vapor, soil and groundwater as applicable. The screening levels will be under industrial or future residential land use scenarios where the declared site goal is site closeout for unrestricted use/unrestricted exposure (UU/UE). The purpose of the SLHHRA will be to assess whether contaminants in these media are present at concentrations greater than the conservative, generic (non-site specific) risk based screening levels (RBSLs) and therefore might present a potential unacceptable risk. A more specific contaminant data driven risk evaluation will be conducted based on the modified RBSLs to account for additive risk from multiple chemicals (USEPA, 1989, 2016) and assess the potential exposure scenarios in more detail.

A human health CSM involves characterizing the exposure setting, identifying complete exposure pathways, setting criteria for selecting receptors, and specifying receptors for exposure evaluation for each specific site. To characterize the exposure setting, potentially complete exposure pathways are identified based on information on release sources, contaminant fate and transport, routes of exposure, exposure points, and potentially exposed populations. Exposure pathways are considered complete when the following elements are present:

- A source or mechanism of chemical release from a source (e.g., contaminated soil) exists;
- A viable environmental transport medium exists (e. g., groundwater) or impacted media are directly available;
- A potential exposure point exists where human contact can occur (e.g., soil, indoor air, or water well); and

- A route of exposure is available through which the receptor may be exposed (e.g., ingestion, dermal contact, or inhalation of exposure media).

If any of these elements is missing, the exposure pathway is considered incomplete, and no adverse effects are anticipated. The incomplete exposure pathways are excluded from the risk assessment. A CSM showing the potential human exposure pathways and the routes for pathway completion is provided on Figure 6-1. Possible receptor populations identified for soil and groundwater exposure, and all possible exposure pathways for these receptor populations, are discussed in more detail below. An example risk assessment summary is provided on Table 8-2.

The RBSLs to be used in the SLHHRA include the USEPA RSLs (USEPA, 2017), the USEPA (2016, 2017) Vapor Intrusion Screening Levels (VISLs), and the ODEQ "Risk Based Decision Making for Site Cleanup (2013) cleanup levels for the industrial and residential exposure scenarios. If the RBSLs are not exceeded, then results of the SLHHRA will be used to support a response complete determination for media at the site. More detailed risk assessment work involving calculating cancer risk and non-cancer hazard estimates using more site-specific assumptions or aggregating concentration data over exposure areas can be completed only if RBSLs are exceeded in the media being assessed (USEPA, 1989, 2017). Standard-of-practice risk assessment methods, including USEPA Risk Assessment Guidance for Superfund Parts A, B, C, and D (USEPA, 1989, 1991a, 1991b, 2001), American Standard for Testing Materials (ASTM) of the International Standard Provisional Guide for Risk-based Corrective Action (ASTM, 2010), and ODEQ (2012, 2013) guidance, will be used when conducting the SLHHRA.

Potential ecological receptors for each site may include soil organisms, herbaceous and woody vegetation, insectivores (shrews), herbivores (mice), predators (hawks), and other types of invertebrate species. However, the industrial setting of most Tinker AFB sites does not present a natural habitat for plant or animal species. The surface at most sites consists of asphalt- and cement-paved areas. A few landscaped trees may exist in a very limited part of a site such as within a traffic island; for most sites at Tinker AFB, no other trees or shrubs exist nearby

4.3 Risk Characterization

Maximum detected contaminant concentrations for soil, sub-slab soil vapor, indoor air, and groundwater will be compared to generic (that is, non-site-specific) RBSLs, soil RSLs (USEPA, 2017) and ODEQ (2012) cleanup levels for Total Petroleum Hydrocarbons (TPH), sub-slab Vapor Intrusion Screening Levels (VISLs) (USEPA, 2016), indoor air Risk Screening Levels (RSLs) (USEPA, 2016, 2017), groundwater VISLs (USEPA, 2016, 2017), and tap water RSLs (USEPA, 2017). If the RBSLs are not exceeded, then results of the SLHHRA will be used to support a response complete determination for media for each site.

Exposure to concentrations greater than the RBSLs does not necessarily mean that a health risk exists, but it does present a scenario that may require additional action (e.g., further assessment, additional sampling, remedial action, or land use controls). In cases where the RBSLs are exceeded in a medium (soil, sub-slab vapor, or indoor air), screening-level cancer risk and non-cancer hazard estimates for all detected chemicals in that medium will be calculated, and the total cancer risk or hazard estimate will be calculated.

4.4 Risk-based Screening Level Basis

The RBSLs are based on non-site-specific exposure assumptions (duration of exposure in years, number of days per year, and rate of ingestion or inhalation per day) and use published values of reasonable maximum exposure assumptions deemed to be protective of most of the population. For example, the RSLs are RBSLs calculated assuming reasonable maximum exposure conditions (for example, 250 days per year over a 25-year exposure duration for industrial workers and 350 days per year over a 26-year exposure duration for residential receptors) (ODEQ, 2013; USEPA, 2017).

For contaminants that are classified as having a potential for causing cancer, the RBSLs are derived based on the probabilities of adverse health effects (cancer risk) from one person getting cancer in a population (for example, one person getting cancer in a population of 10,000, listed in scientific notion as 1 × 10-4). This cancer risk is referred to as excess lifetime cancer risk (ELCR), and the RBSLs correspond to a specific cancer risk level, called the target risk level (TRL). For contaminants exhibiting non-cancer health effects, the RBSLs correspond to a specific hazard level, called the target hazard quotient (THQ). The Hazard Quotient (HQ) is the concentration divided by the risk-based screening level for non-cancer toxic effects.

The RBSLs used in the SLHHRA differ from those used in the nature and extent evaluation to be consistent with the HHRA protocols (USEPA, 1989, 2017). The industrial RBSLs are based on a 1 in 100,000 (1×10^{-5}) TRL or a HQ of 0.1, whichever results in a lower concentration. A TRL of 1×10^{-5} is commonly used instead of 1×10^{-6}, which is used for the residential scenario due to the less restrictive nature of the industrial exposure scenario (ODEQ, 2013). The residential RBSLs are based on a 1 in 1 million (1×10^{-6}) ELCR or a non-carcinogenic HQ of 0.1, whichever results in a lower concentration.

However, in contrast to the RSLs based on a THQ of 1 used in the nature and extent evaluation, a THQ of 0.1 is used to account for the cumulative effect of multiple chemicals (i.e., accounting for the summation of the non-cancer HQs) relative to a threshold hazard index (HI) of 1 (USEPA, 2017). Per USEPA (2017), the "rationale for using THQ=0.1 for screening is that when multiple contaminants of concern are present at a site or one or more are present in multiple exposure media, the total HI could exceed 1.0 if each were screened at the HQ of 1.0." For example, individual chemicals may not exceed a RBSL based on an HQ of 1; however, the concentrations of multiple chemicals may be close enough to the RBSLs that the adding of the ratios of the chemical concentrations to the non-cancer RBSLs (i.e., the HQ) may exceed an HI (which is the sum of HQs) of 1.

4.5 Soil Risk-based Screening Levels

Soil sampling results will be compared with generic (i.e., non-site-specific) risk-based soil screening levels, which are RSLs published by USEPA (2017), assuming industrial and residential exposure scenarios. The soil RSLs are non-site-specific human health risk-based values for COPCs that are protective of human health for specified exposure pathways (i.e., ingestion of contaminants in soil, absorption of contaminants through contact with skin [dermal contact] or inhalation of particulates [dust]). Metal concentrations will be also compared to the background concentrations established for soil at Tinker AFB (i.e., the 95 percent upper tolerance limit) (IT, 1999).

Metals with maximum detected concentrations greater than a soil screening level but less than the background soil concentrations are not planned to be compared to the RSL.

ODEQ risk-based cleanup levels for TPH-GRO and TPH-DRO in soil will be used (ODEQ, 2012). The soil samples will also be analyzed for the individual volatile organic chemicals (VOCs) and semi-volatile organic chemicals (SVOCs) that compose the TPH-GRO and TPH-DRO, and these analytes were compared to the available RSLs.

4.6 Sub-slab Soil Vapor and Indoor Air Risk-based Screening Levels

Indoor air and sub-slab soil vapor sampling results will be compared against industrial and residential RBSLs that are protective of inhalation of volatile organic chemicals (VOCs) in indoor air and are generated from the USEPA VISL calculator, Version 3.5.2 (USEPA, January 2018).

The indoor air sampling results will be compared to the target industrial indoor air concentrations in the VISL calculator, which are exactly equivalent to the indoor air RSLs (USEPA, 2017), to address the current exposure scenario.

Sub-slab soil vapor sampling results will be compared with VISLs (sub-slab soil vapor to indoor air) calculated in the USEPA VISL calculator using the indoor air RSLs and the generic sub-slab soil-vapor-to-indoor-air attenuation factor of 0.03 (USEPA, June 2017).

4.7 Groundwater Risk-based Screening Levels

Groundwater sampling results from the USZ and LSZ will be compared with generic risk-based Tap water RSLs (USEPA, 2017), conservatively assuming that groundwater could be used as a potable water supply in a future residential exposure scenario. Tap water RSLs are human health risk-based values for COPCs that are protective of human health for specified exposure pathways (i.e., ingestion of contaminants in groundwater, absorption of contaminants through contact with skin [dermal contact] or inhalation of volatiles [showering]).

TPH-GRO and TPH-DRO results are not planned to be screened against tap water RSLs. However, the groundwater samples were also analyzed for the individual VOC and SVOC chemicals that compose the TPH-GRO and TPH-DRO, and these analytes will be compared to the available RSLs.

4.8 Groundwater-to-Indoor-Air Risk-based Screening Levels

Groundwater sampling results from the USZ (shallowest groundwater) will be compared with industrial and residential VISLs (groundwater-to-indoor air) calculated in the USEPA VISL calculator (USEPA, 2018) using the indoor air RSLs (USEPA, 2017), the generic groundwater-to indoor-air attenuation factor of 0.001, and the site-specific average groundwater temperature 6 of 21.03°C.

4.9 Characterizing Cancer Risk

The Excess Lifetime Cancer Risk (ELCR) is defined as the potential carcinogenic effects that are characterized by estimating the probability of cancer incidence in a population of individuals for a specific lifetime from projected intakes and exposures and chemical-specific dose-response data. Cancer risk estimates are calculated for each Chemical of Potential Concern (COPC) using the following equation (USEPA, 2017; USEPA, 1989):

$$ELCR = Concentration / RBSLC \times TRL$$

Where

ELCR = excess lifetime cancer risk [unitless]
Concentration = soil, indoor air, or sub-slab soil vapor concentration
RBSLC = cancer soil RSL [mg/kg or µg/kg], indoor air RSL [ppbv], or sub-slab vapor VISL [ppbv] based on a target cancer risk of 1 × 10-6
TRL = target cancer risk level (1 × 10-6) [unitless]

The total risk for the COPCs by medium were calculated using the following equation (USEPA, 1989):

$$\text{Total Cancer Risk} = \text{Sum of } (\text{Cancer Risk1} + \text{Cancer Risk2} + \ldots \text{ Cancer Risk}n)$$

Where

Total ELCR = sum of cancer risk for chemicals by medium
ELCR1,2, … *n* = cancer risk estimate for individual chemical
n = number of chemicals by medium

Cancer risk estimates are assessed according to the USEPA and ODEQ guidance. USEPA's target range for cancer risk associated with Comprehensive Environmental Response, Compensation, and Liability Act sites is risk management range—1 in 10,000 (1×10^{-4}) to 1 in 1 million (1×10^{-6})—with action generally required when ELCR estimates are greater than 1 × 10-4 (USEPA, 1991a; Revised National Contingency Plan [USEPA, 1994]). That is, the total ELCR associated with a site should not exceed this target range. The ODEQ (2013) risk assessment guidance document uses a cumulative ELCR of 1×10^{-5} and an HI of 1 as their onsite decision making criteria.

4.10 Characterizing Non-cancer Hazard

Non-cancer hazard estimates, the HQs, are calculated using the following equations (USEPA, 1989, 2017):

$$HQ = Concentration / RBSLNC \times THQ$$

Where

HQ = chemical-specific non-cancer HQ [unitless]
Concentration = soil, indoor air, or sub-slab soil vapor concentration
RBSLNC = non-cancer soil RSL [mg/kg or µg/kg], indoor air RSL [ppbv], or subslab vapor VISL [ppbv] based on a THQ of 1

THQ = target non-cancer HQ (1) [unitless]

The total HQ (that is, HI) for the COPCs by medium are calculated using the following equation (USEPA, 1989):

HI = Sum of (HQ1 + HQ2 + … HQ*n*)

Where

HI = Hazard Index or sum of non-cancer HQ for chemicals by medium
HQ1,2, … *n* = HQ estimate for individual chemical
n = number of chemicals by medium

Consistent with USEPA guidance (USEPA, 1991a), estimated HIs are presented with one significant figure for comparison with the HI target non-cancer level of 1, and the SLHHRA conclusions are based on comparison of these two values.

5.0 Ongoing Sites Remediation Cleanup Goals and Monitoring

5.1 Completed Remediation and Chemicals of Concern

The table below lists site specific corrective measure activities, impacted media and risk based cleanup goals.

Table 5-1: Completed Remediation and Chemicals of Concern at SWMUs and AOCs

Current SWMU or AOC No.	AF Site No.	Original Site Name	Completed & Ongoing Remediation	Chemicals of Concern	Affected Media	Cleanup Goal
1	LF016	Landfill 6	Preliminary 18-inch clay cap installed in 1986; the cap was extended to cover additional trenches discovered later in 1988. Full RCRA cap started in 1999; vegetation was completed in 2001. Landfill is fenced. Any groundwater contamination is being addressed under GWMU 5.	VOCs – chlorinated solvents	Subsurface Soils Groundwater	Industrial
2	LF015	Landfill 5	Initial clay cap installed in 1990 as an interim action. RCRA landfill cap installed in 1998. The landfill is fenced on the non-airfield sides. Any groundwater contamination is being addressed under CG039 (GWMU 3).	VOCs – chlorinated solvents; SVOCs.	Subsurface Soils	Industrial
3	LF011	Landfill 1	RCRA landfill cap installed in 1991. The landfill is fenced. Any groundwater contamination is being addressed under CG038 (GWMU 2). Interim action groundwater extraction (pump & treat) system installed in 1998; pumping and treatment from a subset of wells is ongoing. RA optimization via EVO injections started 2012.	Primarily household refuse/garbage, non-industrial wastes.	Subsurface Soils	Industrial
4	LF012	Landfill 2	RCRA landfill cap installed in 1998. ISCO (KMNO4) pilot test performed in 2002-2003. The landfill is fenced. Any groundwater contamination is being addressed under CG038 (GWMU 2). Interim action groundwater extraction (pump & treat) system installed in 1998; pumping and treatment from a subset of wells is ongoing. RA optimization via EVO injections started 2012.	VOCs – chlorinated solvents; Cr(VI)	Subsurface Soils Groundwater	Industrial

Current SWMU or AOC No.	AF Site No.	Original Site Name	Completed & Ongoing Remediation	Chemicals of Concern	Affected Media	Cleanup Goal
5	LF013	Landfill 3	A low temperature thermal desorption pilot test to treat contaminated soils conducted at central sludge dump at this landfill in 1989. RCRA landfill cap installed in December 1991. The landfill is fenced. Permeable Reactive Barrier (zero valent iron) installed in 2004 across the toe of the GWMSU 2D Plume. Any groundwater contamination is being addressed under CG038 GWMU 2). Interim action groundwater extraction (pump & treat) system installed in 1998; pumping and treatment from a subset of wells is ongoing. RA optimization via EVO injections started 2012.	VOCs – chlorinated solvents	Subsurface Soils Groundwater	Industrial
6	LF014	Landfill 4	RCRA landfill cap installed in December 1998. Cr(VI) pilot study performed at GWMSU 2F in 2008-2009. The landfill is fenced. Any groundwater contamination is being addressed under CG038 GWMU 2). Interim action groundwater extraction (pump & treat) system installed in 1998; pumping and treatment from a subset of wells is ongoing. RA optimization via EVO injections started 2012.	VOCs – chlorinated solvents; Cr(VI)	Subsurface Soils Groundwater	Industrial
AOC 1	ST007	Fuel Farm 290 (POL Facility)	Two vacuum enhanced pumping (VEP) systems were installed at the site between 1998 and 2000 as interim corrective measures. Collectively, the two systems extract groundwater and soil vapor from 34 recovery wells around Building 214, the former Building 210, near Tank 349, and near Building 117. The two systems where shut down in April 2012.	TPH, VOCs – chlorinated solvents	Sub-Slab Vapors Groundwater	Industrial
SWMU 24	OT034	IWTP - Industrial Wastewater Treatment Plant Soils	Since investigations of the IWTP began, several interim measures (IMs) have been completed. These include removal of the abandoned waste tanks (SWMU 23, later renumbered SWMU 24.14) in 1992, the removal of blending tanks D1/D2 (SWMU 24.2) in 2000, removal of SWMU 24.19 in 1999 and 2000, demolition of SWMU 32 (the STP) in 2001 and 2002, and installation of a dual-phase extraction system, called a vacuum enhanced pumping (VEP) system, between 2000 and 2003. The removal of the 11 underground storage tanks (USTs) associated with SWMU 23 (later renumbered to SWMU 24.14) occurred in 1992 and the SWMU was closed in 1993. In 2000, the D1/D2 tanks were taken out of service and replaced by two aboveground closed-top tanks in another area of the site. Tanks D1/D2 were demolished and removed in 2001. Instead of removing all the impacted subsurface materials, flowable fill was placed in the excavation as a fluid and vapor barrier. Between 2000 and 2003, a seven-well dual phase VEP system was installed at the SWMU 24.2 and SWMU 14.19 areas of the site. Two VEP wells (OT034-VEP-6 and OT034-VEP-7) were installed at the former D1/D2 tanks location. The VEP system approached asymptotic contaminant mass recovery at SWMU 24.2; the VEP system was shut down in June 2012 in preparation for an interim RA. Soil excavation and disposal occurred in 2016.	TPH, VOCs – chlorinated solvents	Groundwater	Industrial
CERCLA	OT003	North Tank Area	Not Applicable – regulated by USEPA Region 6 under the 12/9/88 FFA; CERCLA / NPL. Fuel recovery began 1991 and shut down April 2015	Fuel	Groundwater	Industrial
CERCLA	OT001	Building 3001	Not Applicable – regulated by USEPA Region 6 under the 12/9/88 FFA; CERCLA / NPL. Includes Pit Q51 and MN36 area.	VOCs – chlorinated solvents; Hex-Chrome	Groundwater	Industrial

Current SWMU or AOC No.	AF Site No.	Original Site Name	Completed & Ongoing Remediation	Chemicals of Concern	Affected Media	Cleanup Goal
AOC 20	ST008	Building 201 Vapor Intrusion	No site remediation to date. A potential vapor intrusion condition was identified at Building 201 during a base-wide vapor intrusion survey (inventory) in 2010.	VOCs – chlorinated solvents	Sub-slab vapors	Industrial
AOC 21	CG040	Gator Groundwater Management Unit or CHOT Site.	A groundwater extraction and treatment system (Groundwater Stabilization System or GWSS) including extraction well and French drains began operation as an interim corrective action in October 1999. EVO with wells and bioreactor ongoing. EVO injection wells installed between December 2012 and April 2013; injection began in 2012. Bioreactors installed in 2013, began operating May 2013. GWSS turned off December 2016.	VOCs– chlorinated solvents	Groundwater	Residential
AOC 22	CG041	AWACS Sector	No site remediation to date	VOCs– chlorinated solvents, Fuel	Groundwater	Industrial
AOC 23	OT058	Jet Engine Test Cell	A VEP system began to operate in XXXX and was shut down in 2012	VOCs-chlorinated solvents; TPH	Sub-Slab Vapors; soil; Groundwater	Industrial
AOC 24	OT062	Building 230	An oil/water separator (OWS) was located near the northwest corner of the building. It was filled with concrete in 2000. In the mid-1980s, fuel underground storage tanks (USTs) near the southeast corner of the building were removed. Free mercury was found in and around the drain line located in the building; a removal action was initiated that removed approximately 19 cubic yards of mercury contaminated soil. In 2004 a dual phase VEP system was installed on the northern and western sides of B230 as an interim corrective measure to mitigate the potential risk posed by subsurface contaminants; system began operations November 2005. The VEP system was turned off April 26, 2012 and the treatment building removed.	VOCs– chlorinated solvents, including methylene chloride, MEK; Fuel constituents (TPH), methane, mercury	Groundwater	Industrial
AOC 25	OT064	Building 210	UST 210 removed in October 1999. Mercury in soil north of B210 excavated and disposed of. UST on southeast side of building removed in 1997.	VOCs– chlorinated solvents; Fuel (TPH); mercury	Soils Groundwater	Industrial
AOC 26	OT065	Buildings 283, 284 & 296	No corrective measure activities have occurred to date.	VOCs – chlorinated solvents	Sub-Slab Vapors Groundwater	Industrial
AOC 27	OT066	Building 2110 Oil Water Separator	No corrective measure activities have occurred to date. Planned for non-time critical OWS/soil removal.		Soils	Residential
AOC 28	OT067	Building 2101	Corrective measure is underway. Non-time critical soil removal.	VOCs – chlorinated solvents; Fuels(TPH)	Soils	Residential
AOC 29	OT068	Replaced Fuel Hydrant System	No corrective measure activities have occurred to date.	Fuels(TPH)	Soils	Industrial
AOC 30	OT069	Buildings 2121 and 2122	No corrective measure activities have occurred to date.	VOCs – chlorinated solvents	Sub-slab vapors; soil; groundwater	Industrial
AOC 31	ST033 (CG037)	Arear A Service Station	VEP remediation began June 1997, and fuel product recovery was completed by 1999. The OCC approved site closure on December 18, 2000; however, this is limited to only petroleum hydrocarbons in soil and groundwater. A TCE plume (along with other chlorinated compounds) has been identified in the groundwater beneath the site. The VEP system was shut down in November, 2012 and replaced with an Emulsified vegetable oil mixture injection – In Situ.	VOCs – chlorinated solvents	Groundwater	Industrial
AOC 32	VI080	Building 3105	No corrective measure us underway.	VOCs – chlorinated solvents	Groundwater	Industrial

5.2 Monitoring

Tinker AFB has met, and will continue to meet, all appropriate requirements set out under 40 CFR 264.101 for corrective action at SWMUs and AOCs. The current groundwater well monitoring network consists of around 1175 points installed at appropriate locations and depths to yield representative samples for contaminant plumes in all aquifer zones. Specific requirements of this section are described in section 2 of the Tinker AFB CAS Workplan. Under this permit renewal, the network is anticipated to be reduced by 482 wells over time as noted in Tinker AFB RCRA Permit Renewal Application Section 10.5.4 (2017). Background values for groundwater contamination have been discussed in several previous reports. Since no alternate compliance concentrations are proposed, these reports are not discussed in the permit renewal application, but these documents are available from the Environmental Restoration Office. Tinker AFB will conduct all sampling and analysis efforts in accordance with the ODEQ and EPA approved Unified Federal Policy – Quality Assurance Project Plan (UFP-QAPP) included in the *Final Basewide Workplan* completed August 2012, or later version should it be amended.

6.0 Summary and Conclusions

This Risk Evaluation Report/Risk Management Plan summarizes work already performed (Tables ES-1 and Table 8-2) and additional work to be performed under the RCRA HSWA section of Tinker AFB RCRA Operating Permit and CAS guidelines. The analytical results to be documented in upcoming site specific RCRA Facility Investigation reports demonstrate that the implementation of interim measures has resulted in site conditions that are fully protective of human health and the environment. Basewide long term monitoring and management will be performed under the Tinker AFB Basewide Groundwater Monitoring Program to ensure compliance at the facility boundary and document the natural attenuation process.

7.0 References

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8.0 Figures and Tables

Table ES-1 and Table 8-2 from Area RFI report.

Figure 6-1.

Table B-1
Risk Assessment Summary
Area RCRA Facility Investigation
Tinker AFB, Oklahoma

OT065

Using CH2M Hill (2010) Soil Gas Data	Cancer Risk	HI > 1	Source of Risk > E-04 (Federal Upper Range) and/or HI > 1.0	Source of Risk E-04 to E-05 (ODEQ Lower range)
Current Office Workers	**3.75E-02**	**yes**	SG (TCE, 12DCP)	
Current Maintenance Workers	4.40E-06	no		
Future Construction Workers	NA	NA		
Future Adult Residents	**1.58E-01**	**yes**	GW (TCE, Arsenic, Chromium VI), SG (TCE, 12DCP, 112TCA)	
Future Child Residents	**3.98E-02**	**yes**	GW (TCE, Arsenic, Chromium VI), SG (TCE, 12DCP, 112TCA)	
Future Lifetime Residents	**1.99E-01**	**yes**	GW (TCE, c12DCE, Arsenic, Chromium VI), SG (PCE, TCE, 12DCP, 112TCA)	GW (VC), SG (12DCA)

OT065

Using Modeled Soil Gas from Soil & Groundwater Data	Cancer Risk	HI > 1	Source of Risk > E-04 (Federal Upper Range) and/or HI > 1.0	Source of Risk E-04 to E-05 (ODEQ Lower range)
Current Office Workers	1.38E-05	**yes**	SG (TCE from GW)	
Current Maintenance Workers	4.40E-06	no		
Future Construction Workers	1.56E-05	**yes**	GW (TCE), SG (TCE)	
Future Adult Residents	**7.31E-04**	**yes**	GW (TCE, Arsenic, Chromium VI), SG (TCE)	SG (naphthalene from soil)
Future Child Residents	**4.06E-04**	**yes**	GW (TCE, Arsenic, Chromium VI), SG (TCE)	
Future Lifetime Residents	**1.14E-03**	**yes**	GW (TCE, c12DCE, Arsenic, Chromium VI), SG (TCE)	GW (VC)

OT068

Using Modeled Soil Gas from Soil & Groundwater Data	Cancer Risk	HI > 1	Source of Risk > E-04 (Federal Upper Range) and/or HI > 1.0	Source of Risk E-04 to E-05 (ODEQ Lower range)
Current Office Workers	NA	NA		
Current Maintenance Workers	1.05E-06	no		
Future Construction Workers	1.56E-05	**yes**	GW (TCE), SG (TCE)	
Future Commercial Workers	**1.38E-03**	**yes**	SG (benzene, ethylbenzene, 124TMB, m- & p-xylene from soil)	SG (naphthalene, TCE from groundwater)
Future Adult Residents	**6.46E-03**	**yes**	GW (TCE, As, CrVI), SG (TCE, benzene, ethylbenzene, naphthalene, 124TMB, m- & p-xylene)	
Future Child Residents	**1.84E-03**	**yes**	GW (TCE, As, CrVI), SG (TCE, benzene, ethylbenzene, naphthalene, 124TMB, m- & p-xylene)	
Future Lifetime Residents	**8.30E-03**	**yes**	GW (TCE, c12DCE, As, CrVI) SG (TCE, benzene, ethylbenzene, naphthalene, 124TMB, m- & p-xylene)	GW (VC)

Ecological Risk for OT065

Receptor	Chemicals
Plants	boron*, manganese*, vanadium*
Invertebrates (Earthworms)	manganese*, vanadium*
Omnivorous Birds (Robins)	**cadmium**, zinc
Omnivorous Mammals (Shrew)	vanadium*
Carnivorous Wildlife (Fox)	none

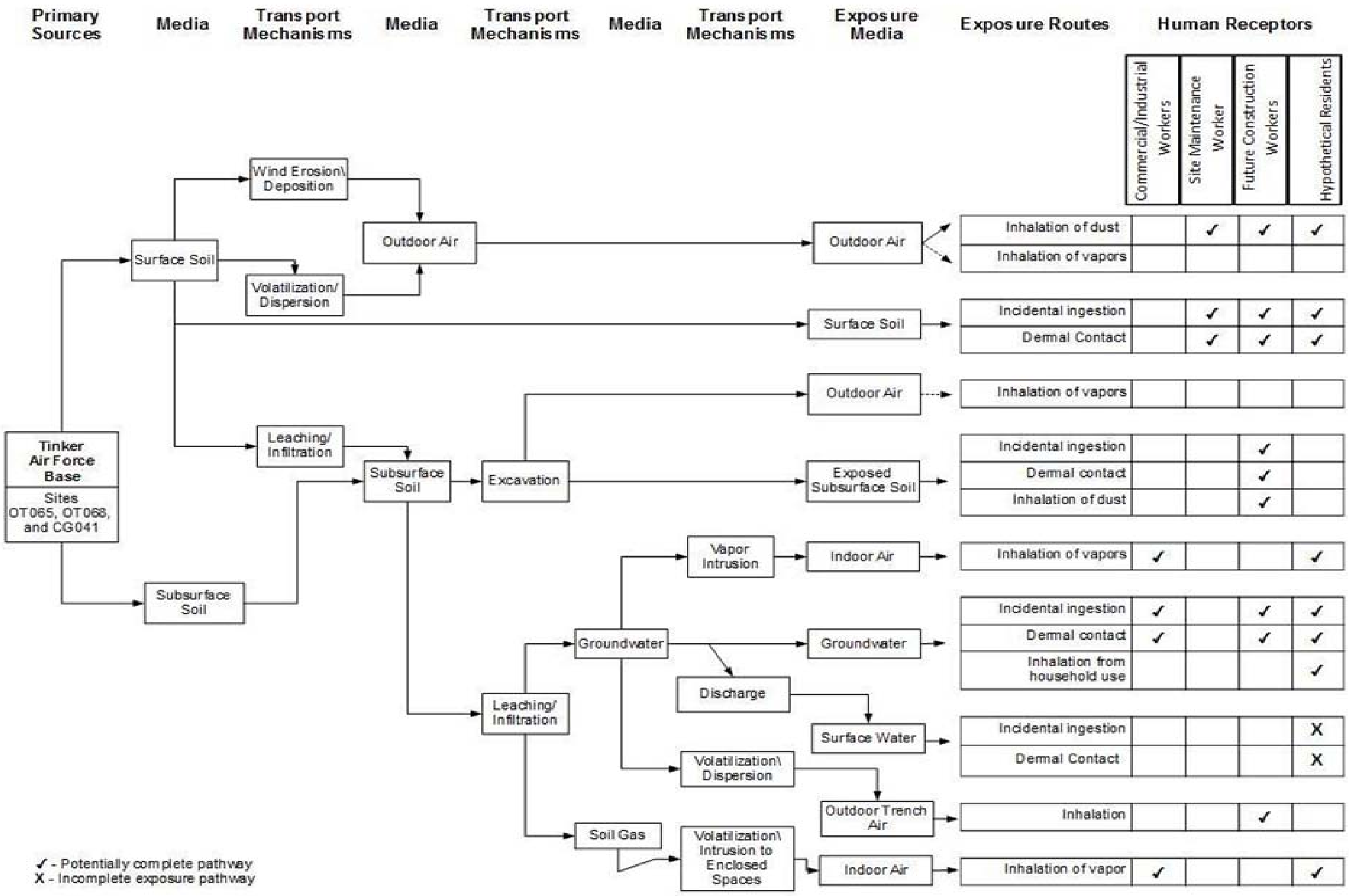
Ecological Risk for OT068

Receptor	Chemicals
Plants	**toluene**, boron*, manganese*, vanadium*
Invertebrates (Earthworms)	**hexavalent chromium**, manganese*, vanadium*
Omnivorous Birds (Robins)	none
Omnivorous Mammals (Shrew)	vanadium*
Carnivorous Wildlife (Fox)	none

NOTES:

Red, Bold = Risk > Criteria
* = Concentration < Background (USGS, 1994)
SG = Soil Gas
GW = Groundwater
VC = Vinyl chloride
TCE = Trichloroethene
PCE = Tetrachloroethene
c12DCE - cis 1,2-Dichloroethene
124TMB = 1,2,4-Trimethylbenzene
112TCA = 1,1,2-Trichloroethane
12DCP = 1,2-Dichloropropane

Figure 6-1. Human Health Conceptual Site Model for OT065, OT068, & CG041 at Tinker AFB, OK



Exposure Route	Commercial/Industrial Workers	Site Maintenance Worker	Future Construction Workers	Hypothetical Residents
Inhalation of dust		✓	✓	✓
Inhalation of vapors				
Incidental ingestion		✓	✓	✓
Dermal Contact		✓	✓	✓
Inhalation of vapors				
Incidental ingestion			✓	
Dermal contact			✓	
Inhalation of dust			✓	
Inhalation of vapors	✓			✓
Incidental ingestion	✓		✓	✓
Dermal contact	✓		✓	✓
Inhalation from household use				✓
Incidental ingestion				X
Dermal Contact				X
Inhalation			✓	
Inhalation of vapor	✓			✓