Final Report
Phase I RCRA Facility Investigation for Appendix I Sites

VOLUME IX

SWMU-19, Radioactive Waste Disposal Site 1030W
SWMU-20, Radioactive Waste Disposal Site 201S
SWMU-21, Radioactive Waste Disposal Site 62598
SWMU-22, Radioactive Waste Disposal Site 1022E

Department of the Air Force
Oklahoma City Air Logistics Center
Tinker Air Force Base, Oklahoma

September 1994

INDEX TO VOLUMES
RFI REPORT

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Department of the Air Force
Oklahoma City Air Logistics Center
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Table of Contents - RFI Summary Report

List of Tables

List of Figures

List of Acronyms

AFB	Air Force Base
AFRAT	U.S. Air Force Radiation Assessment Team
AOC	area of concern
CAL	Corrective Action Limits
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program
CDM	CDM Federal Programs Corporation
CFR	Code of Federal Regulations
DERP	Defense Environmental Response Program
DOD	U.S. Department of Defense
DOT	U.S. Department of Transportation
EID	Engineering Installation Division
EM	electromagnetic
EPA	U.S. Environmental Protection Agency
ES	Engineering Science
ft/ft	foot per foot
GPR	ground penetrating radar
HSWA	Hazardous and Solid Waste Amendments
IRP	Installation Restoration Program
LSZ	lower saturated zone
µR/hr	microroentgen per hour
MCL	maximum concentration level
msl	mean sea level
NAAQS	National Ambient Air Quality Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
PA/SI	preliminary assessment/site investigation
PID	photoionization detector
RCRA	Resource Conservation and Recovery Act
RI/FS	remedial investigation/feasibility study
RFI	RCRA Facility Investigation
ROD	Record of Decision
RWDS	radioactive waste disposal site

List of Acronyms (Continued)

SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TCLP	Toxicity Characteristic Leaching Procedure
TSD	treatment, storage, and disposal (facility)
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USZ	upper saturated zone
UWBZ	upper water bearing zone
VOC	volatile organic compounds
WQS	Water Quality Standards
yd^3	cubic yards

Executive Summary

This report provides a summary of the various investigations that have been conducted at solid waste management (SWMU)-19, Radioactive Waste Disposal Site (RWDS 1030W), Tinker Air Force Base (AFB), Oklahoma. The report has been prepared to determine and document whether sufficient investigations at RWDS-1030W have been performed to meet regulatory requirements. Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County. The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. The Base encompasses approximately 5,000 acres.

Background. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon™, jet fuels, and radium paints.

In 1984, Congress amended the Resource Conservation and Recovery Act (RCRA) with the Hazardous and Solid Waste Amendments (HSWA), which allow the Environmental Protection Agency (EPA) to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989, Tinker AFB submitted its Part B permit application for renewal of its operating RCRA Hazardous Waste Storage facility permit. The final RCRA HSWA permit issued on July 1, 1991, requires Tinker AFB to investigate all SWMUs and areas of concern (AOC) and to perform corrective action at those identified as posing a threat to human health of the environment. The permit specifies that a RCRA Facility Investigation (RFI) be conducted for 43 identified SWMUs and two AOCs on the Base. This document has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for RWDS 1030W.

Source Description. RWDS 1030W is located on Landfill No. 2 (SWMU-4) approximately 1,700 feet west and 550 feet north of Building 1030. Until 1951, radiological waste considered to be of significant nature was sent to the Canadian Radium and Uranium Corporation in Mt. Kiska, New York. As a cost-savings, measure certain types of radiological waste were disposed of on Base from 1951 until the 1960s. RWDS 1030W was reported

to be a burial site for burned radium dial waste including rags and solvent solution. The waste was dumped in a pit, burned, and then covered with soil.

Site Investigations

Nonintrusive Survey Results. Background radiation levels in the site vicinity ranged from 6.1 to 6.5 microrentgen per hour (μR/hr). Radiation levels on the site ranged from background to 1340 μR/hr. General areas, as well as fairly isolated points, of significantly elevated radiation levels were indicated. The results indicate that the area of contamination is large and extends in a southeast to northwest direction.

Geophysical surveys were performed including ground penetrating radar, magnetic field radiometer surveying, and electromagnetic conductivity surveying. These surveys, along with the results from the radiological survey, indicate that RWDS 1030W contains several areas of subsurface soil contamination and/or buried radioactive material. The radiological and geophysical surveys indicate that the elevated radiation levels roughly follow a former trench, which runs between the elevated area and the former location of Pistol Pond, oriented in a northeasterly direction. Geophysical surveys suggest that this trench may be as deep as 26 feet. It is likely that the subsurface soil contamination starts much closer to the surface, and may extend to, or beyond, the depth of 26 feet.

Removal Action - Work Performed. The SWMU removal action consisted of three different methods of excavation: point source excavation, orphan spot excavation, and lift excavation. Point source excavation was performed in areas where radiation levels in excess of 100 μR/hr were identified by a surface geophysical survey conducted by the Air Force in 1990 and by a metal detector and radiation instrument survey conducted on June 1, 1992. Excavation of these areas was conducted by hand to quickly determine and eliminate the source of these elevated readings and minimize the amount of waste generated. Orphan spot excavation occurred in 15 areas outside areas of lift excavation which had surface readings greater than 20 μR/hr according to the 1990 survey. This excavation was also conducted by hand. Excavation by lifts removed contaminated materials from five areas. A lift of uniform depth was excavated over each area.

As the areas were excavated, soils were stockpiled based on the results of the surveys of the lifts prior to removal. The stockpiles were sampled and analyzed for radioactive and chemical contamination in accordance with the Sampling and Analysis Plan (SAP) (CDM

Federal Programs Corporation, 1992). Analytical results determined disposition of the stockpiles, which were either used as backfill or disposed of as waste. This system minimized the amount of waste generated. All the materials exceeding release criteria were containerized in U.S. Department of Transportation (DOT) Type A containers (B-25 boxes) and stored for turnover to Tinker AFB. Postexcavation confirmatory surveys were conducted to ensure no areas of elevated radiation remained. Clean areas were properly backfilled.

Conditions Existing at the Site as of August 21, 1992. Four subareas within the controlled zone contain radiologically contaminated materials that have not been excavated. When excavation operations ceased, radiological readings in these four subareas ranged from 200 μR/hr to 300 μR/hr. It is estimated that 80 to 120 cubic yards (yd^3) of radiologically contaminated materials exist under the hillside in one of the four subareas. These four subareas were backfilled prior to demobilization to reduce exposure to the contaminated soils and to provide sufficient drainage across the site. A radiological survey, performed after backfill operations were completed, indicated that no elevated radiation levels remained at ground surface in these subareas or in any other areas throughout the site.

An additional area of concern was discovered outside of the controlled zone in late July of 1992. This area, between the access road and the creek, and just south of the controlled zone, has elevated levels of radiation. A walkover survey was conducted and surface radiation measurements ranged from 0.10 mR/hr to 4 mR/hr. This area has not been thoroughly surveyed or delineated. The elevated readings were substantially higher than any surface readings found within the RWDS 1030W controlled zone. Tinker AFB was promptly notified of these findings. This investigation did not evaluate this area any further.

Conclusions. The documents reviewed indicate that the previous investigations and the removal action have not provided adequate information regarding the extent of subsurface contamination. The removal action has been successful in excavating and packaging most of the contaminated soil that is known to exist at this site.

Recommendations. Based on the documents reviewed, there is limited data available for adequate characterization of this site. For instance, previous investigations have mainly focused on the analysis of radioactive waste constituents. No hazardous waste constituents have been addressed. Therefore, it is recommended that additional investigations be conducted during the Phase II RFI. Specific data needs to determine the nature and extent of

contamination will be presented in the work plan and sampling plan developed during the Phase II RFI. The following recommendations should be implemented:

- Perform a survey of RWDS 1030W, including the additional area of contamination to the south of this site. This survey should be conducted with the appropriate hand-held instrumentation utilizing a grid system.

- Based on the survey, collect composite soil samples from approximately 0 to 3 feet and have these analyzed for gross alpha, gross beta, radium-226, volatile organic compounds (VOC), semivolatile organic compounds (SVOC), and metals. At this time, it is not possible to determine how many samples will be needed.

- Obtain groundwater samples for the analysis of VOCs, SVOCs, metals, and inorganic parameters.

- Collect site-specific soil background samples to be used in addition to USGS soil data to distinguish site-related from background concentrations in a statistically significant manner during the Phase II investigation.

1.0 Introduction

1.1 Purpose and Scope

This document has been prepared in response to the Department of Air Force, Tinker Air Force Base (AFB), Oklahoma request for a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Summary Report for solid waste management unit (SWMU)-19, Radioactive Waste Disposal Site (RWDS) 1030W.

The objective of this RFI Summary Report is to provide Tinker AFB with one comprehensive report that summarizes the various investigations that have occurred at RWDS 1030W since the first environmental investigation was initiated on Base in 1981. The purpose of this comprehensive summary document is to:

- Characterize the site (Environmental Setting).
- Define the source (Source Characterization).
- Define the degree and extent of contamination (Contamination Characterization).
- Identify potential receptors.
- Identify all action levels for the protection of human health and the environment.

Additionally, this document briefly describes the procedures, methods, and results of all previous investigations, removal actions, and baseline risk assessments that relate to RWDS 1030W and contaminant releases, including information on the type and extent of contamination at the site, and actual or potential receptors. Where previous investigations, reports, or studies were not comprehensive and did not furnish the information required to determine the nature and extent of contamination, future work that can be conducted to complete the investigation has been recommended.

1.2 Preface

In 1980, Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to address the cleanup of hazardous waste disposal sites across the country. CERCLA gave the president authority to require responsible parties to remediate the sites or to undertake response actions through use of a fund (the Superfund). The president, through Executive Order 12580, delegated the U.S. Environmental Protection Agency (EPA) with the responsibility to investigate and remediate private party hazardous waste disposal sites that created a threat to human health and the environment. The president delegated responsibility for investigation and cleanup of federal facility disposal sites to the various federal agency heads. The Defense Environmental Restoration Program (DERP) was formally

established by Congress in Title 10 U.S. Code (USC) 2701-2707 and 2810. DERP provides centralized management for the cleanup of U.S. Department of Defense (DOD) hazardous waste sites consistent with the provisions of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] 300), and Executive Order 12580. To support the goals of DERP, the Installation Restoration Program (IRP) was developed to identify, investigate, and clean up contamination at installations.

Under the Air Force IRP, Tinker AFB began a Phase I study similar to a preliminary assessment/site investigation (PA/SI) in 1981 (Engineering Science [ES], 1982). This study helped locate 14 sites that needed further investigation. A Phase II study was performed in 1983 (Radian Corporation [Radian], 1985 a,b).

In 1986, Congress amended CERCLA through the SARA. SARA waived sovereign immunity for federal facilities. This act gave EPA authority to oversee the cleanup of federal facilities and to have the final authority for selecting the remedial action at federal facilities placed on the National Priorities List (NPL) if the EPA and the relevant federal agency cannot concur in the selection. Congress also codified DERP (SARA Section 211), establishing a fund for the DOD to remediate its sites because the Superfund is not available for the cleanup of federal facilities. DERP specifies the type of cleanup responses that the fund can be used to address.

In response to SARA, the DOD realigned its IRP to follow the investigation and cleanup stages of the EPA:

- PA/SI
- Remedial investigation/feasibility study (RI/FS)
- Record of Decision (ROD) for selection of a remedial action
- Remedial design/remedial action.

In 1984, Congress amended RCRA with the Hazardous and Solid Waste Amendments (HSWA) which allow the EPA to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989 Tinker AFB submitted its Part B permit application for renewal of its operating RCRA hazardous waste storage facility permit.

EPA, in the Hazardous Waste Management Permit for Tinker AFB, dated July 1, 1991, identified 43 SWMUs and two areas of concern (AOC) on Tinker AFB that need to be addressed. This permit requires Tinker AFB to investigate all SWMUs and AOCs and to perform corrective action at those identified as posing a threat to human health or the environment. This RFI Summary Report has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for RWDS 1030W and to document all determinations.

1.3 Facility Description

Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County (Figure 1-1) with its approximate geographic center located at 35° 25' latitude and 97° 24' longitude (U.S. Geological Survey [USGS], 1978). The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. An additional area east of the main Base is used by the Engineering Installation Division (EID) and is known as Area D. The Base encompasses approximately 5,000 acres. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon^{TM}, jet fuels, and radium paints. Wastes that are currently generated are managed at two permitted hazardous waste storage facilities. However, prior to enactment of RCRA, industrial wastes were discharged into unlined landfills and waste pits, streams, sewers, and ponds. Past releases from these landfills, pits, etc., as well as from underground tanks, have occurred. As a result, there are numerous sites of soil, groundwater, and surface water contamination on the Base.

The various reports generated as a result of investigative activities conducted at the RWDS 1030W have been reviewed and evaluated in terms of the sites' status under RCRA regulations. A summary based on the review of these reports for RWDS 1030W is presented in the following chapters and sections. In addition, recommendations for additional work is given at the end of the summary report.

STARTING DATE: 03/17/94	DATE LAST REV.:	DRAFT. CHCK. BY:G. PACHECO	INITIATOR: C. WALLACE
DRAWN BY:P.O. TERRY	DRAWN BY:	ENGR. CHCK. BY: C. WALLACE	PROJ. MGR.J. TAYLOR

DWG. NO.:

PROJ. NO.:

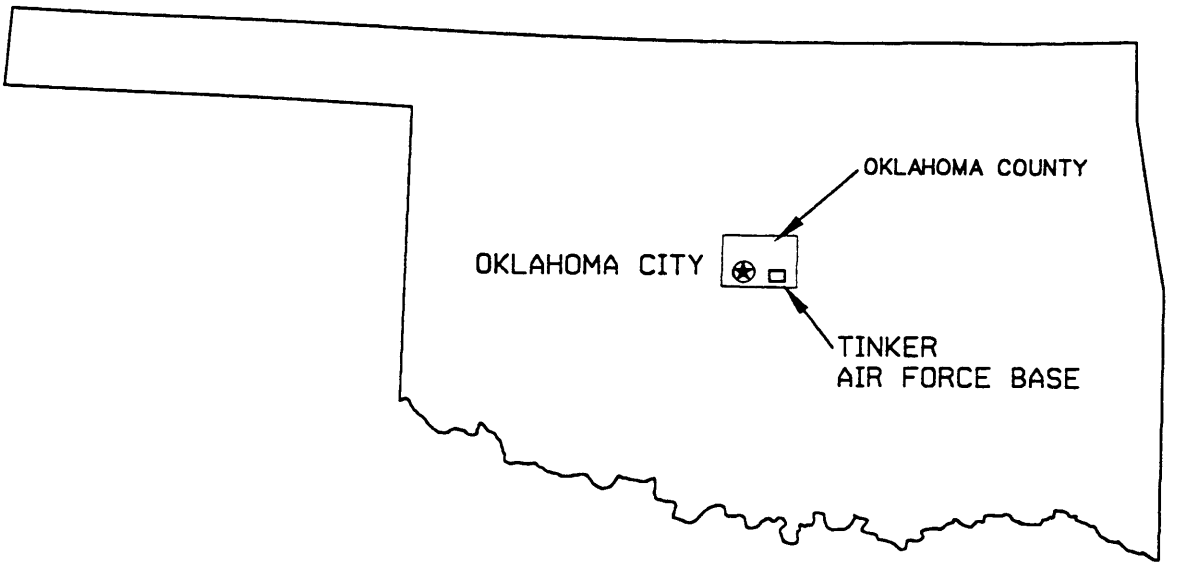


FIGURE 1-1
TINKER AIR FORCE BASE
OKLAHOMA
STATE INDEX MAP

PREPARED FOR
TINKER AFB
OKLAHOMA

3/23/94 POI
FILENAME: G:\TINKER\40983202.075

1.4 Site Description

RWDS 1030W is located on Landfill 2 (SWMU-4) approximately 1,700 feet west and 550 feet north of Building 1030 (Figure 1-2). RWDS 1030W is located in a depression to the west and north of a former picnic area and is covered with fairly heavy brush. In the early 1970s, Pistol Pond was constructed on top of Landfill 2, adjacent to RWDS 1030W, but was drained in 1986 (Figure 1-3). A small stream still flows through the site which, along with poor drainage, creates ponds on the site when it rains.

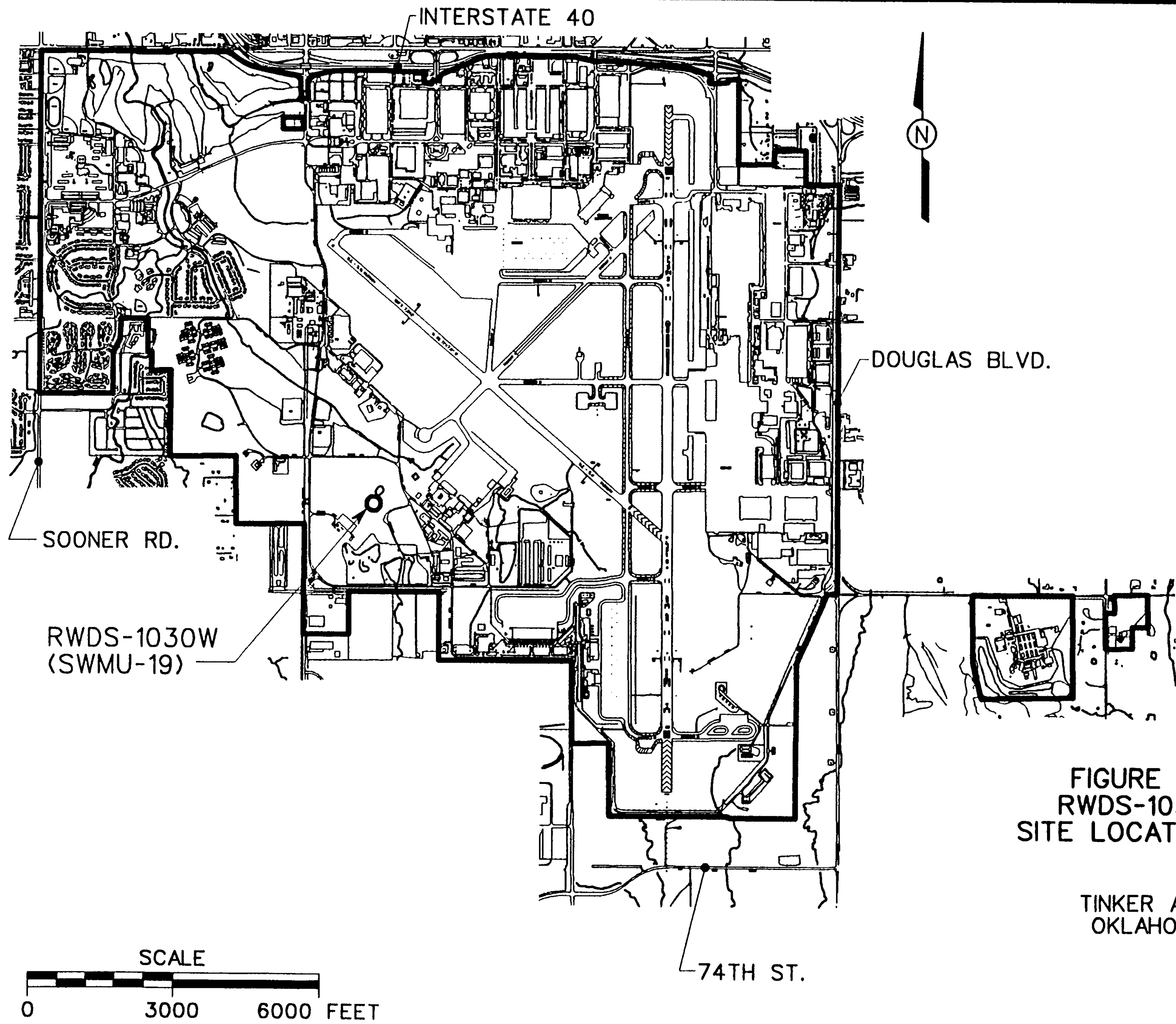
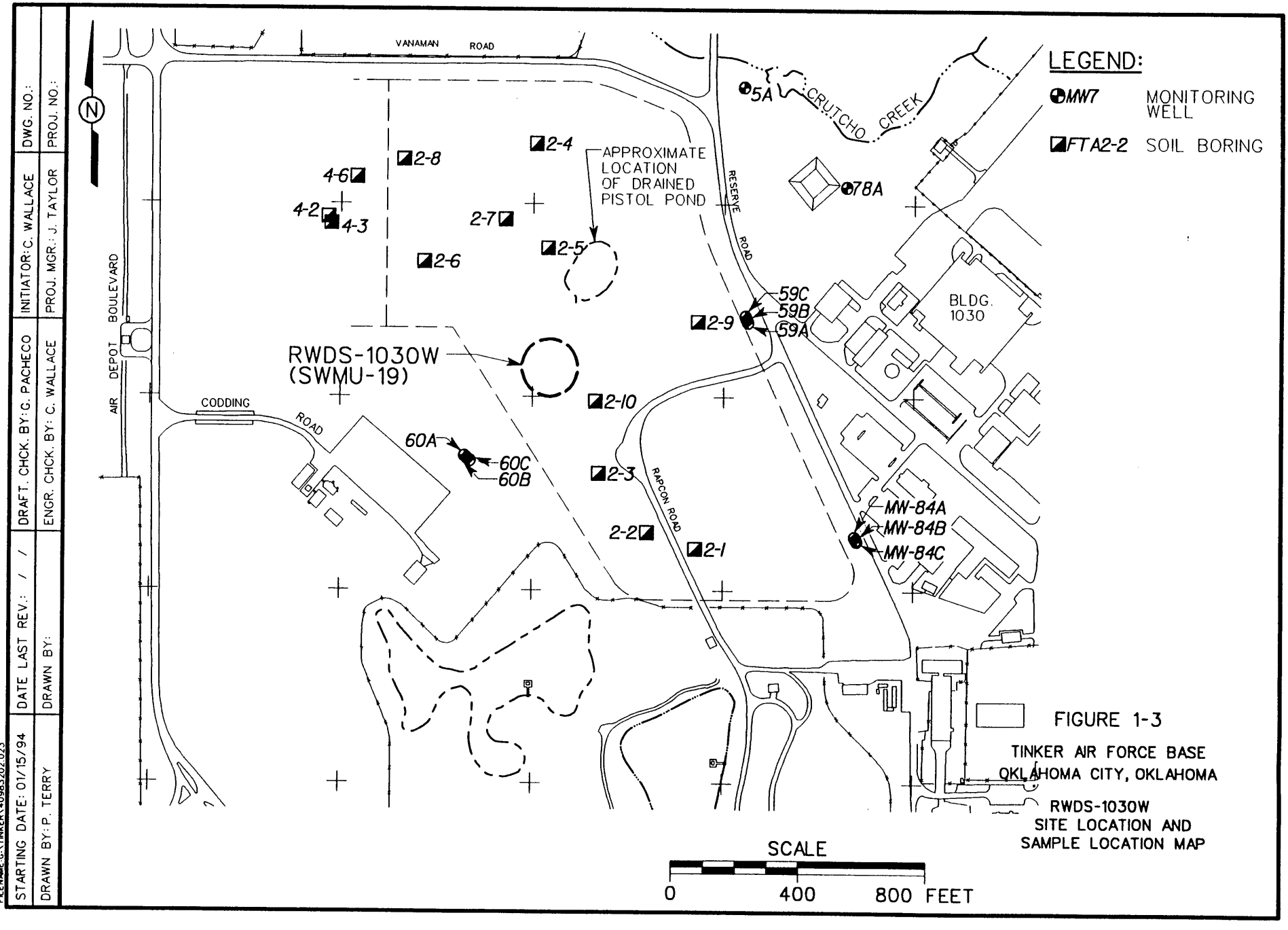


FIGURE 1-2
RWDS-1030W
SITE LOCATION MAP

TINKER AFB
OKLAHOMA

STARTING DATE: 3/18/94	DATE LAST REV.:	DRAFT. CHCK. BY:G. PACHECO	INITIATOR:C. WALLACE	DWG. NO.:
DRAWN BY:P.O. TERRY	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.:J. TAYLOR	PROJ. NO.:

FILENAME:G:\TINKER\40983202.088



2.0 Background

2.1 Site Operations and History

Tinker AFB was originally known as the Midwest Air Depot and began operations in July 1941. The site was activated March 1942. During World War II, the depot was responsible for reconditioning, modifying, and modernizing aircraft, vehicles, and equipment. The past and present industrial activities used many different types of radiological materials in the construction and repair of aircraft. Until 1951, radioactive waste considered to be of significant nature was sent to the Canadian Radium and Uranium Corporation in Mt. Kisco, New York. As a cost-savings measure, certain types of radiological waste were disposed of on Base from 1951 until the 1960s. Radiological waste considered insignificant was disposed of, along with the other Base refuse, in the landfills located in the southwest portion of the Base.

Radioactive waste has been disposed of in at least four RWDSs. One of these sites, RWDS 1030W, is located on Landfill 2.

2.2 Summary of Previous Investigations

As part of the Tinker AFB IRP, an effort to identify and remediate any RWDS was initiated. The RWDS investigation and remediation effort is structured into three phases. Phase I consisted of a record search and personal interviews. Phase II consisted of site investigations and remediation proposal. Phase III involved the remediation and waste disposal of each site. As a result of the Phase I work, RWDS-1030W was identified as a burn and bury site for radium paint residue, including rags and solvents.

As part of the Phase II investigations, site surveys were conducted at RWDS 1030W by both Chem-Nuclear Environmental Services and the U.S. Air Force Radiation Assessment Team (AFRAT) in 1990. Results of those surveys indicated the presence of elevated radiation readings across the site, some in excess of 1,000 microroentogen per hour (μR/hr). The survey results also indicated that the contamination was shallow (within the top 2 to 4 feet).

Phase III consisted of a removal action. The objective of this action was to close the site in accordance the with approved work plan. The removal action is discussed in detail in Section 5.0.

2.3 Current Regulatory Status

The IRP has been ongoing at Tinker AFB since the early 1980s. IRP studies on the Base were conducted according to IRP guidance, which is essentially the same as EPA's guidance for conducting RI/FS under CERCLA. All investigation and removal actions have been closely monitored and approved by the EPA.

Since receiving the Hazardous Waste Management Permit on July 1, 1991, many of the IRP sites have come under the jurisdiction of the RCRA permits branch of EPA. As such, they have been identified as SWMUs; however, a large amount of work has already been performed at most of these sites under the IRP. Additional investigation at the SWMUs will be performed under the IRP.

3.0 Environmental Setting

3.1 Topography and Drainage

3.1.1 Topography

Regional/Tinker AFB. The topography of Oklahoma City and surrounding area varies from generally level to gently rolling in appearance. Local relief is primarily the result of dissection by erosional activity or stream channel development. At Oklahoma City, surface elevations are typically in the range of 1,070 to 1,400 feet mean sea level (msl). At Tinker AFB, ground surface elevations vary from 1,190 feet msl near the northwest corner where Crutcho Creek intersects the Base boundary to approximately 1,320 feet msl at Area D (EID).

Site. RWDS 1030W is located on Landfill 2 approximately 1,700 feet west and 550 feet north of Building 1030. Surface elevations in the vicinity of RWDS 1030W range approximately about 1,230 to 1,235 feet msl and are relatively flat.

3.1.2 Surface Drainage

Regional/Tinker AFB. Drainage of Tinker AFB land areas is accomplished by overland flow of runoff to diversion structures and then to area surface streams, which flow intermittently. The northeast portion of the Base is drained primarily by unnamed tributaries of Soldier Creek, which is itself a tributary of Crutcho Creek. The north and west sections of the Base, including the main instrument runway, drain to Crutcho Creek, a tributary of the North Canadian River. Two small unnamed intermittent streams crossing installation boundaries south of the main instrument runway generally do not receive significant quantities of Base runoff due to site grading designed to preclude such drainage. These streams, when flowing, extend to Stanley Draper Lake, approximately one-half mile south of the Base.

Site. Surface drainage in the vicinity of RWDS 1030W is towards a former recreation pond area, Pistol Pond, located on the eastern half of Landfill 2. The pond was drained in 1986. The pond area drains to Crutcho Creek through a culvert under Landfill Road.

3.2 Geology

3.2.1 Regional/Tinker AFB Geology

Tinker AFB is located within the Central Redbed Plain Section of the Central Lowland physiographic province, which is tectonically stable. No major fault or fracture zones have been mapped near Tinker AFB. The major lithologic units in the area of the Base are relatively flat-lying and have a regional westward dip of about 0.0076 foot per foot (ft/ft) (Bingham and Moore, 1975).

Geologic formations that underlie Tinker AFB include, from oldest to youngest, the Wellington Formation, Garber Sandstone, and the Hennessey Group; all are Permian in age.

All geologic units immediately underlying Tinker AFB are sedimentary in origin. The Garber Sandstone and Wellington Formation are commonly referred to as the Garber-Wellington Formation due to strong lithologic similarities. These formations are characterized by fine-grained, calcareously-cemented sandstones interbedded with shale. The Hennessey Group consists of the Fairmont Shale and the Kingman Siltstone. It overlies the Garber-Wellington Formation along the eastern portion of Cleveland and Oklahoma counties. Quaternary alluvium is found in many undisturbed streambeds and channels located within the area.

Stratigraphy. Tinker AFB lies atop a sedimentary rock column composed of strata that ranges in age from Cambrian to Permian above a Precambrian igneous basement. Quaternary alluvium and terrace deposits can be found overlying bedrock in and near present-day stream valleys. At Tinker AFB, Quaternary deposits consist of unconsolidated weathered bedrock, fill material, wind-blown sand, and interfingering lenses of sand, silt, clay, and gravel of fluvial origin. The terrace deposits are exposed where stream valleys have downcut through older strata and have left them topographically above present-day deposits. Alluvial sediments range in thickness from less than a foot to nearly 20 feet.

Subsurface (bedrock) geologic units which outcrop at Tinker AFB and are important to understanding groundwater and contaminant concerns at the Base consist of, in descending order, the Hennessey Group, the Garber Sandstone, and the Wellington Formation (Table 3-1). These bedrock units were deposited during the Permian Age (230 to 280 million years ago) and are typical of redbed deposits formed during that period. They are composed of a conformable sequence of sandstones, siltstones, and shales. Individual beds are lenticular and vary in thickness over short horizontal distances. Because lithologies are similar and because

Table 3-1

Major Geologic Units in the Vicinity of Tinker AFB (Modified from Wood and Burton, 1968)

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
QUATERNARY	PLEISTOCENE AND RECENT	Alluvium	0-70	Unconsolidated and interfingering lenses of sand, silt, clay, and gravel in the flood plains and channels of stream	Moderately permeable. Yields small to moderate quantities of water in valleys of larger streams. Water is very hard, but suitable for most uses, unless contaminated by industrial wastes or oil field brines.
		Terrace deposits	0-100	Unconsolidated and interfingering lenses of sand, silt, gravel, and clay that occur at one or more levels above the flood plains of the principal streams.	Moderately permeable. Locally above the water table and not saturated. Where deposits have sufficient saturated thickness, they are capable of yielding moderate quantities of water to wells. Water is moderately hard to very hard, but less mineralized than water in other aquifers. Suitable for most uses unless contaminated by oil field brines.

Table 3-1

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
PERMIAN	LOWER PERMIAN	Hennessey Group (includes Kingman Siltstone and Fairmont Shale)	700	Deep-red clay shale containing thin beds of red sandstone and white or greenish bands of sandy or limey shale. Forms relatively flat to gently rolling grass-covered prairie.	Poorly permeable. Yields meager quantities or very hard, moderately to highly mineralized water to shallow domestic and stock wells. In places water contains large amounts of sulfate.
		Garber Sandstone	500±	Deep-red clay to reddish-orange, massive and cross-bedded fine-grained sandstone interbedded and interfingered with red shale and siltstone	Poorly to moderately permeable. Important source of groundwater in Cleveland and Oklahoma counties. Yields small to moderate quantities of water to deep wells; heavily pumped for industrial and municipal uses in the Norman and Midwest City areas. Water from shallow wells hard to very hard; water from deep wells moderately hard to soft. Lower part contains water too salty for domestic and most industrial uses.
		Wellington Formation	500±	Deep-red to reddish-orange massive and cross-bedded fine-grained sandstone interbedded with red, purple, maroon, and gray shale. Base of formation not exposed in the area.	

of a lack of fossils or key beds, the Garber Sandstone and the Wellington Formation are difficult to distinguish and are often informally lumped together as the Garber-Wellington Formation. Together, they are about 900 feet thick at Tinker AFB. The interconnected, lenticular nature of sandstones within the sequence forms complex pathways for groundwater movement.

The surficial geology of the north section of the Base is dominated by the Garber Sandstone, which outcrops across a board area of Oklahoma County. Generally, the Garber outcrop is covered by a veneer of soil and/or alluvium up to 20 feet thick. To the south, the Garber Sandstone is overlain by outcropping strata of the Hennessey Group, including the Kingman Siltstone and the Fairmont Shale (Bingham and Moore, 1975). Drilling information obtained as a result of geotechnical investigations and monitoring well installation confirms the presence of these units.

Depositional Environment. The Permian-age strata presently exposed at the surface in central Oklahoma were deposited along a low-lying north-south oriented coastline. Land features included meandering to braided sediment-loaded streams that flowed generally westward from highlands to the east (ancestral Ozarks). Sand dunes were common, as were cut-off stream segments that rapidly evaporated. The climate was arid and vegetation sparse. Off shore the sea was shallow and deepened gradually to the west. The shoreline's position varied over a wide range. Isolated evaporitic basins frequently formed as the shoreline shifted.

Across Oklahoma, this depositional environment resulted in an interfingering collage of fluviatile and wind-blown sands, clays, shallow marine shales, and evaporite deposits. The overloaded streams and evaporitic basins acted as sumps for heavy metals such as iron, chromium, lead, and barium. Oxidation of iron in the arid climate resulted in the reddish color of many of the sediments. Erosion and chemical breakdown of granitic rocks from the highlands resulted in extensive clay deposits. Evaporite minerals such as anhydrite ($CaSO_4$), barite ($BaSO_4$), and gypsum ($CaSO_4 \cdot 2H_2O$) are common.

Around Tinker AFB, the Hennessey Group represents deposition in a tidal flat environment cut by shallow, narrow channels. The Hennessey Group is comprised predominantly of red shales which contain thin beds of sandstone (less than 10 feet thick) and siltstone. In outcrop, "mudball" conglomerates, burrow surfaces, and dessication cracks are recognized. These units

outcrop over roughly the southern half of the Base, thickening to approximately 70 feet in the southwest from their erosional edge (zero thickness) across the central part of Tinker AFB.

In contrast, the Garber Sandstone and the Wellington Formation around Tinker AFB consist of an irregularly-interbedded system of lenticular sandstones, siltstones, and shales deposited either in meandering streams in the upper reaches of a delta or in a braided stream environment. Outcrop units north of Tinker AFB exhibit many small to medium channels with cut and fill geometries consistent with a stream setting. Sandstones are typically cross-bedded. Individual beds range in thickness from a few inches to approximately 50 feet and appear massive, but thicker units are often formed from a series of "stacked" thinner beds. Geophysical and lithologic well logs indicate that from 65 to 75 percent of the Garber Sandstone and the Wellington Formation are composed of sandstone at Tinker AFB. The percentage of sandstone in the section decreases to the north, south, and west of the Base. These sandstones are typically fine to very fine grained, friable, and poorly cemented. However, where sandstone is cemented by red muds or by secondary carbonate or iron cements, local thin "hard" intervals exist along disconformities at the base of sandstone beds. Shales are described as ranging from clayey to sandy, are generally discontinuous, and range in thickness from a few inches to approximately 40 feet.

Stratigraphic Correlation. Correlation of geologic units is difficult due to the discontinuous nature of the sandstone and shale beds. However, cross-sections (Figure 3-1) demonstrate that two stratigraphic intervals can be correlated over large sections of the Base in the conceptual model. These intervals are represented on geologic cross-sections A-A' and B-B' (Figures 3-2 and 3-3). Section A-A' is roughly a dip section and B-B' is approximately a strike section. The first correlatable interval is marked by the base of the Hennessey Group and the first sandstone at the top of the Garber Sandstone. This interval is mappable over the southern half of Tinker AFB. The second interval consists of a shale zone within the Garber Sandstone which, in places, is comprised of a single shale layer and, in other places, of multiple shale layers. This interval is more continuous than other shale intervals and in cross-sections appears mappable over a large part of the Base. It is extrapolated under the central portion of Tinker AFB where little well controls exists.

Structure. Tinker AFB lies within a tectonically stable area; no major near-surface faults or fracture zones have been mapped near the Base. Most of the consolidated rock units of the

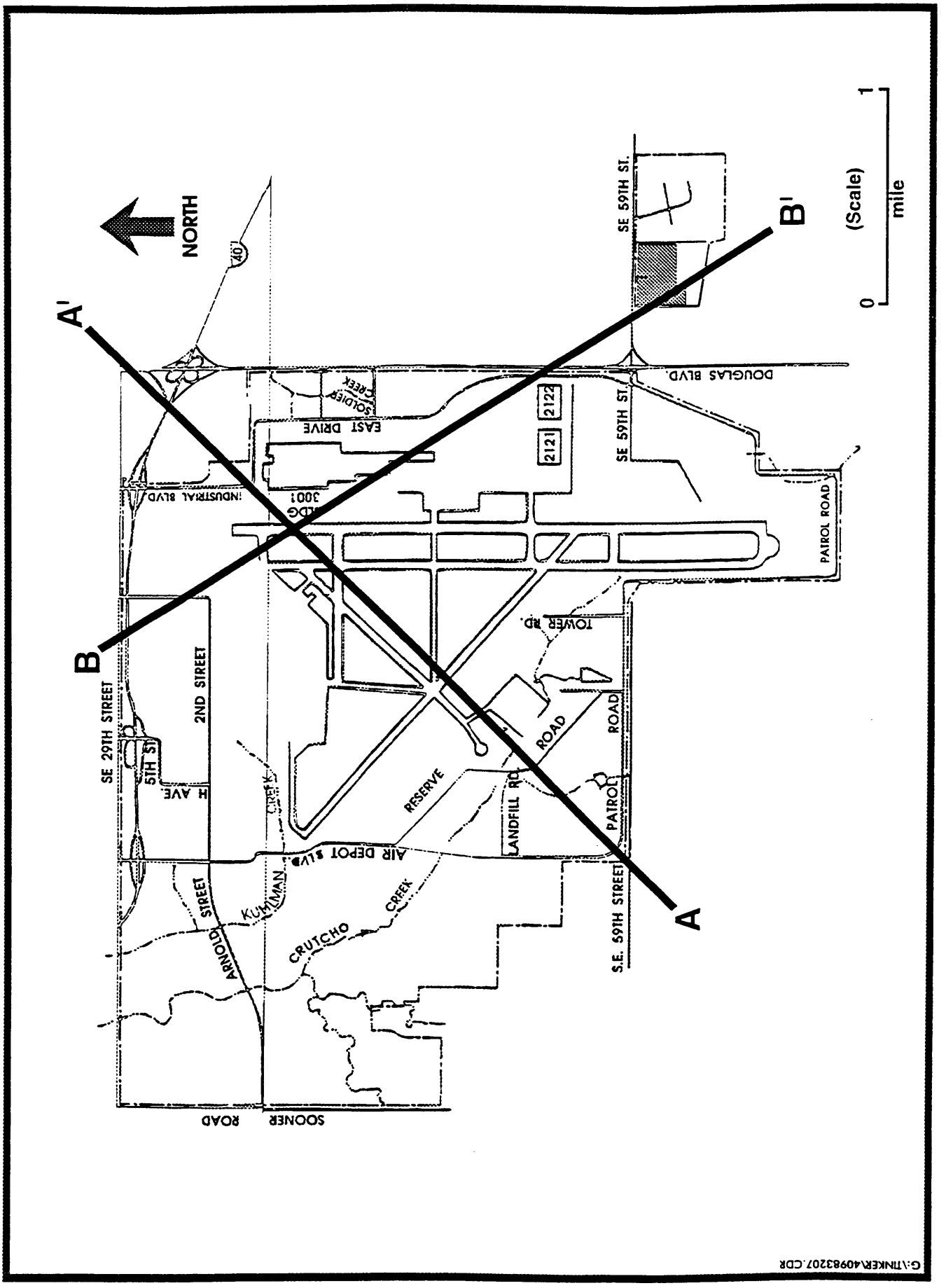


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FIGURE 3-1 TINKER AFB GEOLOGIC CROSS SECTION LOCATION MAP

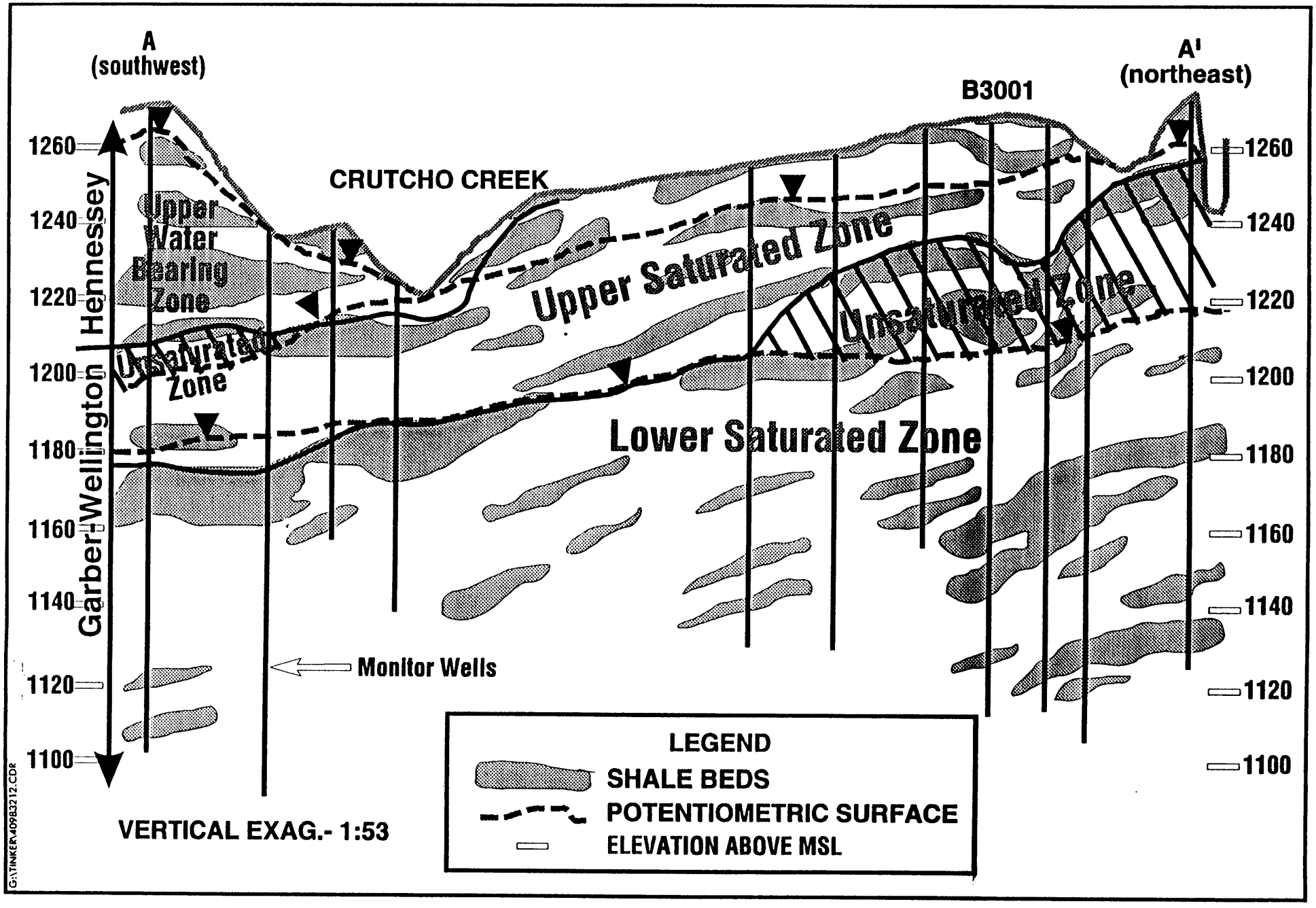


FIGURE 3-2 TINKER AFB GEOLOGIC CROSS SECTION A-A'

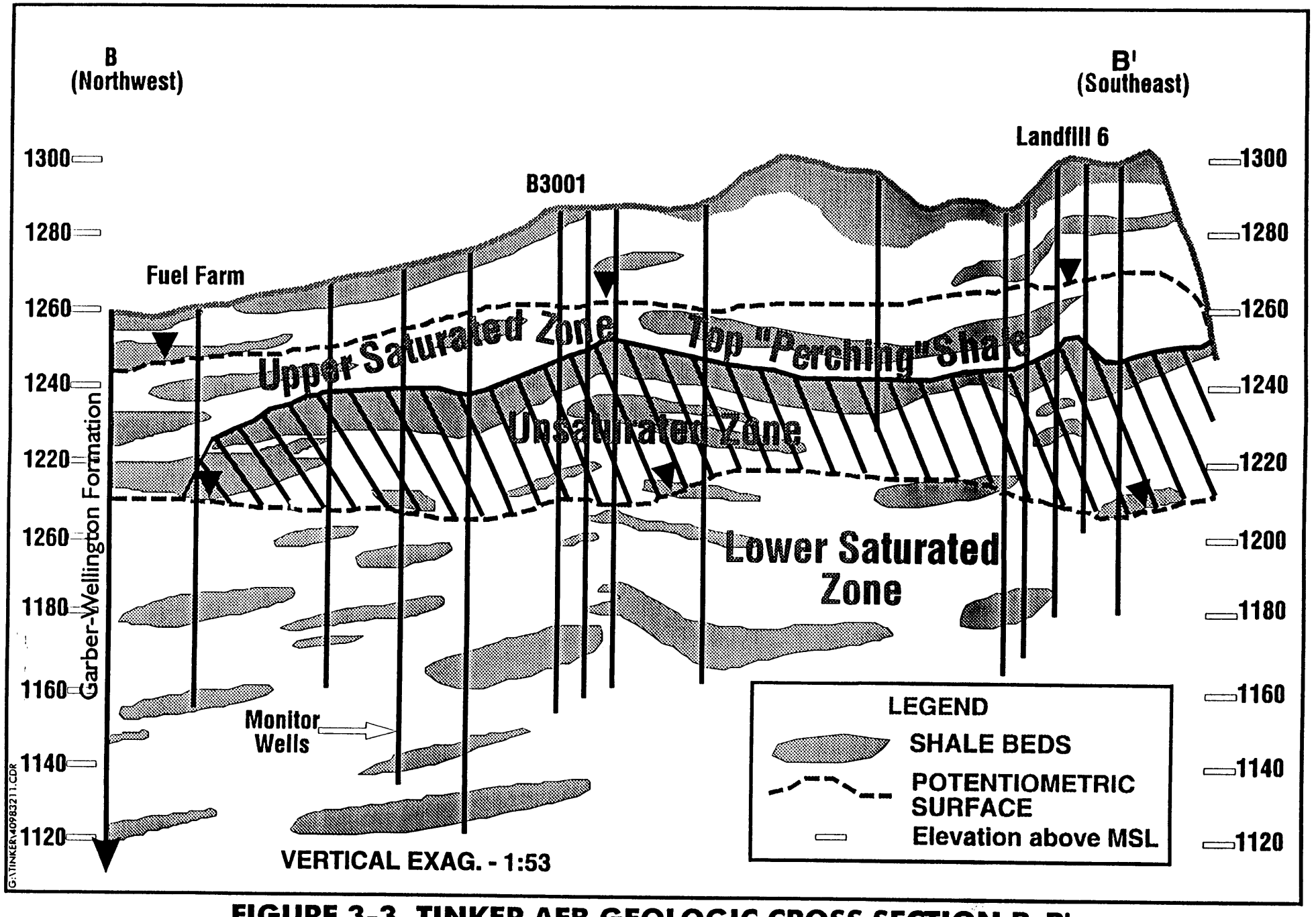


FIGURE 3-3 TINKER AFB GEOLOGIC CROSS SECTION B-B'

Oklahoma City area dip westward at a low angle. A regional dip of 0.0057 to 0.0076 ft/ft in a generally westward direction is supported by stratigraphic correlation on geologic cross-sections at Tinker AFB. Bedrock units strike slightly west of north.

Although Tinker AFB lies in a tectonically stable area, regional dips are interrupted by buried structural features located west of the Base. A published east-to-west generalized geologic cross-section, which includes Tinker AFB, supports the existence of a northwest-trending structural trough or syncline located near the western margin of the base. The syncline is mapped adjacent to and just east of a faulted anticlinal structure located beneath the Oklahoma City Oil Field. The fault does not appear to offset Permian-age strata. There are indications that the syncline may act as a "sink" for some regional groundwater (southwest flow) at Tinker AFB before it continues to more distant discharge points.

3.2.2 Site Geology

RWDS 1030W is located within the Hennessey Group, south of the contact between the Hennessey and the Garber-Wellington Formation. The Hennessey Formation outcrops over the southern half of Tinker AFB. The Hennessey thins to the north and pinches out just north Landfills 1 through 4. This formation consists of reddish-brown shale with beds of siltstone and silty sandstone. Where present, the Hennessey separates the regional water table in the Gerber-Wellington from the overlying perched water.

3.3 Hydrology

3.3.1 Regional/Tinker AFB Hydrology

The most important source of potable groundwater in the Oklahoma City metropolitan area is the Central Oklahoma aquifer system. This aquifer extends under much of central Oklahoma and includes water in the Garber Sandstone and Wellington Formation, the overlying alluvium and terrace deposits, and the underlying Chase, Council Grove, and Admire Groups. The Garber Sandstone and the Wellington Formation portion of the Central Oklahoma aquifer system is commonly referred to as the "Garber-Wellington aquifer" and is considered to be a single aquifer because these units were deposited under similar conditions and because many of the best producing wells are completed in this zone. On a regional scale, the aquifer is confined above by the less permeable Hennessey Group and below by the Late Pennsylvanian Vanoss Group.

Tinker AFB lies within the limits of the Garber-Wellington Groundwater Basin. Currently, Tinker derives most of its water supply from this aquifer and supplements the supply by purchasing from the Oklahoma City Water Department. The nearby communities of Midwest City and Del City derive water supplies from both surface sources and wells tapping the aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by a municipal distribution system also depend on the Garber-Wellington aquifer. Communities presently depending upon surface supplies (such as Oklahoma City) also maintain a well system drilled into the Garber-Wellington as a standby source of water in the event of drought.

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 AFB is located in an aquifer outcrop area, the Base is considered to be situated in a recharge zone.

According to Wood and Burton (1968) and Wickersham (1979), the quality of groundwater 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.

Tinker AFB presently obtains its water supplies from a distribution system comprised of 29 water wells constructed along the east and west Base boundaries and by purchase from the Oklahoma City Water Department. All Base wells are finished into the Garber-Wellington aquifer. Base wells range from 700 to 900 feet in finished depth, with yields ranging from 205 to 250 gallons per minute. The wells incorporate multiple screens, deriving water supplies from sand zones with a combined thickness from 103 to 184 feet (Wickersham, 1979).

Although the variability in the geology and the recharge system at Tinker AFB makes it difficult to predict local flow paths, Central Oklahoma aquifer water table data show that regional groundwater flow under Tinker varies from west-northwest to southwest, depending on location. This theory is supported by contoured potentiometric data from base monitoring wells which show groundwater movement in the upper and lower aquifer zones to generally follow regional dip. Measured normal to potentiometric contours, groundwater flow gradients

range from 0.0019 to 0.0057 ft/ft. However, because flow in the near-surface portions of the aquifer at Tinker AFB is strongly influenced by topography, local stream base-levels, complex subsurface geology, and location in a recharge area, both direction and magnitude of groundwater movement is highly variable. The interaction of these factors not only influences regional flow but gives rise to complicated local, often transient, flow patterns at individual sites.

As a result of ongoing environmental investigations and the approximately 450 groundwater monitoring wells installed on the Base during various investigations, a better understanding of the specific hydrological framework has emerged. The current conceptual model developed by Tinker AFB (Tinker, 1993), based on the increased understanding of the hydrological framework, has been revised from an earlier model adopted by the USACE. Previous studies reported that groundwater was divided into four water-bearing zones: the perched aquifer, the top of regional aquifer, the regional aquifer, and the producing zone. In the current model, two principal water table aquifer zones and a third less extensive zone have been identified. The third is limited to the southwest quadrant. The third aquifer zone consisted of saturated siltstone and thin sandstone beds in the Hennessey Shale and equates to the upper water bearing zone (UWBZ) described by the USACE (1993) at Landfills 1 through 4. In addition, numerous shallow, thin saturated beds of siltstone and sandstone exist throughout the Base. These are of limited areal extent and are often perched.

In the current conceptual hydrologic model, an upper saturated zone (USZ) and a lower saturated zone (LSZ) are recognized in the interval from ground surface to approximately 200 feet. Below this is found the producing zone from which the Base draws much of its water supply. Figure 3-4 shows the potentiometric surface for the USZ and Figure 3-5 shows the potentiometric surface for the LSZ. The USZ exists mainly under water table (unconfined) conditions, but may be partially confined locally. Conditions in the LSZ are difficult to determine due to screen placement and overly long sandpacks below the screen interval.

The USZ is found at a depth of 5 to 70 feet below ground surface and has a saturated thickness ranging from less than 1 foot at its eastern boundary to over 20 feet in places west of Building 3001. The USZ is erosionally truncated by Soldier Creek along the northeastern margin of Tinker AFB. This aquifer zone is considered to be a perched aquifer over the eastern one-third of Tinker AFB, where it is separated from the LSZ by an underlying confining shale layer and a vadose zone. The confining interval extends across the entire Base, but the vadose zone exists over the eastern one-third of this area. The available

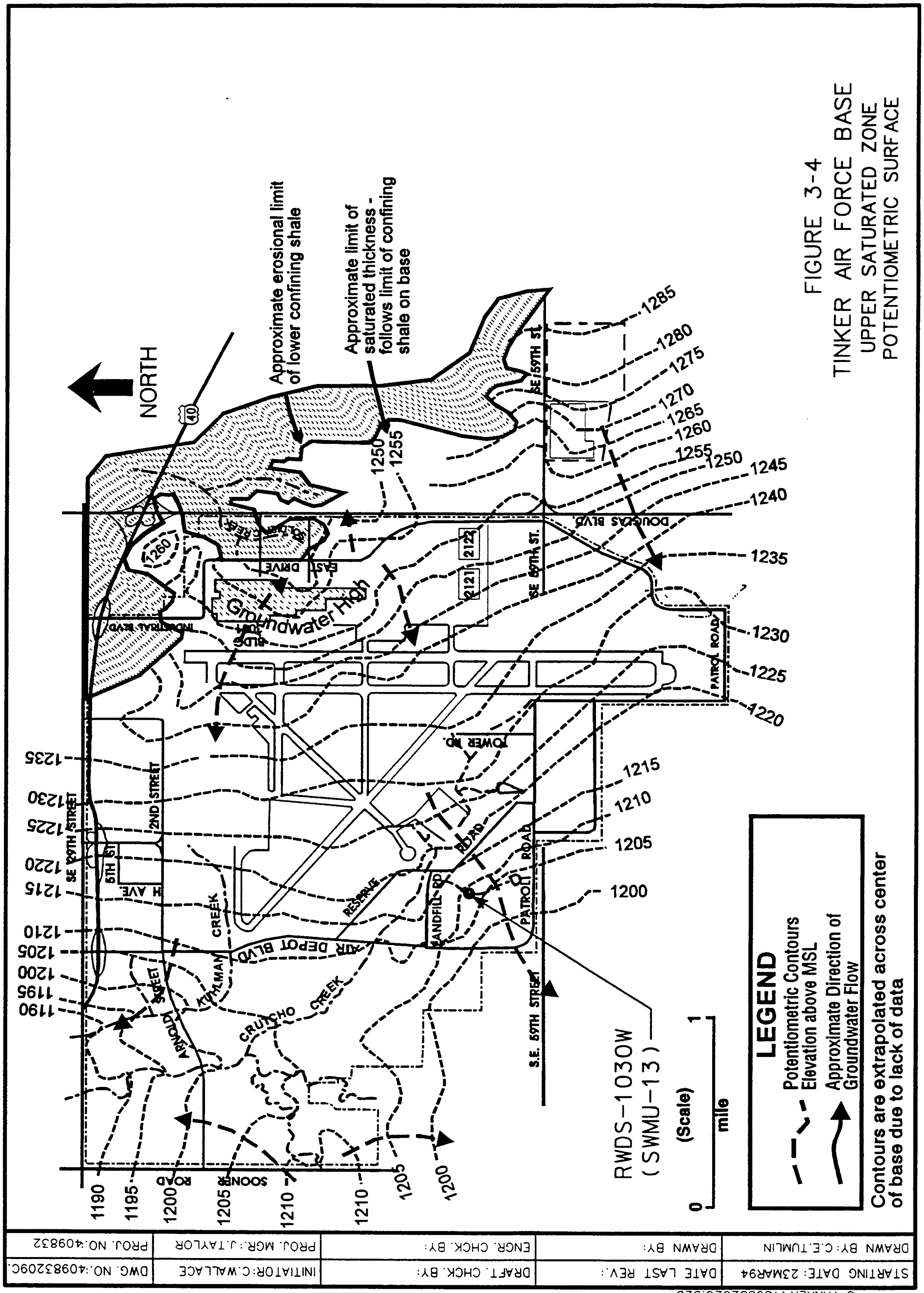
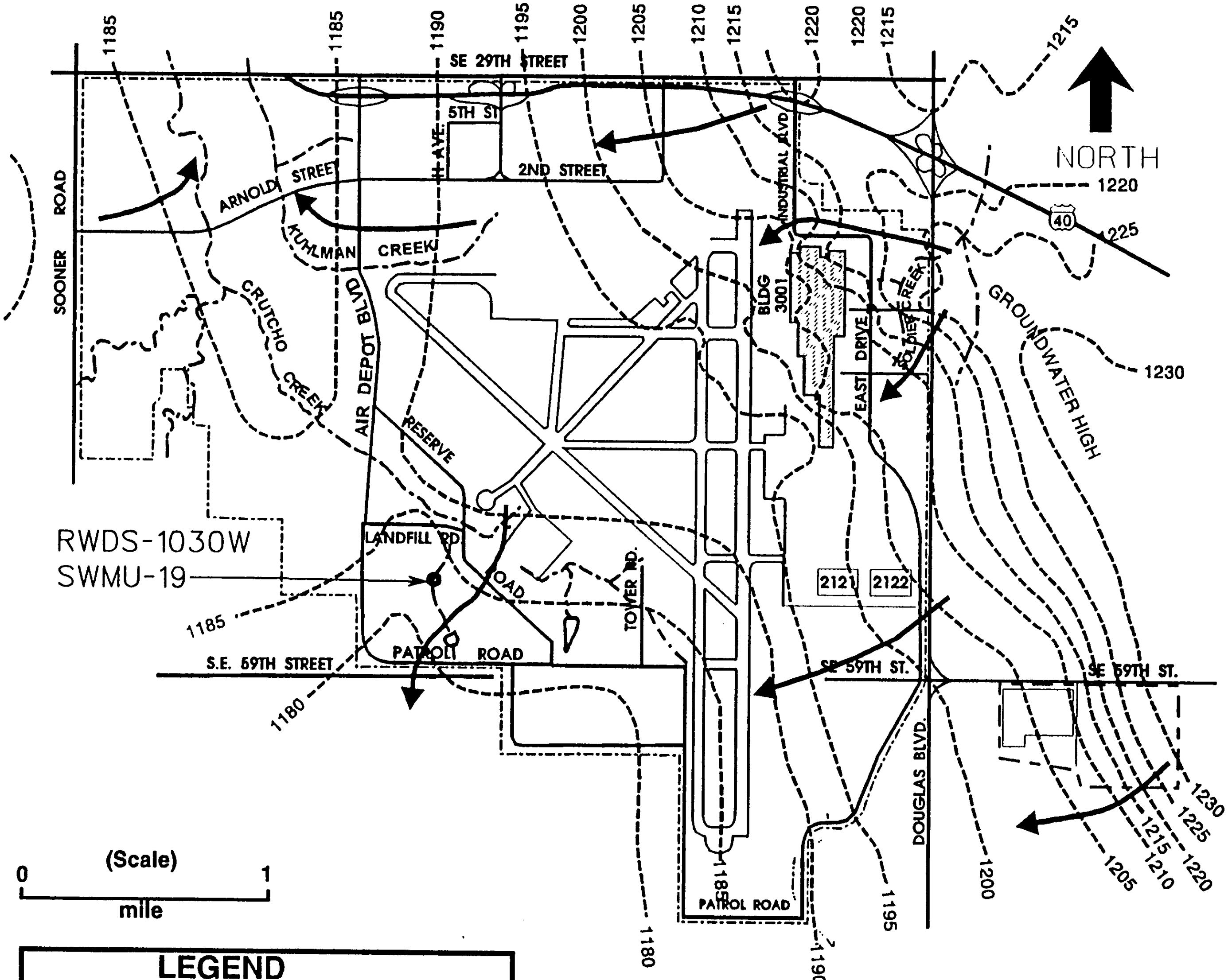


FIGURE 3-4
TINKER AIR FORCE BASE
UPPER SATURATED ZONE
POTENTIOMETRIC SURFACE



LEGEND

- - - - - - Potentiometric Surface Elevation above MSL

→ Approximate Direction of Groundwater Flow

Contours are extrapolated across center of base due to lack of data

FIGURE 3-5
TINKER AIR FORCE BASE
LOWER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 23MAR94	DATE LAST REV.:	DRAFT. CHCK. BY:	INITIATOR: C.WALLACE	DWG. NO.: 40983209C.
DRAWN BY: C.E.TUMLIN	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.:	PROJ. NO.:

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hydrogeologic data indicate that the vadose zone does not exist west of a north-south line located approximately 500 to 1,000 feet west of the main runway; consequently, the USZ is not perched west of this line. However, based on potentiometric head data from wells screened above and below the confining shale layer, the USZ remains a discrete aquifer zone distinct from the LSZ even over the western part of the Base. In areas where several shales interfinger to form the lower confining interval rather than a single shale bed, "gaps" may occur. In general, these "gaps" are not holes in the shale, but are places where multiple shales exist that are separated by slightly more permeable strata. Hydrologic data from monitoring wells indicate that these zones allow increased downward flow of groundwater above normal rates through the confining layer.

The LSZ is hydraulically interconnected and can be considered one aquifer zone down to approximately 200 feet. This area includes what was referred to by the USACE as the top of regional and regional zones. Hydrogeologic data from wells screened at different depths at the same location within this zone, however, provide evidence that locally a significant vertical (downward) component of groundwater flow exists in conjunction with lateral flow. The magnitude of the vertical component is highly variable over the Base. Preliminary evidence suggests that the LSZ is hydraulically discrete from the producing zone. Due to variations in topography, the top of the lower zone is found at depths ranging from 50 to 100 feet below ground surface under the eastern parts of the Base and as shallow as 30 feet to the west. Differences in potentiometric head values found at successive depths are due to a vertical (downward) component of groundwater flow in addition to lateral flow and the presence or absence of shale layers which locally confine the aquifer system. The LSZ extends east of the Base (east of Soldier Creek) beyond the limits of the USZ where it becomes the first groundwater zone encountered in off-Base wells. Because of the regional dip of bedding, groundwater gradient, and topography, the LSZ just east of the Base is generally encountered at depths less than 20 feet.

3.3.2 Site Hydrology

In the Landfills 1 through 4 RI report (USACE, 1993), the USACE identified three water bearing formations in the following descending order: (1) UWBZ, which exists only at Landfills 2 and 4; (2) a perched zone that is continuous over the Landfills 1 through 4 area, but discontinuous over Tinker AFB; and (3) the top of regional zone, which is the uppermost water bearing sandstone unit layer of the regional Garber-Wellington aquifer.

RWDS 1030W is located on top of Landfill 2, which is located on the northern portion of the Hennessey Formation that outcrops the southern half of Tinker AFB. Based on the USACE investigations, the trenches of the landfill are within the UWBZ. This zone consists of the water held in the trenches and disturbed soil between the trenches. This zone is underlain by shale that varies from 6 to 25 feet thick. A local high point of the UWBZ is located in the southeastern corner of Landfill 2. The groundwater flow in the UWBZ is radial from this high point to low spots along Landfill Road, the former location of Pistol Pond, and a depression that intersects Rapcon Road near boring location L2-2. Because this zone is so close to the ground surface, groundwater recharge in this zone is primarily from surface infiltration. The estimated flow velocity for groundwater through the trenches in the UWBZ was approximately 130 to 160 feet per year. Flow through the material surrounding the trenches was estimated to be approximately 17 feet per year.

Based on the USACE investigation of Landfill 2, the UWBZ appears to be hydraulically connected to the underlying perched zone based on chemical analysis data. This perched zone is unconfined to the Landfills 1 and 3 area and then dips under the UWBZ in the Landfills 2 and 4 area. In the vicinity of Landfills 2 and 4, this zone is confined above by the shale layer that serves as a lower confining layer for the UWBZ and confined below by a siltstone/shale unit.

3.4 Soils

Three major soil types have been mapped in the Tinker AFB area and are described in Table 3-2 (U.S. Department of Agriculture [USDA], 1969). The three soil types, the Darrell-Stephenville, Renfrow-Vernon-Bethany, and Dale-Canadian-Port, consist of sandy to fine sandy loam, silt loam, and clay loam, respectively. The Darrell-Stephenville and the Renfrow-Vernon-Bethany are primarily residual soils derived from the underlying shales of the Hennessey Group. The Dale-Canadian-Port association is predominantly a stream-deposited alluvial soil restricted to stream floodplains. The thickness of the soils ranges from 12 to 60 inches.

Table 3-2

Tinker AFB Soil Associations
(Source: USDA, 1969)

Association	Description	Thickness (in.)	Unified Classification[a]	Permeability (in./hr)
Darrell-Stephenville: loamy soils of wooded uplands	Sandy loam Sandy clay loam Soft sandstone (Garber Sandstone)	12-54	SM,ML,SC	2.0-6.30
Renfrow-Vernon-Bethany: loamy and clayey soils on prairie uplands	Silt loam - clay Clay loam Shale (Fairmont Shale)	12-60	ML,CL,MH,CH	<0.60-0.20
Dale-Canadian-Port: loamy soil on low benches near large streams	Fine sandy loam Silty clay loam Loam Clay loam	12-60	SM,ML,CL	0.05-6.30

[a]Unified classifications defined in U.S. Bureau of Reclamation, 5005-86.

4.0 Source Characterization

RWDS 1030W is located on Landfill 2 approximately 1,700 feet west and 550 feet north of Building 1030. RWDS 1030W is located in a depression to the west and north of a former picnic area. According to records, the site was used for the burning and burial of radium paint residues, including rags and solvents. The waste was dumped in a pit, then burned, and then covered with soil.

In the early 1970s, Pistol Pond was constructed on top of Landfill 2, adjacent to RWDS 1030W, but was drained in 1986. A small stream flowed through the site which, along with poor drainage, created ponds on the site when it rained. This stream was diverted around the excavation area prior to the start of the RWDS 1030W removal action.

5.0 Contaminant Characterization

Nonintrusive Surveys. According to records, RWDS 1030W was used for the burning and burial of radiation paint residues, including rags and solvents. The site radiological and geophysical survey results from the documents reviewed for this RFI (USACE, 1989; Chem-Nuclear, 1990) are summarized as follows:

- Radiological surveys performed by Armstrong Laboratory identified an "area of concern" approximately 100 feet by 200 feet, elongated north to south. The Chem-Nuclear survey considerably expanded on the original area of concern. Background radiation levels (read by hand-held instruments) ranged from 6.1 to 6.5 μR/hr. General areas, as well as fairly isolated points, of significantly elevated radiation levels were discovered. In general, the results indicated that the area of radioactive contamination was large and extended in a southwest to northeast direction. Some "point" readings were found to be in excess of 1,000 μR/hr with the highest being 1,340 μR/hr.

- An area at the southeastern portion of the site (adjacent to the former picnic area) was approximately 8 to 10 feet higher in elevation. Although no radiation levels above background were detected in this elevated area, some contamination may be present in the subsurface soil. The additional 8 to 10 feet of soil (presumed clean) provides sufficient shielding of any subsurface radiation to reduce soil to background at the surface. Elevated radiation levels were also detected during walkover surveys of the northeastern portion of the site and along the stream. A definite northern boundary could not be established.

- A ground-penetrating radar (GPR) survey was conducted over the site. Uneven terrain, heavy vegetation, and the presence of surface water restricted the GPR survey paths. Due to characteristics of the soil, the GPR penetration was limited to approximately 12 feet. An anomaly, possibly caused by a previously excavated trench, was detected near the southern boundary of the elevated radiation levels.

- An EM conductivity survey was conducted, using a EM-31 instrument, along 12 east-west lines and 3 north-south lines across the site. These lines were designed to concentrate on the areas with maximum radiation levels. A conductivity contrast, suggestive of a soil interface, was detected near the northwest corner of the elevated picnic area, stretching to the north-northeast. Indications of numerous metallic objects were detected throughout the site, corroborating the magnetic survey results. Another EM conductivity survey, using a EM-34 instrument (which has a greater effective search depth), was conducted along an east-west line across the area which contained the anomaly indicative of a soil interface. This survey corroborated the location of the probable soil interface and also provided a marked conductivity change at a depth of 23 to 26 feet.

- Magnetic surveys were conducted along 21 east-west lines across the site. Many of the anomalies found are coincident with both the electromagnetic (EM) conductivity anomalies and the elevated radiation levels.

Intrusive Soil Sampling. Ten borings were drilled at the RWDS 1030W site in December 1991 to sample for potential chemical and radiological contamination and to establish limits to the 1990 survey. The site's location on Landfill 2 dictated that site characterization include chemical analysis. Soil samples collected from these borings were analyzed for volatile organic compounds (VOC), semivolatile organic compounds (SVOC), and the Toxicity Characteristic Leaching Procedure (TCLP) metals (except mercury, which is not a concern for the site). The TCLP metals analyzed included: arsenic, barium, cadmium, total chromium, lead, selenium, and silver. A completed EPA Contract Laboratory Program (CLP) documentation package was not required because these samples were used for screening purposes only.

The intrusive survey soil samples were screened with a photoionization detector (PID) and the sample with the highest PID reading was collected and analyzed for VOCs and SVOCs.

The soil, air, and water samples were shipped to Armstrong Laboratory and analyzed for gross alpha, gross beta, and gamma spectroscopy. The results of the radiological analysis are presented in Table 5-1. Approximate coordinates of the drilled borings, relative to the project area, are presented in Table 5-2.

Groundwater. Groundwater sampling was not performed specifically for RWDS 1030W. However, since RWDS 1030W sits atop Landfill 2, the groundwater sampling information collected for this landfill can be used to determine if the extent of contamination has extended past the boundaries of Landfill 2. Although groundwater samples were collected from nearby wells by the USACE from 1986 to 1990, radiological analysis was performed only on the samples collected in 1989 and 1990.

In the HWBZ, monitoring wells MW-79A and MW-84A are upgradient of the landfill. At present, there are no monitoring wells downgradient in the HWBZ relative to Landfill 2. Monitoring wells MW-60A and MW-79B are downgradient of the landfill in the USZ. Monitoring wells MW-5A and possibly MW-84B are upgradient of the landfill in the USZ. Based upon the 1987 contour map, monitoring wells MW-79C, MW-84C, and possibly MW-60B are downgradient of the landfill in the LSZ. In the 1990 contour map, monitoring

Table 5-1

Radiological Analyses of Intrusive Survey SWMU-19, RWDS 1030W, Tinker AFB

Sample ID No.	Date Sampled	Depth (Ft.)	Gross Alpha	Gross Beta	Radium 226 (pCi/gm)
RS3-BH1-SS-001	12/11/91	4.5 - 5.5	10.4 ± 3.6	18 ± 1.2	<1.6
RS3-BH1-SS-002	12/11/91	11 - 12	10.6 ± 3.6	17.1 ± 1.2	<1.9
RS3-BH2-SS-001	12/11/91	0.5 - 1.5	11.0 ± 3.6	17.6 ± 1.2	<1.9
RS3-BH3-SS-001	12/18/91	1.5 - 2.5	14.4 ± 4	21.2 ± 1.3	<2.4
RS3-BH3-SS-002	12/18/91	5 - 6	8 ± 3.3	16.4 ± 1.2	<2
RS3-BH3-SS-003	12/18/91	11 - 12.5	13 ± 3.8	18.1 ± 1.2	<1.96
RS3-BH4-SS-001	12/18/91	1 - 2.5	93.2 ± 8.8	77.4 ± 2.4	<3.9
RS3-BH4-SS-002	12/18/91	5 - 6.5	9 ± 3.5	17.7 ± 1.2	<1.9
RS3-BH4-SS-003	12/18/91	10 - 11	14.2 ± 4	20.5 ± 1.3	<2.3
RS3-BH5-SS-001	12/18/91	1.5 - 2.5	19 ± 4.4	23.2 ± 1.4	<2.4
RS3-BH5-SS-002	12/18/91	5 - 6	11.0 ± 3.6	17.9 ± 1.2	<2.2
RS3-BH5-SS-003	12/18/91	10 - 11	12.8 ± 3.8	19.7 ± 1.3	<2.1
RS3-BH6-SS-001	12/18/91	1 - 1.5	11.6 ± 3.7	19.3 ± 1.3	<2.2
RS3-BH6-SS-002	12/18/91	6 - 7	10.6 ± 3.6	18.7 ± 1.2	<2
RS3-BH6-SS-003	12/18/91	10 - 11	16.5 ± 4.2	19.3 ± 1.3	<1.9
RS3-BH7-SS-001	12/18/91	1 - 3	14.0 ± 3.9	17.5 ± 1.2	<2.1
RS3-BH7-SS-002	12/18/91	5 - 6	13.7 ± 3.9	18.9 ± 1.3	<2.1
RS3-BH7-SS-003	12/18/91	10.5 - 11.5	13.4 ± 3.9	22.0 ± 1.3	<2.1
RS3-BH7-SS-004	12/18/91	1 - 3	9.5 ± 3.5	17.3 ± 1.3	<2.1
RS3-BH8-SS-001	12/17/91	1 - 2.5	14.4 ± 4.0	20.7 ± 1.3	<2.1
RS3-BH8-SS-002	12/17/91	5 - 6	8.4 ± 3.4	16.8 ± 1.2	<2.1
RS3-BH8-SS-003	12/17/91	10 - 11	7.3 ± 3.3	22.9 ± 1.3	<1.66
RS3-BH9-SS-001	12/17/91	1.5 - 3	16.1 ± 4.1	20.6 ± 1.3	<2.1
RS3-BH9-SS-002	12/17/91	5 - 6	13.7 ± 3.9	16.5 ± 1.2	<1.94
RS3-BH9-SS-003	12/17/91	10 - 11	13.0 ± 3.9	23.0 ± 1.2	<1.9
RS3-BH10-SS-001	12/11/91	1 - 2	11.1 ± 3.7	18.2 ± 1.2	<1.8
RS3-BH10-SS-002	12/11/91	9 - 10	15.5 ± 4.1	17.7 ± 1.2	2.2 ± 0.7

Table 5-1

(Page 2 of 2)

Sample ID No.	Date Sampled	Depth (Ft.)	Gross Alpha	Gross Beta	Radium 226 (pCi/gm)
RS3-BH2-GW-001	12/11/91	--	948.8 ± 41.4	772 ± 26.7	3.5 ± 0.3
RS3-BH3-GW-001	12/18/91	--	152.9 ± 12.1	37 ± 5.2	524 ± 108
RS3-BH4-GW-001	12/18/91	--	8.2 ± 2.3	16.6 ± 2.6	628 ± 123
RS3-BH4-GW-002	12/18/91	--	0.5 ± 0.4	<1.9	<274
RS3-BH5-GW-001	12/18/91	--	7.5 ± 1.8	7.5 ± 2.1	<261.7
RS3-BH6-GW-001	12/18/91	--	2.7 ± 1.4	4.2 ± 2.0	233 ± 95
RS3-BH7-GW-001	12/18/91	--	3.1 ± 3.2	<6.9	<302
RS3-BH7-GW-002	12/18/91	--	3.4 ± 3.1	<9.9	<330
RS3-BH8-GW-001	12/17/91	--	6.4 ± 1.7	5.5 ± 2.0	<252
RS3-BH9-GW-001	12/17/91	--	5.6 ± 2.1	17.4 ± 2.6	<247
RS3-BH7-RB-002	12/18/91	--	1.3 ± 0.6	3.5 ± 1.8	<244

Table 5-2

Boring Coordinates for Intrusive Survey SWMU-19, RWDS 1030W, Tinker AFB

Item Description	Coordinates	
	Easting	Northing
Powerpole[a]	2,178,687	150,160
BH01	2,178,680	150,166
BH02	2,178,667	150,166
BH03	2,178,671	150,169
BH04	2,178,667	150,177
BH05	2,178,673	150,189
BH06	2,178,668	150,189
BH07	2,178,683	150,198
BH08	2,178,688	150,212
BH09	2,178,699	150,203
BH10	2,178,681	150,175

[a] Powerpole given the coordinates E 2,178,687; N 150,160 based on Base Comprehensive Plan, Composite Utility Systems provided by Tinker AFB.

wells MW-60B and MW-79C are downgradient of the landfill in the LSZ. Monitoring well MW-4B is crossgradient of the landfill in the 1987 LSZ contour map and upgradient of the landfill in the 1990 LSZ contour map. Summaries of the 1989 and 1992 groundwater radiological results are presented in Table 5-3 for the USZ, and in Table 5-4 for LSZ.

Removal Action. The objectives of the RDWS 1030W removal action were to close the site in accordance with the approved work plan and to minimize the amount of waste produced. Radiological release of the site requires removal of contamination to the point that future use of the site is exempt from Nuclear Regulatory Commission (NRC) regulations.

Work Performed. The RDWS 1030W removal action consisted of three different methods of excavation: point source excavation, orphan spot excavation, and lift excavation. Point source excavation was performed in areas where radiation levels in excess of 100 μR/hr were identified by a surface geophysical survey conducted by the Air Force in 1990 and by a metal detector and radiation instrument survey conducted on June 1, 1992. Excavation of these areas was conducted by hand to quickly determine and eliminate the source of these elevated readings and minimize the amount of waste generated. Orphan spot excavation occurred in 15 areas outside areas of lift excavation which had elevated surface readings (greater than 20 μR/hr) in the 1990 survey. This excavation was also conducted by hand. Excavation by lifts removed contaminated materials from Areas A through E (Figure 5-1). A lift of uniform depth was excavated over the entire area.

As the sites were excavated, soils were stockpiled based on the results of the surveys of the lifts prior to removal. The stockpiles were sampled and analyzed for radioactive and chemical contamination in accordance with the Sampling and Analysis Plan (SAP) (CDM, 1992). Analytical results determined disposition of the stockpiles, which were either used as backfill or disposed of as waste. This system minimized the amount of waste generated. All the materials exceeding release criteria were containerized in U.S. Department of Transportation (DOT) Type A containers (B-25 boxes) and stored for turnover to Tinker AFB. Post-excavation confirmatory surveys were conducted to ensure no areas of elevated radiation remained. Clean areas were properly backfilled.

Conditions Existing at the Site as of August 21, 1992. Some subareas within the controlled zone contain radiologically contaminated materials that have not been excavated. When excavation operations ceased, radiological readings in these subareas (B, A, B_2A, B_2D,

Table 5-3

Summary of 1990 and 1992 Radiological Analytical Results, Upper Saturated Zone Monitoring Wells, SWMU-19, RWDS 1030W, Tinker AFB

	DWS[a]	MW-5A		MW-60A		MW-79B		MW-84B	
		1989	1990	1989	1990	1989	1990	1989	1990
Radiometrics (pCi/L)									
Gross alpha	15	2.89	4	1.66	2	NRT	NRT	NA	NRT
Counting error		6.31	2	1.91	1				
Gross beta	50[b]	13	<3	4.35	5	0.98	3	5	<2
Counting error		6.67	-	3.91	3	5.76	2	7	NRT
Ra-226 + Ra-228	5[c]	0.11	NRT	0.13	NRT	3.66	8	NRT	6
Counting error		0.09	NRT	0.1	NRT	6.29	3	4	3
Total radium	5	NRT	2	NRT	3	0.17	NRT	0.3	NRT
Counting error		NRT	1	NRT	1	0.11	NRT	0.2	NRT

[a]Drinking water standards (DWS) are comprised of maximum contaminant levels (MCL) and secondary maximum contaminant levels (SMCL) as specified in 40 CFR Parts 141, 142, 143, amended July 17, 1992 (FR, Vol. 57, No. 138).
[b]The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 mrem/year (Oklahoma Drinking Water Regulations, as amended through February 1, 1991).
[c]The combined MCL for Ra-226 and Ra-228 is 5 pCi/L; however, total radium measurements include other Ra isotopes.
NRT = Not reported and/or tested.

Table 5-4
Summary of 1989, 1990, and Radiological Analytical Results, Lower Saturated Zone SWMU-19, RWDS 1030W, Tinker AFB

Compound	DWS[a]	MW-60B		MW-79C		MW-84C		MW-4B	
		1989	1990	1989	1990	1989	1990	1989	1990
Radiometrics (pIC/L)									
Gross Alpha	15	1.81	3		5[a]	2	11	2	6
Counting error		3.58	2	5	2[a]	5	10	6	4
Gross beta	50[b]	3.08	4	9	6[a]	NRT	142	5	21
Counting error		4.59	3	5	3[a]	4	11	0	6
Ra-226 and Ra-228	5[c]	0.07	NRT	0.08	NRT[a]	0.2	NRT	0.1	NRT
Counting error		0.08	NRT	0.2	NRT[a]	0.2	NRT	0.1	NRT
Total radium	5[c]	NRT	3	NRT	4[a]	NRT	49	NRT	7
Counting error		NRT	1	NRT	1[a]	NRT	4	NRT	2

NOTE: Where analytical data could not be verified, results from the USACE RI (1993) were used.

[a] Drinking water standards (DWS) are comprised of maximum contaminated levels (MCL) and secondary maximum contaminant levels (SMCL) as specified in 40 CFR Parts 141, 142, and 143, amended July 17, 1992, (FR, Vol. 57, No. 138).

[b] The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 mrem/year (Oklahoma Drinking Water Regulations, as amended through February 1, 1991).

[c] The combined MCL for Ra-226 and Ra-228 is 5 pCi/L; however, total radium measurements include other Ra isotopes.

NRT -Not reported and/or tested.

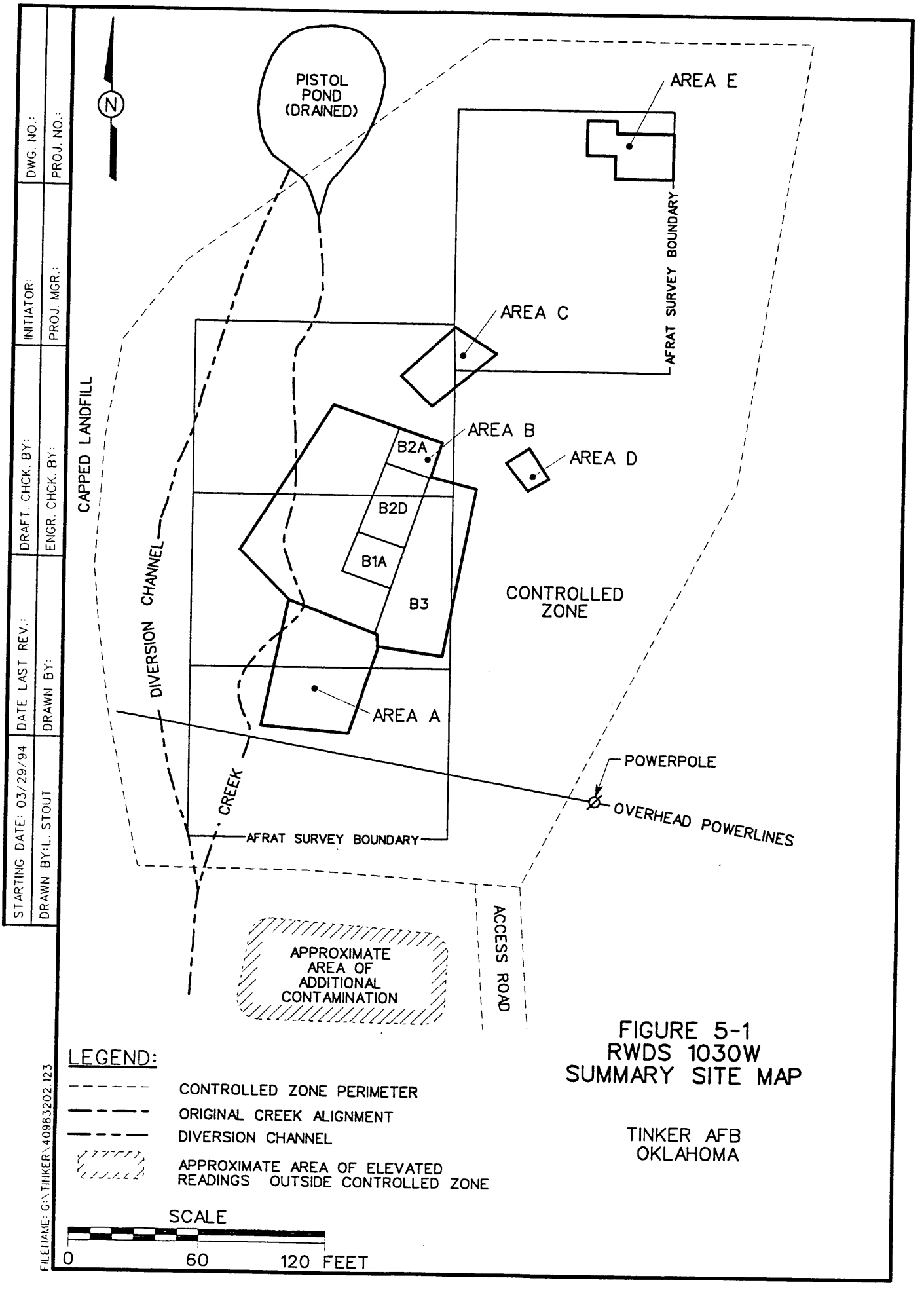

FIGURE 5-1
RWDS 1030W
SUMMARY SITE MAP

TINKER AFB
OKLAHOMA

and B_3) ranged from 200 μR/hr to 300 μR/hr. It is estimated that 80 to 120 cubic yards (yd^3) of radiologically contaminated materials exist under the hillside in one subarea. These four subareas were backfilled prior to demobilization to reduce exposure to the contaminated soils and to provide sufficient drainage across the site (CDM, 1993). A radiological survey, performed after backfill operations were completed, indicated that no elevated radiation levels remained at ground surface in these subareas or in any other areas throughout the site.

An additional area of concern was discovered outside of the controlled zone in late July of 1992. This area, between the access road and the creek, and just south of the controlled zone, has elevated levels of radiation. A walkover survey was conducted and surface radiation measurements ranged from 0.1 mR/hr to 4 mR/hr. This area has not been thoroughly surveyed or delineated. The elevated readings were substantially higher than any surface readings found within the RWDS 1030W controlled zone. Tinker AFB was promptly notified of these findings. This investigation did not further evaluate this area (CDM, 1993).

The RWDS 1030W removal action was not completed as established in the project work plan. The principal reasons listed in the Interim Status Report (CDM, 1993) can be summarized as follows:

- Previous survey data did not provide adequate information regarding the amount and extent of subsurface contamination.

- Intrusive reconnaissance within the zone of concern "underestimated the volume of contaminated material." Because the site was located on a landfill, an "observational" approach to the project was applied. Limited site characterization was conducted prior to excavation in an attempt to delineate the contamination. However, due to the landfill area being more extensive than indicated by records, the borings did not fully delineate the contamination. Instead, the spatial extent of the contamination was determined during excavation.

- Severe and unusual weather conditions occurred on a consistent basis. These weather conditions often created unsafe working conditions, slowing and sometimes halting operations.

Although the removal action has not been completed, four of the five locations within the RWDS 1030W site have been remediated. Approximately 920 yd^3 of excavated materials were containerized in 253 B-25 boxes and disposed of by Tinker AFB.

The Interim Status Report suggests that if RWDS 1030W must be placed on "safe-standby status" for an extended period, Tinker AFB may want to consider the following interim measures:

- Provide chain link fence around the entire site.
- Physically evaluate the site and perform a radiological survey of the site as it currently exists.
- Provide additional drainage control around the controlled zone so that surface runoff does not transport any contamination.
- Maintain site on the duty log of the Tinker AFB military police.
- Perform a radiological survey of the additional area of contamination to the south of RWDS 1030W to further define the extent of contamination. Once surveyed, the area of the controlled zone may be expanded and additional fencing may be required.

6.0 Potential Receptors

A specific potential human and ecological receptor search has not been performed for RWDS 1030W. Data are available in the form of chemical analysis of soils and groundwater, and can be used to initiate a potential receptors search. The following sections describe the data available to begin identification of potential receptors.

6.1 Human Receptors

Tinker AFB is situated on a relatively flat expanse of grassland. Prior to the development of the Base, the area was characterized by large tracts of agricultural land. The Base currently occupies approximately 5,000 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.

The Garber-Wellington aquifer, which underlies Tinker AFB, is the single most important source of potable groundwater in the Oklahoma City area. The recharge area for the Garber-Wellington aquifer covers the eastern half of Oklahoma County, including Tinker AFB. Approximately 75 percent of the Base's water supply is obtained from production wells pumping from this aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by municipal distribution systems also depend on the Garber-Wellington aquifer. Communities, such as Oklahoma City, presently depending upon surface water supplies also maintain a well system drilled into this aquifer as a standby source of water in the event of drought. Lake Stanley Draper, a local surface water supply reservoir with a small portion of its drainage basin within the boundaries of Tinker AFB, serves a significant recreational function as well.

In 1989, approximately 26,000 military and civilian personnel worked at Tinker AFB. Of these, approximately 2,722 personnel occupied on-Base housing, which consisted of 530 family housing units and seven dormitories. At that time, 1,262 of these residents were children. Military personnel and their families who reside on Base represent the nearest receptors to releases from Tinker AFB.

The current land use at and near the Base is not expected to change because the facilities have decades of useful life remaining and the Base has an important and continuing mission. However, other future land use scenarios and any human receptors associated with those scenarios may need to be considered.

6.2 Ecological Receptors

Tinker AFB lies within a grassland ecosystem, which is typically composed of grasses, forbes, and riparian (i.e., trees, shrubs, and vines associated with water courses) vegetation. This ecosystem has generally experienced fragmentation and disturbances as result of urbanization and industrialization at and near the Base. While no threatened or endangered plant species occur on the Base, the Oklahoma penstemon (*Penstemon oklahomensis*), identified as a rare plant under the Oklahoma Natural Heritage Inventory Program, thrives in several locations on Base. Tinker AFB policy considers rare species as if they were threatened or endangered and provides the same level of protection for these species.

In general, wildlife on the Base is typically tolerant of human activities and urban environments. No federal threatened or endangered species have been reported at the Base. However, one specie found on the Base, the Texas horned lizard (*Phrynosoma cornutum*), is a Federal Category 2 candidate specie and under review for consideration to be listed as threatened or endangered. Air Force policy (AFR 126-1) considers candidate species as threatened or endangered and provides the same level of protection.

The Oklahoma Department of Wildlife Conservation also lists several species within the state as Species of Special Concern. Information on these species suggests declining populations but information is inadequate to support listing, and additional monitoring of populations is needed to determine the species status. These species also receive protection by Tinker AFB as threatened or endangered species. Of these species, the Swainson's hawk (*Buteo swainsoni*) and the burrowing owl (*Athene cunicularia*) have been sighted on Tinker AFB. The Swainson hawk, a summer visitor and prairie/meadow inhabitant, has been encountered Basewide. The burrowing owl has been known to inhabit the Air Field at the Base.

7.0 Action Levels

An "action level" is defined by EPA in proposed rule 40 CFR 264.521 (55 FR 30798; 7/27/90), "Corrective Action for Solid Waste Management Units (SWMU) at Hazardous Waste Management Facilities," as a health- and environment-based level, determined by EPA to be an indicator for protection of human health and the environment. In the preamble to this proposed rule, the focus of the RFI phase is defined as "characterizing the actual environmental problems at the facilities." As part of this characterization, a comparison of the contaminant concentrations to certain action levels should be made to determine if a significant release of hazardous constituents has occurred. This comparison is then used to determine if further action or corrective measures are required for a SWMU or an AOC. The preamble to the proposed rule states that the concept of action levels was introduced because of the need for "a trigger that will indicate the need for a Corrective Measures Study (CMS) and below which a CMS would not ordinarily be required" (55 FR 30798; 7/27/90). If constituent concentrations exceed certain action levels at a SWMU or an AOC, further action or a CMS may be warranted; if constituent concentrations are below action levels, a finding of no further action may be warranted. This chapter of the report presents the initial analytical data as compared to certain potential action levels.

Action levels are concentrations of contaminants at or below which exposure to humans or the environment should not produce acute or chronic effects.

The action level information is presented in this chapter so that a constituent concentration at a sample location can be compared with its potential action level. Only constituents identified in the analysis are listed in the SWMU-19, RWDS 1030W table. Table 7-1 shows the action levels for soil, water, and air as published in federal or state regulations, policies, guidance documents, or proposed rules.

The action levels listed in Table 7-1 are:

- ***SWMU Corrective Action Levels (CAL)*** - The first set of action levels provided in the table are those taken from the proposed rule (40 CFR 264.521) and provided as Appendix A to the rule as "Examples of Concentrations Meeting Criteria for Action Levels." These levels are health-risk based and are provided

Table 7-1

Action Levels
SWMU-20, RWDS 201S, Tinker AFB

Parameters	SWMU CAL[a]			MCL[b]
	Soil (mg/kg)	Water (mg/L)	Air (ug/m^3)	Water (mg/L)
Organics				
Acetone	8000	4.0		
Carbon Tetrachloride	5.0	0.0003	0.03	0.005
Methyl Ethyl Ketone	4000	2.0	300	
Methylene Chloride	90	0.005	0.3	0.005
Radiometrics				
Gross Alpha				15 pCi/L
Radium-226/Radium-228				20 pCi/L
Radon				300 pCi/L

[a]CAL - Corrective Action Levels
[b]MCL - Maximum Contaminant Levels

as specific examples of levels below which corrective action would not be required.

- ***Maximum Contaminant Levels (MCL)*** - These values are provided from 40 CFR Subpart G, Sections 141.60 through 0.63 as promulgated under the Safe Drinking Water Act. These levels are designated for water media only.

- ***USGS Background*** - These values are provided from the USGS report titled "Elemental Composition of Surficial Materials from Central Oklahoma" (USGS, 1991). These values represent the levels of metals which naturally occur in Central Oklahoma soils.

- ***Background*** - These levels are provided where background could be determined. Where available, background concentrations are listed for metals in soil samples taken on site, which were thought to be unaffected by releases from a unit.

- ***National Ambient Air Quality Standards (NAAQS)*** - These standards are published in 40 CFR Part 50 under the Clean Air Act (CAA) and apply to point sources that emit a limited number of constituents to the air. The constituents regulated are nitrogen dioxide, sulphur dioxide, carbon monoxide, lead, ozone, and particulate matter. Currently, it is assumed that none of the SWMUs or AOCs emit these compounds in regulated quantities and no air samples have been taken which would allow for a valid comparison.

- ***Water Quality Standards (WQS)*** - The WQS are the standards for surface water quality as established by the State of Oklahoma. These standards apply to point source discharges to surface waters and have been listed for those units adjacent to surface water.

8.0 Summary and Conclusions

RWDS 1030W is located on Landfill 2 approximately 1,700 feet west and 550 feet north of Building 1030. Until 1951, radiological waste considered to be of significant nature was sent to the Canadian Radium and Uranium Corporation in Mt. Kiska, New York. As a cost-savings measure, certain types of radiological waste were disposed of on Base from 1951 until the 1960s. RWDS 1030W was reported to be a burial site for burned radium dial waste including rags and solvent solution. The waste was dumped in a pit, burned, and then covered with soil.

Nonintrusive Survey Results. Background radiation levels in the site vicinity ranged from 6.1 to 6.5 μR/hr. Radiation levels on the site ranged from background to 1,340 μR/hr. General areas, as well as fairly isolated points of significantly elevated radiation levels, were indicated. The results indicate that the area of contamination is large and extends in a southeast to northeast direction.

Geophysical surveys were performed, including GPR, Magnetic Field Gradiometer Surveying, and EM conductivity surveying. Theses surveys along with the results from the radiological survey, indicated that RWDS 1030W contained several areas of subsurface soil contamination and/or buried radioactive material. It is probable that the contamination is migrating from the site and will continue to do so until the area is remediated. The radiological and geophysical surveys indicated that the elevated radiation levels roughly follow a former trench, which runs between the elevated picnic area and the remnants of Pistol Pond, oriented in a northeasterly direction. Geophysical surveys suggested that this trench may be as deep as 26 feet. It was considered likely that the subsurface soil contamination started much closer to the surface, and may have extended to, or beyond, the depth of 26 feet.

Removal Action - Work Performed. The RWDS 1030W removal action consisted of three different methods of excavation: point source excavation, orphan spot excavation, and lift excavation. Point source excavation was performed in areas where radiation levels in excess of 100 μR/hr were identified by a surface geophysical survey conducted by the Air Force in 1990 and by a metal detector and radiation instrument survey conducted on June 1, 1992. Excavation of these areas was conducted by hand to quickly determine and eliminate the source of these elevated readings and minimize the amount of waste generated. Orphan spot excavation occurred in 15 areas outside areas of lift excavation, which had surface

readings (greater than 20 μR/hr) according to the 1990 survey. This excavation was also conducted by hand. A lift of uniform depth was excavated over the entire area.

As the sites were excavated, soils were stockpiled based on the results of the surveys of the lifts prior to removal. The stockpiles were sampled and analyzed for radioactive and chemical contamination in accordance with the SAP. Analytical results determined disposition of the stockpiles, which were either used as backfill or disposed of as waste. This system minimized the amount of waste generated. All the materials exceeding release criteria were containerized in DOT Type A containers (B-25 boxes) and stored for turnover to Tinker AFB. Post-excavation confirmatory surveys were conducted to ensure no areas of elevated radiation remained. Clean areas were properly backfilled.

Conditions Existing at the Site as of August 21, 1992. Some subareas within the controlled zone contain radiologically contaminated materials that have not been excavated. When excavation operations ceased, radiological readings in these subareas for ranged from 200 μR/hr to 300 μR/hr. It is estimated that 80 to 120 yd^3 of radiologically contaminated materials exist under the hillside in one of the four subareas. These four subareas were backfilled prior to demobilization to reduce exposure to the contaminated soils and to provide sufficient drainage across the site. A radiological survey, performed after backfill operations were completed, indicated that no elevated radiation levels remained at ground surface in these subareas or in any other areas throughout the site.

An additional area of concern was discovered outside of the controlled zone in late July of 1992. This area, between the access road and the creek, and just south of the controlled zone, has elevated levels of radiation. A walkover survey was conducted and surface radiation measurements ranged from 100 μR/hr to 4 mR/hr. This area has not been thoroughly surveyed or delineated. The elevated readings were substantially higher than any surface readings found within the RWDS 1030W controlled zone. Tinker AFB was promptly notified of these findings. This investigation did not further evaluate.

Conclusions. The RWDS 1030W removal action was not completed as established in the project work plan. The principal reasons listed in the Interim Status Report can be summarized as follows:

- Previous survey data did not provide adequate information regarding the amount and extent of subsurface contamination.

- Intrusive reconnaissance within the zone of concern "underestimated the volume of contaminated material." Because the site was located on a landfill, an "observational" approach to the project was applied. Limited site characterization was conducted prior to excavation in an attempt to delineate the contamination. However, due to the landfill area being more extensive than indicated by records, the borings did not fully delineate the contamination. Instead, the spatial extent of the contamination was determined during excavation.

- Severe and unusual weather conditions occurred on a consistent basis. These weather conditions often created unsafe working conditions, slowing and sometimes halting operations.

Although the removal action has not been completed, four of the five locations within the RWDS 1030W site have been remediated. Approximately 920 yd^3 of excavated materials were containerized in 253 B-25 boxes and disposed of by Tinker AFB. These five areas have been cleared and backfilled.

9.0 Recommendations

This RFI Summary Report has been prepared to determine and document whether sufficient investigation have been performed for RWDS 1030W to meet the permit requirements. Based on the documents reviewed, the previous surveys and the removal action have not provided adequate information regarding the extent of subsurface contamination. The main focus of all the previous investigations at this site have involved mainly the analysis of radioactive constituents. However, hazardous waste constituents have not been addressed. Also, based on the documents reviewed, data collected at this site are limited. Additional investigations are necessary to confirm the presence or absence of hazardous waste constituents at the site. In addition, the nature and extent of contamination, if any, should be determined.

In view of these deficiencies, several additional investigations are recommended during the Phase II RFI. Based on the location of RWDS 1030W, it will be more appropriate to investigate this site as part of a group comprising several waste units in close proximity: RWDS 1022E, RWDS 62598, Landfills 1 through 4, the SP, and FTA1. Specific sampling needs to meet the objectives of the additional investigations will be presented in the work plan and sampling plan for the Phase II RFI. The following recommendations should be implemented under the Phase II RFI:

- Perform a survey of RWDS 1030W, including the additional area of contamination to the south of this site. This survey should be conducted with the appropriate hand-held instrumentation utilizing a grid system.

- Based on the survey, conduct composite soil samples from approximately 0 to 20 feet and have these samples analyzed for gross alpha, gross beta, radium-226, VOCs, SVOCs, and metals. At this time, it is not possible to determine how many samples will be needed. Soil samples should be analyzed for VOCs, SVOCs, metals, and inorganic parameter.

- Obtain groundwater samples for the analysis of VOCs, SVOCs, metals, and inorganic parameters.

In addition, to fully evaluate the extent of soil contamination at this site it is recommended that site-specific soil background samples be collected during the Phase II RFI. This additional information along with the USGS background values should be used in the Phase II report to distinguish site-related from background concentrations in a statistically significant manner. During the development of the Phase II RFI work plan, the number of background

samples to be collected, the location of the soil borings, and the soil analysis to be performed on the samples should be determined for EPA approval.

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Final Report
Phase I RCRA Facility Investigation for Appendix I Sites

VOLUME IX

SWMU-20, Radioactive Waste Disposal Site 201S

Department of the Air Force
Oklahoma City Air Logistics Center
Tinker Air Force Base, Oklahoma

September 1994

Table of Contents - RFI Summary Report

Table of Contents *(Continued)*

List of Tables

List of Figures

List of Acronyms

AFB	Air Force Base
AOC	area of concern
CAL	Corrective Action Levels
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CMS	Corrective Measures Study
cm/s	centimeters per second
cpm	counts per minute
DERP	Defense Environmental Restoration Program
DOD	U.S. Department of Defense
EID	Engineering Installation Division
EM	electromagnetic
EPA	U.S. Environmental Protection Agency
ES	Engineering Science
ft^2	square feet
ft/ft	feet per foot
GPR	ground penetrating radar
HSWA	Hazardous and Solid Waste Amendments
ILCR	incremental lifetime cancer risk
IRP	Installation Restoration Program
LSZ	lower saturated zone
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µR/hr	microroentgen per hour
m^2	square meters
MCL	maximum concentration level
MHz	megahertz
mrem/hr	millirems per hour
msl	mean sea level
NAAQS	National Ambient Air Quality Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
OEHL	Occupational and Environmental Health Laboratory

List of Acronyms (Continued)

PA/SI	preliminary assessment/site investigation
pCi/g	picocuries per gram
POL	petroleum and oil lubricants
RCRA	Resource Conservation and Recovery Act
RESRAD	Residual Radioactive (Materials)
RI/FS	remedial investigation/feasibility study
RFI	RCRA Facility Investigation
ROD	Record of Decision
RWDS	Radioactive Waste Disposal Site
SARA	Superfund Amendments and Reauthorization Act
SWMU	solid waste management unit
TSD	treatment, storage, and disposal (facility)
USACE	U.S. Army Corps of Engineers
USAF	U.S. Air Force
USC	U.S. Code
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UST	underground storage tank
USZ	upper saturated zone
UWBZ	upper water bearing zone
WSCI	Water and Soil Consultants, Inc.
WQS	Water Quality Standards
yd^3	cubic yards

Executive Summary

This report provides a summary of the various investigations that have been conducted at the solid waste management unit (SWMU)-20 Radioactive Waste Disposal Site (RWDS) 201S, Tinker Air Force Base (AFB), Oklahoma. The report has been prepared to determine and document whether sufficient investigations at RWDS 201S have been performed to meet regulatory requirements. Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County. The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. The Base encompasses approximately 5,000 acres.

Background. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon™, jet fuels, and radium paints.

In 1984, Congress amended the Resource Conservation and Recovery Act (RCRA) with the Hazardous and Solid Waste Amendments (HSWA), which allow the Environmental Protection Agency (EPA) to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989, Tinker AFB submitted its Part B permit application for renewal of its operating RCRA Hazardous Waste Storage facility permit. The final RCRA HSWA permit issued on July 1, 1991, requires Tinker AFB to investigate all SWMUs and areas of concern (AOC) and to perform corrective action at those identified as posing a threat to human health of the environment. The permit specifies that a RCRA Facility Investigation (RFI) be conducted for 43 identified SWMUs and two AOCs on the Base. This document has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for RWDS 201S.

Source Description. RWDS 201S is located in the southern alcove of Building 201. This site was reported to contain radium paint solids and dials from the radium paint room previously located in Building 201. The estimated volume of waste at the site is less than 10 cubic yards (yd^3). The depth of burial was reported to be less than 10 feet.

Site Investigations. The Tinker AFB RWDS effort is structured into three phases:

Phase I - Record Search and Personal Interviews
Phase II - Site Investigations and Remedial Proposal
Phase III - Site Remediations and Waste Disposal.

Phase I of the RWDS effort consisted of a record search and personal interviews to collect information pertaining to the disposal of radioactive waste generated by U.S. Air Force (USAF) activities on or near Tinker AFB.

In 1990, the U.S. Air Force Occupational and Environmental Health Laboratory (OEHL) conducted radiological surveys in an attempt to substantiate the discoveries of the Phase I research.

Phase II of the RWDS effort was conducted by Chem-Nuclear Environmental Services and Battelle Pacific Northwest Laboratories. The work performed by Chem-Nuclear had two major objectives. The first was to conduct extensive non-intrusive radiation and geophysical surveys of the five sites. The second objective was to develop a proposed remediation plan for the five sites, based on the results of the surveys, and derive an approximate cost for the proposed plan. Volume I of the Chem-Nuclear report (1990) contains the results of the extensive surveys, as well as recommendations for future RWDS remediation.

Battelle performed an intrusive survey and a risk assessment for RWDS-201S under Phase II. The objective of this study was to determine the risk to human health caused by possible radium (Ra)-226 contamination at RWDS 201S. Analysis of surfical soil samples collected by Battelle measured as high as 45.5 picocuries per gram (pCi/g) Ra-226. The surficial gamma ray survey delineated a potential contaminated source area of 60 square meters (m^2) at RWDS-201S. Hand-augering within this 60m^2 area implied that contamination extends no more than 0.25 meters below ground surface.

Phase III of the RWDS effort will consist of the ultimate remediation of the sites believed to actually contain radioactive waste, and subsequent disposal of that waste at an authorized disposal facility. Phase III has not yet been performed at RWDS-201S.

Baseline Risk Assessment. The U.S. Department of Energy's Residual Radioactive Material Guidelines (RESRAD) code was used to perform pathway analysis and risk assessment, and to determine dose restricting levels for soil cleanup.

Output from RESRAD indicates that the existing source causes a maximum dose of 190 millirems per year (mrem/yr), which occurs at time zero (time of the investigation). The primary pathway is direct external exposure to humans living on site (the model assumes a family farm scenario). The dose drops as time progresses and reaches about 11 mrem/yr after 300 years. This reduction in dose is primarily due to removal of much of the source by erosion (assuming a 0.0005 meter per year erosion rate). However, after 1,000 years, leaching radium breaks through into the saturated zone, elevating the total dose to 40 mrem/yr. Soil removal or dilution must lower the soil concentration to 8 pCi/g to ensure that dose does not exceed the 25 mrem/yr limit. EPA radium regulations are 5 pCi/g for surficial soil contamination (0-15 centimeters below ground surface). If sufficient radium-contaminated soil is removed from the site to reach this EPA level, the total dose will drop below 25 mrem/yr, meeting the USAF Radioisotope Committee dose standard. Risk values calculated by RESRAD show that excess cancer rate from all exposure pathways at the time of the survey (t=0) amount to 2.180×10^{-3}. Exposure risk drops to a total 1.175×10^{-4} after 1,000 years.

Conclusions. The radiation and geophysical survey results for RWDS 201S support the Phase I record search description of a general dumping area for radioactive materials. The elevated radiation levels associated with both the general areas and isolated points, coupled with the geophysical anomalies indicative of past excavation, led to the conclusion that this site may contain several buried radioactive objects with possible subsurface soil contamination. The depth of the excavation (which may contain the buried radioactive material/contamination) appears to be limited to a depth of less than 10 feet, most likely in the range of 6 to 8 feet. The area under the concrete slab may also be contaminated, but this cannot be determined without intrusive sampling. It is unlikely that the contamination extends as far out as the underground storage tanks (UST) or underneath Building 201. Therefore, any remediation activities would probably not require prior removal of the UST and should not result in structural damage to Building 201. The underground steam line and electrical cable shown on the utility map may interfere with excavation activities.

Recommendations. Based on the documents reviewed, there is limited data available for adequate characterization of this site. For instance, previous investigations have mainly focused on the analysis of radioactive waste constituents. No hazardous waste constituents have been addressed. Therefore, it is recommended that additional investigations be conducted during the Phase II RFI. Specific data needs to determine the nature and extent of

contamination will be presented in the work plan and sampling plan developed during the Phase II RFI. At a minimum, the following recommendations should be implemented:

- Obtain soil samples for VOC and SVOC analyses.
- Collect site-specific soil background samples to be used in addition to USGS soil data to distinguish site-related from background concentrations in a statistically significant manner during the Phase II investigation.
- Obtain groundwater samples for VOC, SVOC, metals, and inorganic parameters analyses.

2.0 Background

2.1 Site Operations and History

Tinker AFB was originally known as the Midwest Air Depot and began operations in July 1941. The site was activated March 1942. During World War II, the depot was responsible for reconditioning, modifying, and modernizing aircraft, vehicles, and equipment.

The Tinker AFB RWDS effort is structured into three phases:

Phase I - Record Search and Personal Interviews
Phase II - Site Investigations and Remedial Proposal
Phase III - Site Remediations and Waste Disposal.

Phase I of the RWDS effort revealed the probability of this site containing radium paint solids and dials generated in a radium paint room which was located in Building 201. The radium paint room has reportedly been remediated and the shell of the structure released for unrestricted access. The U.S. Army Corps of Engineers (USACE) 1989 report contains an estimate that approximately 10 cubic yards of waste is buried at this site, at a depth of less than 10 feet. The report did not explain the basis for this estimate (Chem-Nuclear Environmental Services, 1990).

2.2 Summary of Previous Investigations

2.2.1 Nonintrusive Surveys

Radiological Surveys. During 1971, a radiologic survey was performed at this site that indicated a background for the area of 0.02 microroentgen per hour (μR/hr). A reading of 0.3 μR/hr was obtained at ground level by the concrete marker and a reading of 0.1 μR/hr was obtained at 3 feet above ground level (Burris, 1971). In 1988, an ionizing survey was performed that gave a reading 5 feet east of the concrete monument of 0.05 μR/hr at ground level. No values were detected during the survey at the monument and north, south, and west of the monument (USACE, 1989).

These investigations consisted of extensive surface radiological and geophysical surveys. The Air Force specifically directed that no intrusive sampling was permitted during this phase of

the investigation. As a result, all surveys were designed to be nonintrusive in nature, and were restricted to activities on or above the ground surface.

Radiological Survey Equipment and Technique. The radiological surveys consisted primarily of ground surface radiation surveys using an Eberline ESP-2 with a SPA-3 probe (2 by 2 inches sodium iodine crystal) in the ratemeter mode. At each RWDS that contained locations with surface radiation levels above background, on-contact readings were taken with an Eberline RM-20 instrument with an HP-260 probe, to confirm the absence of surface contamination.

Based on the RWDS Phase I record search (ES,1982), RWDS 201S was known to contain radium contaminated objects and/or residue. Among other radioactive decay particles, radium emits gamma rays during the decay process. Since the radioactive materials and contaminated objects are suspected to be buried at approximately 10 feet, the soil above the objects will attenuate all except the gamma radiation before it reaches the surface. The gamma radiation is also subject to some degree of attenuation, thereby lowering its energy. The SPA-3 probe was chosen for the radiological surveys due to its sensitivity to low energy gamma rays. To ensure a thorough radiological survey, the site was divided into grids of appropriate size.

Geophysical Survey Equipment and Technique. Following the previously described surface radiation surveys, RWDS 201S was subjected to a series of nonintrusive geophysical surveys. The lateral and/or vertical variations mapped by geophysical techniques can provide a model for the geologic environment of the investigated site, as well as delineate cultural or synthetic variations in the materials present beneath the surface. The geophysical surveys were conducted in an attempt to correlate inconsistencies in the subsurface physical properties with information available on and above the surface.

An inconsistency in the subsurface properties detected as the result of a geophysical survey is referred to as an "anomaly." Because the RWDS Phase I research revealed that the site was associated with excavation and subsequent burial activities, and probably contained radium-contaminated metals and/or metallic containers, the geophysical survey techniques were designed with emphasis on the detection of metallic and soil density variation anomalies.

The site was subjected to various types of geophysical surveys that were independent of the preceding radiological surveys. Additional concentrated geophysical surveys were conducted

in the vicinity of the "hot spot(s)" to maximize the probability of detecting an anomaly that could be related to the elevated radiation level(s).

Several types of geophysical survey equipment were utilized to measure different physical properties. The following is a basic description of the geophysical survey equipment used during this RWDS investigation, and the physical properties that they exploit.

Ground Penetrating Radar. Ground penetrating radar (GPR) is a system that transmits high-frequency electromagnetic (EM) energy into the earth and detects return energy reflected from subsurface structural interfaces or buried objects. GPR is useful in detecting and mapping near-surface structures, soil-unit interfaces, and buried natural or man-made objects. It is especially useful in the location of utility lines, underground storage tanks, and buried waste containers, which are not readily detectable by other geophysical methods by virtue of their physical properties or nearby interference (such as power lines, metal fences, buildings, etc.).

Three different GPR antennas were utilized during the course of the RWDS investigations to maximize the resolution and/or depth of the subsurface search. The highest frequency of EM energy utilized was 500 megahertz (MHz). This frequency offered the best resolution of near-surface anomalies, but its depth of search was limited to approximately 3 feet. The middle frequency employed was 300 MHz, which increased the effective search depth, but sacrificed the degree of resolution between various anomalies. The lowest frequency of EM energy used was 80 MHz. This low frequency energy maximized the effective search depth, but offered the least amount of resolution.

The GPR geophysical survey was performed in an attempt to examine the variation of soil density characteristic of sites subject to previous extraction. It is also effective in detecting voids created by containers.

Induction EM Conductivity (EM-31 and EM-34). The induction EM method measures the apparent conductivity of the subsurface environment. The conductivity is a function of the properties of the materials it contains, such as soil or rock type, moisture content, metallic properties, organic or inorganic concentrations, permeability, and porosity.

Both the EM-31 and the EM-34 instruments were used for these geophysical surveys. The EM-34 has a greater effective search depth than the EM-31 due to the greater distance

between the transmitter and receiver poles. The EM-31 and EM-34 instruments measure the subsurface conductivity by radiating an EM field that induces eddy currents in the earth. The magnitude of these eddy currents is proportional to the conductivity of the material through which they flow. The induced currents generate secondary magnetic fields, which intercept the receiver coil of the instrument. The instrument processes the received signal and produces an output voltage related to the conductivity of the subsurface material. The varying output voltages for different locations are recorded in a data storage device during the actual survey process. Upon completion of the survey, the data can be transferred for automated or manual interpretation.

EM conductivity geophysical surveys were performed in an attempt to examine the conductivity properties of the metallic objects reported to be the source of the radioactive contamination at RWDS 201S.

Total Magnetic Field Gradiometer (Magnetometer). The total magnetic field intensity method measures the cumulative perturbation of the earth's magnetic field. Magnetic field perturbations are a function of the properties of the subsurface materials, such as soil or rock type, buried debris, or any accumulation or aggregation of ferromagnetic materials.

The magnetometer measures the total magnetic field intensity at two sensor heights and records the readings in a data storage device during the course of the survey. Upon completion of the survey, the data can be transferred for automated or manual interpretation.

A magnetometer geophysical survey was performed in an attempt to exploit the magnetic properties of ferrous materials that may be associated with the radium contaminated objects, or their containers, buried at the disposal sites.

Survey of Radiological Waste Sites, 1990. In 1990, personnel from the Air Force Occupational and Environmental Health Laboratory (OEHL) performed a surface exposure rate survey at six radiological waste sites on Tinker AFB. RWDS 201S was included as one of the sites surveyed.

Scope. Surface exposure rates were obtained at six sites where, subsequent to an earlier IRP records search, it was suspected that radioactive waste was disposed of in the past. A 5-minute background count was obtained at each of the sites. If exposure rates above background were detected, areas of highest activity were determined and posted.

Equipment Used. The following equipment was used to perform the survey:

- Eberline survey meter, model ESP-2, serial number 00714, calibrated October 30, 1989.
- Calcium fluoride FIDLER probe, serial number 10, calibrated October 30, 1989.
- Dosimeter Corporation survey meter, model 5-0002, serial number 43-189, calibrated December 12, 1989.

Findings. For RWDS 201S, the 5-minute background reading indicated an average radiation background of 6,720 cycles per minute at 18 μR/hr. The measurements in the RWDS 201S area ranged from slightly below background to 100,000 cpm and 100 μR/hr.

2.2.2 Intrusive Surveys

Battelle Pacific Northwest Laboratories was contracted to perform an intrusive survey on the site and, using the results of that survey, to conduct a risk assessment evaluating the threat to human health caused by the presence of radium waste (Battelle, 1990). The intrusive survey failed to confirm the presence of any radioactively-contaminated soil, waste materials, or groundwater in the subsurface. However, a gamma-ray survey of surficial soil, a limited amount of surficial sampling, and gamma logging of soil cores and hand-augured holes indicated that surficial contamination may exist at the site.

2.3 Current Regulatory Status

The IRP has been ongoing at Tinker AFB since the early 1980s. IRP studies on the Base were conducted according to IRP guidance, which is essentially the same as EPA's guidance for conducting RI/FS under CERCLA. All investigation and removal actions have been closely monitored and approved by the EPA.

Since receiving the Hazardous Waste Management Permit on July 1, 1991, many of the IRP sites have come under the jurisdiction of the RCRA permits branch of EPA. As such, they have been identified as SWMUs; however, a large amount of work has already been performed at most of these sites under the IRP. Additional investigation at the SWMUs will be performed under the IRP.

3.0 Environmental Setting

3.1 Topography and Drainage

3.1.1 Topography

Regional/Tinker AFB. The topography of Oklahoma City and surrounding area varies from generally level to gently rolling in appearance. Local relief is primarily the result of dissection by erosional activity or stream channel development. At Oklahoma City, surface elevations are typically in the range of 1,070 to 1,400 feet mean sea level (msl). At Tinker AFB, ground surface elevations vary from 1,190 feet msl near the northwest corner where Crutcho Creek intersects the Base boundary to approximately 1,320 feet msl at Area D (EID).

Site. RWDS 201S lies on the southern side of the addition to Building 201 and to the west of Building 205. Building 201 is at an elevation of approximately 1,245 feet msl. The ground slopes gently toward the west.

3.1.2 Surface Drainage

Regional/Tinker AFB. Drainage of Tinker AFB land areas is accomplished by overland flow of runoff to diversion structures and then to area surface streams, which flow intermittently. The northeast portion of the Base is drained primarily by unnamed tributaries of Soldier Creek, which is itself a tributary of Crutcho Creek. The north and west sections of the Base, including the main instrument runway, drain to Crutcho Creek, a tributary of the North Canadian River. Two small unnamed intermittent streams crossing installation boundaries south of the main instrument runway generally do not receive significant quantities of Base runoff due to site grading designed to preclude such drainage. These streams, when flowing, extend to Stanley Draper Lake, approximately one-half mile south of the Base.

Site. Surface drainage in the vicinity of Building 201 area, which includes RWDS 201S, is influenced by the topography. The ground surface slope is very gentle, sloping to the west toward Kuhlman Creek. However, excess surface runoff from the Building 201 area is drained by storm sewers.

3.2 Geology

3.2.1 Regional/Tinker AFB Geology

Tinker AFB is located within the Central Redbed Plain Section of the Central Lowland physiographic province, which is tectonically stable. No major fault or fracture zones have been mapped near Tinker AFB. The major lithologic units in the area of the Base are relatively flat-lying and have a regional westward dip of about 0.0076 foot per foot (ft/ft) (Bingham and Moore, 1975).

Geologic formations that underlie Tinker AFB include, from oldest to youngest, the Wellington Formation, Garber Sandstone, and the Hennessey Group; all are Permian in age.

All geologic units immediately underlying Tinker AFB are sedimentary in origin. The Garber Sandstone and Wellington Formation are commonly referred to as the Garber-Wellington Formation due to strong lithologic similarities. These formations are characterized by fine-grained, calcareously-cemented sandstones interbedded with shale. The Hennessey Group consists of the Fairmont Shale and the Kingman Siltstone. It overlies the Garber-Wellington Formation along the eastern portion of Cleveland and Oklahoma counties. Quaternary alluvium is found in many undisturbed streambeds and channels located within the area.

Stratigraphy. Tinker AFB lies atop a sedimentary rock column composed of strata that ranges in age from Cambrian to Permian above a Precambrian igneous basement. Quaternary alluvium and terrace deposits can be found overlying bedrock in and near present-day stream valleys. At Tinker AFB, Quaternary deposits consist of unconsolidated weathered bedrock, fill material, wind-blown sand, and interfingering lenses of sand, silt, clay, and gravel of fluvial origin. The terrace deposits are exposed where stream valleys have downcut through older strata and have left them topographically above present-day deposits. Alluvial sediments range in thickness from less than a foot to nearly 20 feet.

Subsurface (bedrock) geologic units which outcrop at Tinker AFB and are important to understanding groundwater and contaminant concerns at the Base consist of, in descending order, the Hennessey Group, the Garber Sandstone, and the Wellington Formation (Table 3-1). These bedrock units were deposited during the Permian Age (230 to 280 million years ago) and are typical of redbed deposits formed during that period. They are composed of a conformable sequence of sandstones, siltstones, and shales. Individual beds are lenticular and vary in thickness over short horizontal distances. Because lithologies are similar and because

Table 3-1

Major Geologic Units in the Vicinity of Tinker AFB (Modified from Wood and Burton, 1968)

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
QUATERNARY	PLEISTOCENE AND RECENT	Alluvium	0-70	Unconsolidated and interfingering lenses of sand, silt, clay, and gravel in the flood plains and channels of stream	Moderately permeable. Yields small to moderate quantities of water in valleys of larger streams. Water is very hard, but suitable for most uses, unless contaminated by industrial wastes or oil field brines.
		Terrace deposits	0-100	Unconsolidated and interfingering lenses of sand, silt, gravel, and clay that occur at one or more levels above the flood plains of the principal streams.	Moderately permeable. Locally above the water table and not saturated. Where deposits have sufficient saturated thickness, they are capable of yielding moderate quantities of water to wells. Water is moderately hard to very hard, but less mineralized than water in other aquifers. Suitable for most uses unless contaminated by oil field brines.

Table 3-1

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
PERMIAN	LOWER PERMIAN	Hennessey Group (includes Kingman Siltstone and Fairmont Shale)	700	Deep-red clay shale containing thin beds of red sandstone and white or greenish bands of sandy or limey shale. Forms relatively flat to gently rolling grass-covered prairie.	Poorly permeable. Yields meager quantities or very hard, moderately to highly mineralized water to shallow domestic and stock wells. In places water contains large amounts of sulfate.
		Garber Sandstone	500±	Deep-red clay to reddish-orange, massive and cross-bedded fine-grained sandstone interbedded and interfingered with red shale and siltstone	Poorly to moderately permeable. Important source of groundwater in Cleveland and Oklahoma counties. Yields small to moderate quantities of water to deep wells; heavily pumped for industrial and municipal uses in the Norman and Midwest City areas. Water from shallow wells hard to very hard; water from deep wells moderately hard to soft. Lower part contains water too salty for domestic and most industrial uses.
		Wellington Formation	500±	Deep-red to reddish-orange massive and cross-bedded fine-grained sandstone interbedded with red, purple, maroon, and gray shale. Base of formation not exposed in the area.	

of a lack of fossils or key beds, the Garber Sandstone and the Wellington Formation are difficult to distinguish and are often informally lumped together as the Garber-Wellington Formation. Together, they are about 900 feet thick at Tinker AFB. The interconnected, lenticular nature of sandstones within the sequence forms complex pathways for groundwater movement.

The surficial geology of the north section of the Base is dominated by the Garber Sandstone, which outcrops across a board area of Oklahoma County. Generally, the Garber outcrop is covered by a veneer of soil and/or alluvium up to 20 feet thick. To the south, the Garber Sandstone is overlain by outcropping strata of the Hennessey Group, including the Kingman Siltstone and the Fairmont Shale (Bingham and Moore, 1975). Drilling information obtained as a result of geotechnical investigations and monitoring well installation confirms the presence of these units.

Depositional Environment. The Permian-age strata presently exposed at the surface in central Oklahoma were deposited along a low-lying north-south oriented coastline. Land features included meandering to braided sediment-loaded streams that flowed generally westward from highlands to the east (ancestral Ozarks). Sand dunes were common, as were cut-off stream segments that rapidly evaporated. The climate was arid and vegetation sparse. Off shore the sea was shallow and deepened gradually to the west. The shoreline's position varied over a wide range. Isolated evaporitic basins frequently formed as the shoreline shifted.

Across Oklahoma, this depositional environment resulted in an interfingering collage of fluviatile and wind-blown sands, clays, shallow marine shales, and evaporite deposits. The overloaded streams and evaporitic basins acted as sumps for heavy metals such as iron, chromium, lead, and barium. Oxidation of iron in the arid climate resulted in the reddish color of many of the sediments. Erosion and chemical breakdown of granitic rocks from the highlands resulted in extensive clay deposits. Evaporite minerals such as anhydrite ($CaSO_4$), barite ($BaSO_4$), and gypsum ($CaSO_4 \cdot 2H_2O$) are common.

Around Tinker AFB, the Hennessey Group represents deposition in a tidal flat environment cut by shallow, narrow channels. The Hennessey Group is comprised predominantly of red shales which contain thin beds of sandstone (less than 10 feet thick) and siltstone. In outcrop, "mudball" conglomerates, burrow surfaces, and dessication cracks are recognized. These units

outcrop over roughly the southern half of the Base, thickening to approximately 70 feet in the southwest from their erosional edge (zero thickness) across the central part of Tinker AFB.

In contrast, the Garber Sandstone and the Wellington Formation around Tinker AFB consist of an irregularly-interbedded system of lenticular sandstones, siltstones, and shales deposited either in meandering streams in the upper reaches of a delta or in a braided stream environment. Outcrop units north of Tinker AFB exhibit many small to medium channels with cut and fill geometries consistent with a stream setting. Sandstones are typically cross-bedded. Individual beds range in thickness from a few inches to approximately 50 feet and appear massive, but thicker units are often formed from a series of "stacked" thinner beds. Geophysical and lithologic well logs indicate that from 65 to 75 percent of the Garber Sandstone and the Wellington Formation are composed of sandstone at Tinker AFB. The percentage of sandstone in the section decreases to the north, south, and west of the Base. These sandstones are typically fine to very fine grained, friable, and poorly cemented. However, where sandstone is cemented by red muds or by secondary carbonate or iron cements, local thin "hard" intervals exist along disconformities at the base of sandstone beds. Shales are described as ranging from clayey to sandy, are generally discontinuous, and range in thickness from a few inches to approximately 40 feet.

Stratigraphic Correlation. Correlation of geologic units is difficult due to the discontinuous nature of the sandstone and shale beds. However, cross-sections (Figure 3-1) demonstrate that two stratigraphic intervals can be correlated over large sections of the Base in the conceptual model. These intervals are represented on geologic cross-sections A-A' and B-B' (Figures 3-2 and 3-3). Section A-A' is roughly a dip section and B-B' is approximately a strike section. The first correlatable interval is marked by the base of the Hennessey Group and the first sandstone at the top of the Garber Sandstone. This interval is mappable over the southern half of Tinker AFB. The second interval consists of a shale zone within the Garber Sandstone which, in places, is comprised of a single shale layer and, in other places, of multiple shale layers. This interval is more continuous than other shale intervals and in cross-sections appears mappable over a large part of the Base. It is extrapolated under the central portion of Tinker AFB where little well controls exists.

Structure. Tinker AFB lies within a tectonically stable area; no major near-surface faults or fracture zones have been mapped near the Base. Most of the consolidated rock units of the Oklahoma City area dip westward at a low angle. A regional dip of 0.0057 to 0.0076 ft/ft in

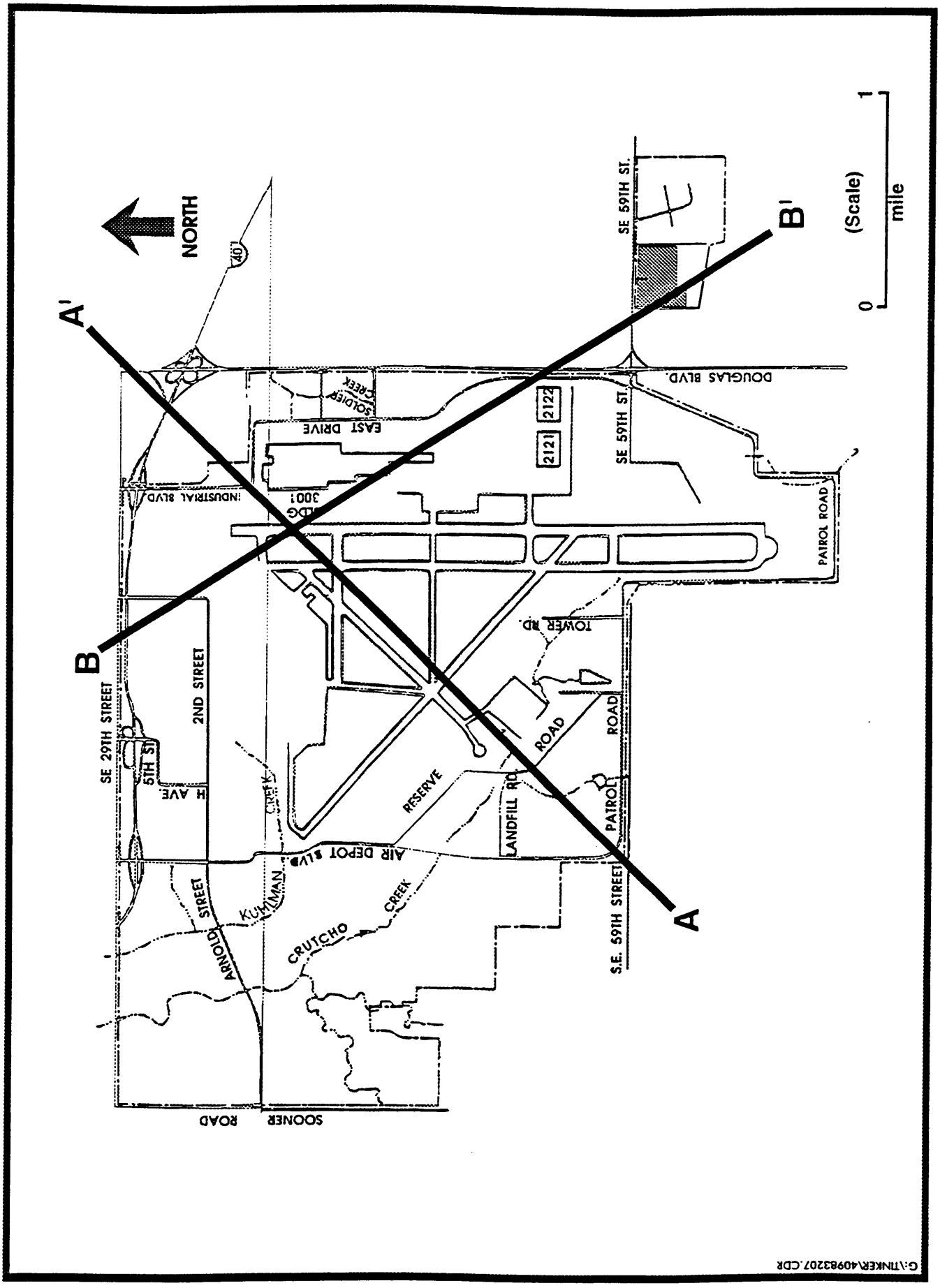


FIGURE 3-1 TINKER AFB GEOLOGIC CROSS SECTION LOCATION MAP

G:\TINKER\40983207.CDR

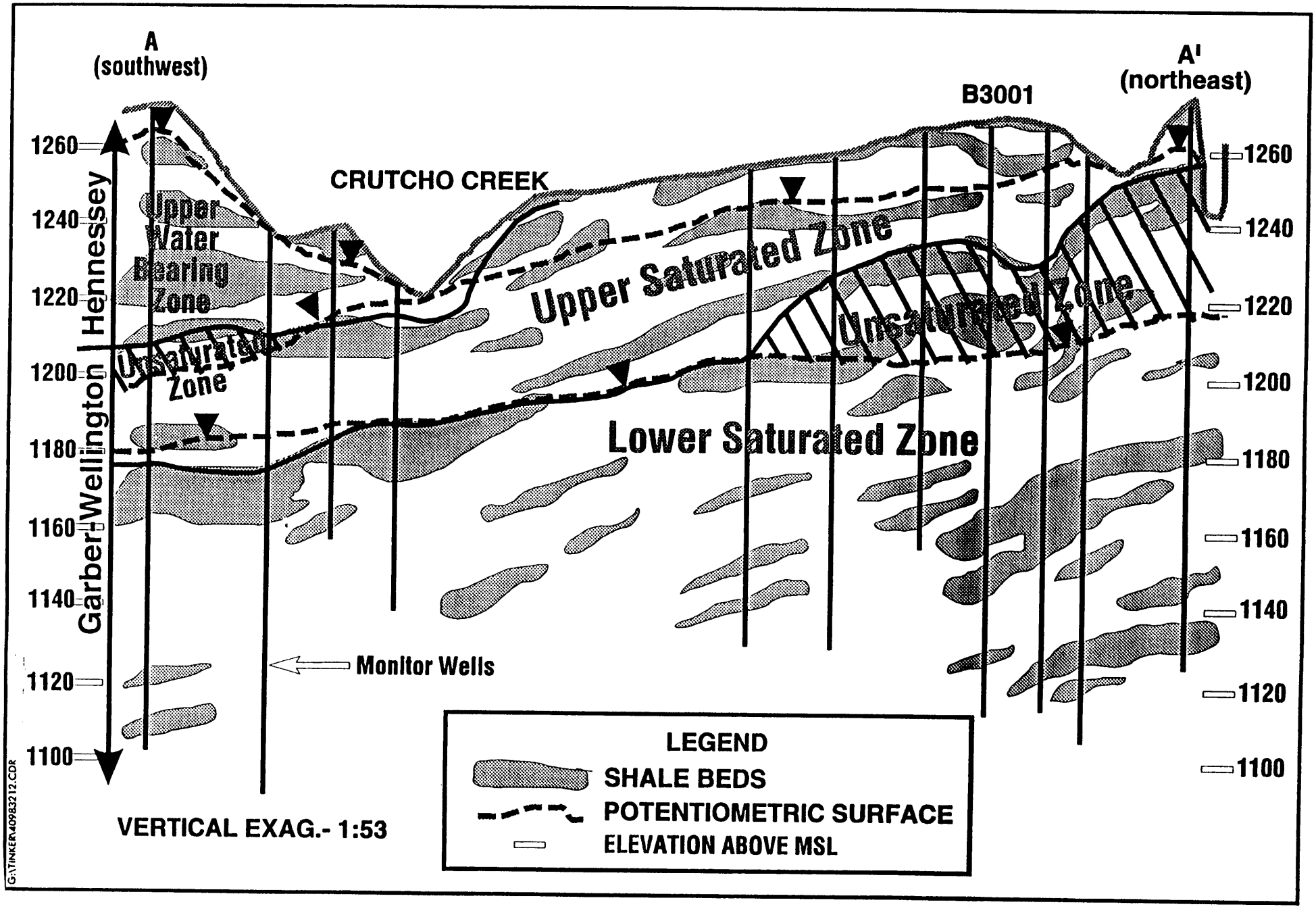


FIGURE 3-2 TINKER AFB GEOLOGIC CROSS SECTION A-A'

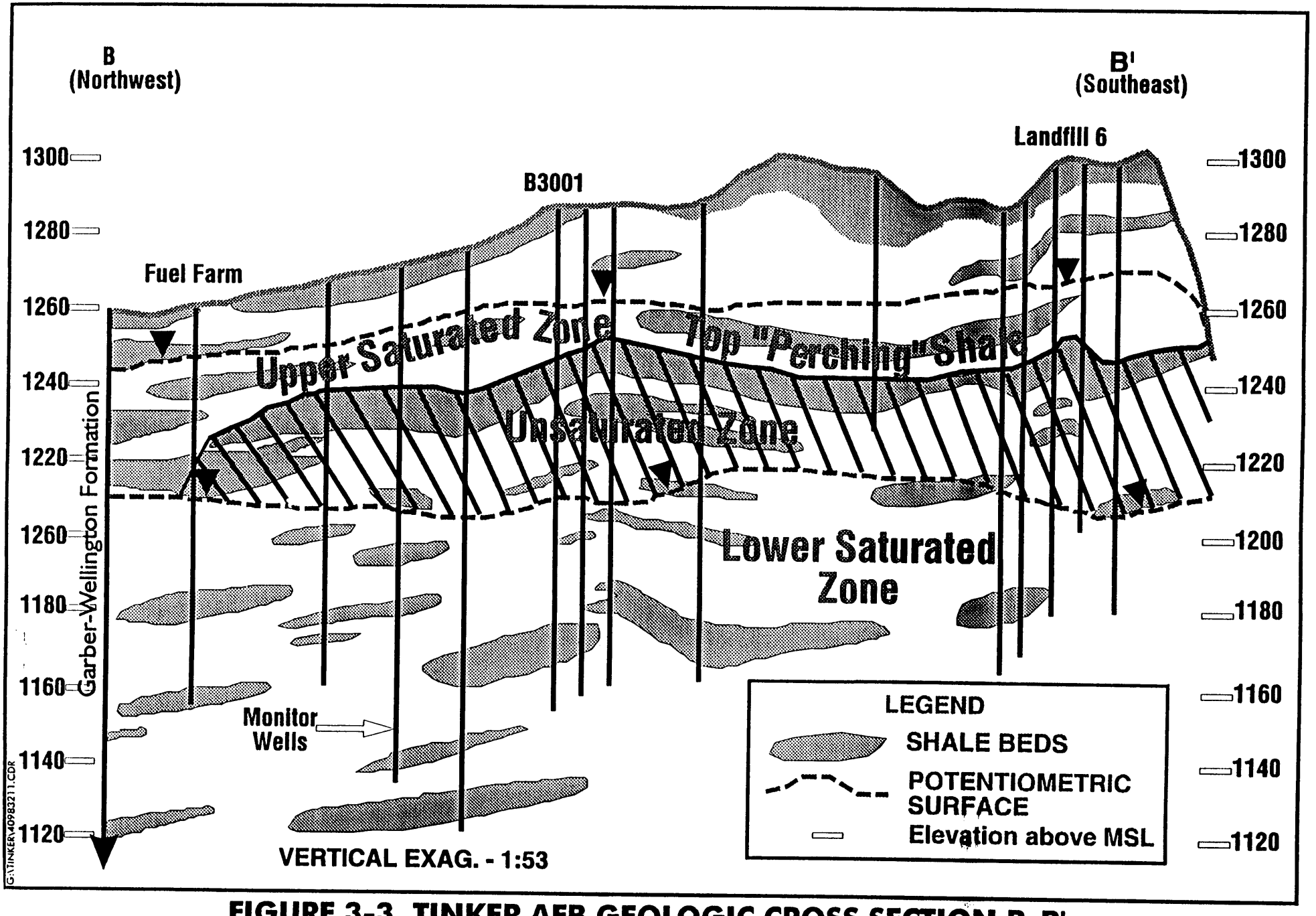


FIGURE 3-3 TINKER AFB GEOLOGIC CROSS SECTION B-B'

a generally westward direction is supported by stratigraphic correlation on geologic cross-sections at Tinker AFB. Bedrock units strike slightly west of north.

Although Tinker AFB lies in a tectonically stable area, regional dips are interrupted by buried structural features located west of the Base. A published east-to-west generalized geologic cross-section, which includes Tinker AFB, supports the existence of a northwest-trending structural trough or syncline located near the western margin of the base. The syncline is mapped adjacent to and just east of a faulted anticlinal structure located beneath the Oklahoma City Oil Field. The fault does not appear to offset Permian-age strata. There are indications that the syncline may act as a "sink" for some regional groundwater (southwest flow) at Tinker AFB before it continues to more distant discharge points.

3.2.2 Site Geology

Soil borings drilled in the vicinity of Building 210 indicate the presence of a shallow sandstone aquifer that is a part of the upper saturated zone (USZ). The sandstone occurs at depths ranging from 9.5 to 14.5 feet and is a red, fine grained, silty, clayey, loosely cemented sandstone with occasional interbeds of reddish brown shale. The thickness of this shallow sandstone unit is estimated to range from approximately 12 to 17 feet.

3.3 Hydrology

3.3.1 Regional/Tinker AFB Hydrology

The most important source of potable groundwater in the Oklahoma City metropolitan area is the Central Oklahoma aquifer system. This aquifer extends under much of central Oklahoma and includes water in the Garber Sandstone and Wellington Formation, the overlying alluvium and terrace deposits, and the underlying Chase, Council Grove, and Admire Groups. The Garber Sandstone and the Wellington Formation portion of the Central Oklahoma aquifer system is commonly referred to as the "Garber-Wellington aquifer" and is considered to be a single aquifer because these units were deposited under similar conditions and because many of the best producing wells are completed in this zone. On a regional scale, the aquifer is confined above by the less permeable Hennessey Group and below by the Late Pennsylvanian Vanoss Group.

Tinker AFB lies within the limits of the Garber-Wellington Groundwater Basin. Currently, Tinker derives most of its water supply from this aquifer and supplements the supply by purchasing from the Oklahoma City Water Department. The nearby communities of Midwest

City and Del City derive water supplies from both surface sources and wells tapping the aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by a municipal distribution system also depend on the Garber-Wellington aquifer. Communities presently depending upon surface supplies (such as Oklahoma City) also maintain a well system drilled into the Garber-Wellington as a standby source of water in the event of drought.

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 AFB is located in an aquifer outcrop area, the Base is considered to be situated in a recharge zone.

According to Wood and Burton (1968) and Wickersham (1979), the quality of groundwater 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.

Tinker AFB presently obtains its water supplies from a distribution system comprised of 29 water wells constructed along the east and west Base boundaries and by purchase from the Oklahoma City Water Department. All Base wells are finished into the Garber-Wellington aquifer. Base wells range from 700 to 900 feet in finished depth, with yields ranging from 205 to 250 gallons per minute. The wells incorporate multiple screens, deriving water supplies from sand zones with a combined thickness from 103 to 184 feet (Wickersham, 1979).

Although the variability in the geology and the recharge system at Tinker AFB makes it difficult to predict local flow paths, Central Oklahoma aquifer water table data show that regional groundwater flow under Tinker varies from west-northwest to southwest, depending on location. This theory is supported by contoured potentiometric data from base monitoring wells which show groundwater movement in the upper and lower aquifer zones to generally follow regional dip. Measured normal to potentiometric contours, groundwater flow gradients range from 0.0019 to 0.0057 ft/ft. However, because flow in the near-surface portions of the aquifer at Tinker AFB is strongly influenced by topography, local stream base-levels, complex subsurface geology, and location in a recharge area, both direction and magnitude of ground-

water movement is highly variable. The interaction of these factors not only influences regional flow but gives rise to complicated local, often transient, flow patterns at individual sites.

As a result of ongoing environmental investigations and the approximately 450 groundwater monitoring wells installed on the Base during various investigations, a better understanding of the specific hydrological framework has emerged. The current conceptual model developed by Tinker AFB (Tinker, 1993), based on the increased understanding of the hydrological framework, has been revised from an earlier model adopted by the USACE. Previous studies reported that groundwater was divided into four water-bearing zones: the perched aquifer, the top of regional aquifer, the regional aquifer, and the producing zone. In the current model, two principal water table aquifer zones and a third less extensive zone have been identified. The third is limited to the southwest quadrant. The third aquifer zone consisted of saturated siltstone and thin sandstone beds in the Hennessey Shale and equates to the upper water bearing zone (UWBZ) described by the USACE at Landfills 1 through 4 (SWMUs 3 through 6) (USACE, 1993). In addition, numerous shallow, thin saturated beds of siltstone and sandstone exist throughout the Base. These are of limited areal extent and are often perched.

In the current conceptual hydrologic model, an USZ and a lower saturated zone (LSZ) are recognized in the interval from ground surface to approximately 200 feet. Below this is found the producing zone from which the Base draws much of its water supply. Figure 3-4 shows the potentiometric surface for the USZ and Figure 3-5 shows the potentiometric surface for the LSZ. The USZ exists mainly under water table (unconfined) conditions, but may be partially confined locally. Conditions in the LSZ are difficult to determine due to screen placement and overly long sandpacks below the screen interval.

The USZ is found at a depth of 5 to 70 feet below ground surface and has a saturated thickness ranging from less than 1 foot at its eastern boundary to over 20 feet in places west of Building 3001. The USZ is erosionally truncated by Soldier Creek along the northeastern margin of Tinker AFB. This aquifer zone is considered to be a perched aquifer over the eastern one-third of Tinker AFB, where it is separated from the LSZ by an underlying confining shale layer and a vadose zone. The confining interval extends across the entire Base, but the vadose zone exists over the eastern one-third of this area. The available hydrogeologic data indicate that the vadose zone does not exist west of a north-south line located approximately 500 to 1,000 feet west of the main runway; consequently, the USZ is not perched west of this line. However, based on potentiometric head data from wells

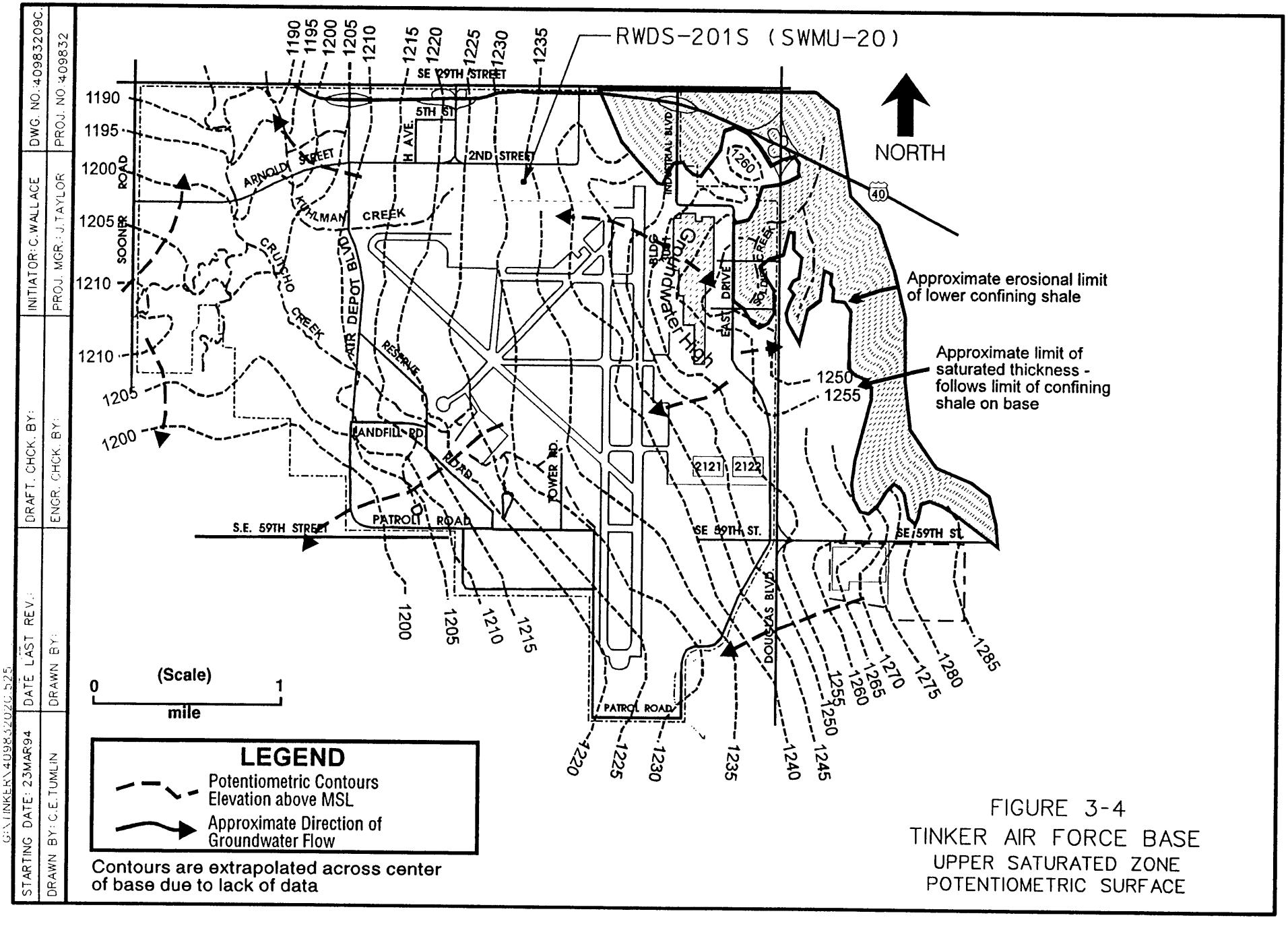


FIGURE 3-4
TINKER AIR FORCE BASE
UPPER SATURATED ZONE
POTENTIOMETRIC SURFACE

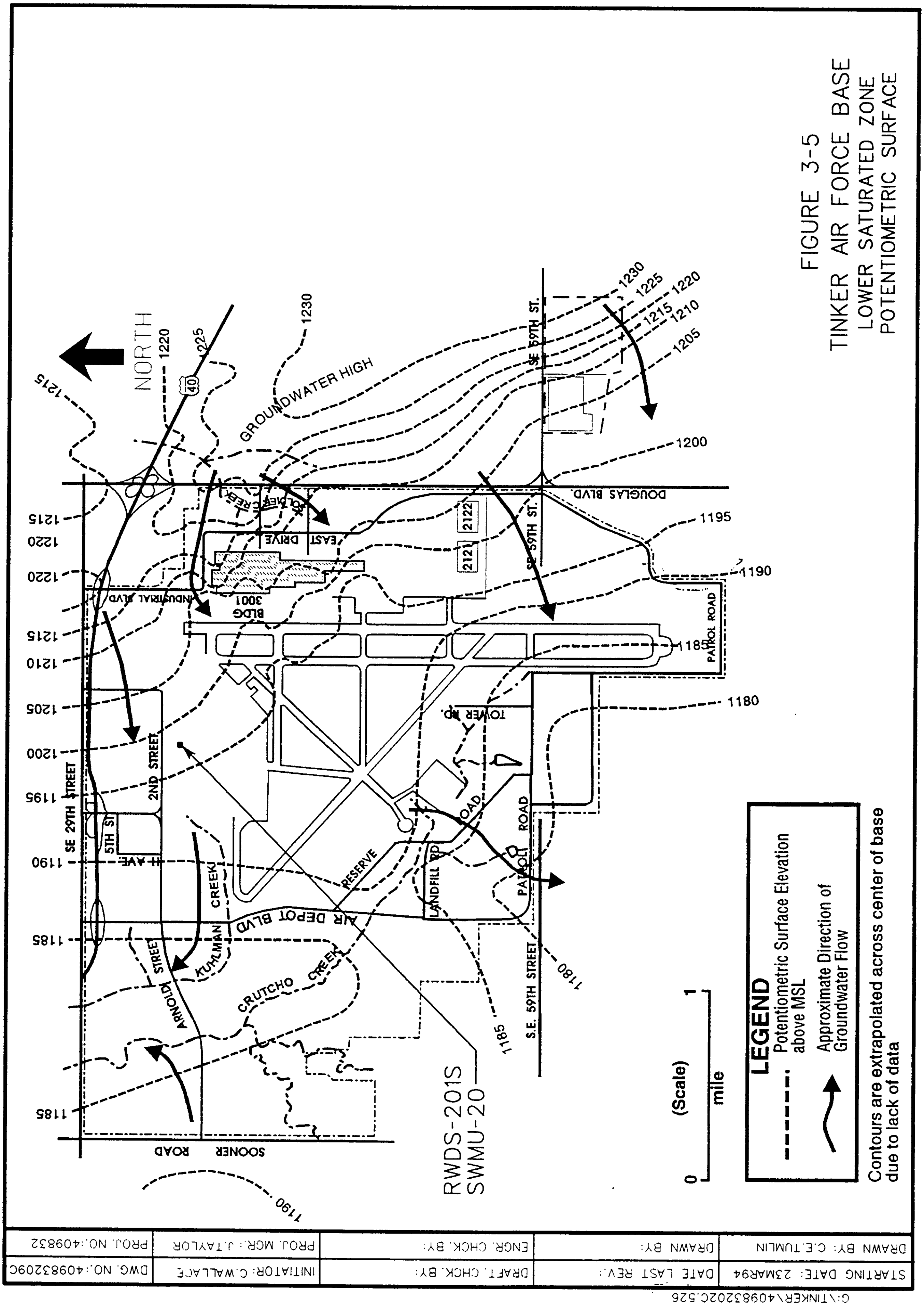


FIGURE 3-5
TINKER AIR FORCE BASE
LOWER SATURATED ZONE
POTENTIOMETRIC SURFACE
NORTH
GROUNDWATER HIGH
RWDS-201S
SWMU-20
LEGEND
Potentiometric Surface Elevation above MSL
Approximate Direction of Groundwater Flow
Contours are extrapolated across center of base due to lack of data
(Scale)
0
1
mile
SE 29TH STREET
SE 59TH ST.
S.E. 59TH STREET
DOUGLAS BLVD.
SOONER ROAD
AIR DEPOT BLVD
ARNOLD STREET
2ND STREET
5TH ST
H AVE
INDUSTRIAL BLVD
EAST DRIVE
BLDG 3001
TOWER RD.
PATROL ROAD
LANDFILL RD
RESERVE ROAD
KUHLMAN CREEK
CRUTCHO CREEK
SOLDIER CREEK
40
DRAWN BY: C.E.TUMLIN
STARTING DATE: 23MAR94
DRAWN BY:
DATE LAST REV.:
ENGR. CHCK. BY:
DRAFT. CHCK. BY:
PROJ. MGR.: J.TAYLOR
INITIATOR: C.WALLACE
PROJ. NO.:40983Z
DWG. NO.:40983Z09C
G:\TINKER\40983Z02C.526

screened above and below the confining shale layer, the USZ remains a discrete aquifer zone distinct from the LSZ even over the western part of the Base. In areas where several shales interfinger to form the lower confining interval rather than a single shale bed, "gaps" may occur. In general, these "gaps" are not holes in the shale, but are places where multiple shales exist that are separated by slightly more permeable strata. Hydrologic data from monitoring wells indicate that these zones allow increased downward flow of groundwater above what normally leaks through the confining layer.

The LSZ is hydraulically interconnected and can be considered one aquifer zone down to approximately 200 feet. This area includes what was referred to by the USACE as the top of regional and regional zones. Hydrogeologic data from wells screened at different depths at the same location within this zone, however, provide evidence that locally a significant vertical (downward) component of groundwater flow exists in conjunction with lateral flow. The magnitude of the vertical component is highly variable over the Base. Preliminary evidence suggests that the LSZ is hydraulically discrete from the producing zone. Due to variations in topography, the top of the lower zone is found at depths ranging from 50 to 100 feet below ground surface under the eastern parts of the Base and as shallow as 30 feet to the west. Differences in potentiometric head values found at successive depths are due to a vertical (downward) component of groundwater flow in addition to lateral flow and the presence or absence of shale layers which locally confine the aquifer system. The LSZ extends east of the Base (east of Soldier Creek) beyond the limits of the USZ where it becomes the first groundwater zone encountered in off-Base wells. Because of the regional dip of bedding, groundwater gradient, and topography, the LSZ just east of the Base is generally encountered at depths less than 20 feet.

3.3.2. Site Hydrology

The general direction of groundwater flow in the vicinity of RWDS 201S is to the west-southwest towards Kuhlman Creek. The slope of the perched water surface closely mimics the local topographic slope. The permeability of the shallow aquifer at the site is estimated to be on the order of 5.0×10^{-4} centimeters per second (cm/s). This estimate is based on comparable pump test conducted by USACE (1988) at the 290 Fuel Farm and by Water and Soil Consultants, Inc. (WSCI, 1992) at the Petroleum and Oil Lubricants (POL) Site A, located 1,500 feet north-northwest of Building 201.

3.4 Soils

Three major soil types have been mapped in the Tinker AFB area and are described in Table 3-2 (U.S. Department of Agriculture [USDA], 1969). The three soil types, the Darrell-Stephenville, Renfrow-Vernon-Bethany, and Dale-Canadian-Port, consist of sandy to fine sandy loam, silt loam, and clay loam, respectively. The Darrell-Stephenville and the Renfrow-Vernon-Bethany are primarily residual soils derived from the underlying shales of the Hennessey Group. The Dale-Canadian-Port association is predominantly a stream-deposited alluvial soil restricted to stream floodplains. The thickness of the soils ranges from 12 to 60 inches.

Table 3-2

Tinker AFB Soil Associations
(Source: USDA, 1969)

Association	Description	Thickness (in.)	Unified Classification[a]	Permeability (in./hr)
Darrell-Stephenville: loamy soils of wooded uplands	Sandy loam Sandy clay loam Soft sandstone (Garber Sandstone)	12-54	SM,ML,SC	2.0-6.30
Renfrow-Vernon-Bethany: loamy and clayey soils on prairie uplands	Silt loam - clay Clay loam Shale (Fairmont Shale)	12-60	ML,CL,MH,CH	<0.60-0.20
Dale-Canadian-Port: loamy soil on low benches near large streams	Fine sandy loam Silty clay loam Loam Clay loam	12-60	SM,ML,CL	0.05-6.30

[a]Unified classifications defined in U.S. Bureau of Reclamation, 5005-86.

4.0 Source Characterization

RWDS 201S contains radium paint solids and radium-painted dials from the radium paint room located in Building 201. The Building 201 radium paint room was completely removed, including the duct work and the dry wall. The remaining shell was tested to ensure that there was no further contamination, and the construction debris was sent to a Nuclear Regulatory Commission (NRC) landfill in Utah. The estimated volume of waste at RWDS 201S is less than 10 cubic yards (yd^3). The exact depth of burial is unknown, but is estimated to be less than 10 feet.

5.0 Contaminant Characterization

Chem-Nuclear performed an investigation of the Tinker AFB RWDSs (Chem-Nuclear, 1990). The investigation included a radiological survey and a geophysical survey. The geophysical survey consisted of a GPR survey, magnetometer survey, and an EM survey. The results of this investigation are summarized below.

Chem-Nuclear Environmental Services Overall RWDS 201S Survey Results. Based on the radiation and geophysical surveys, Chem-Nuclear confirmed that RWDS 201S definitely contains radioactive material (of some type) below the ground surface, as well as numerous subsurface geophysical anomalies (i.e., buried metal objects, soil density changes, etc.). The location of elevated radiation levels and subsurface anomalies did coincide in many cases.

Because RWDS 201S contained elevated surface radiation levels, additional measurements were taken to determine if radioactive contamination existed at the ground surface. Because the suspected radionuclide was radium (Ra)-226 in equilibrium with its decay progeny (which are alpha, beta, and gamma emitters), the ground surface was measured for the presence of beta radiation. Readings were taken with an Eberline RM-20 instrument equipped with an unshielded HP-260 probe. The readings were then repeated with a beta shield placed over the probe. In every instance, the levels with and without the beta shield did not vary significantly. This confirms that the material/substance creating the elevated radiation levels, and its associated soil contamination, was not located on the ground surface.

Radiological Survey Results. Three general areas exist with radiation levels significantly above background on contact with the ground surface. The background radiation level taken about 50 feet from RWDS 201S was approximately 6.75 μR/hr. The highest surface radiation level at this site detected during the survey was 105 μR/hr. The three general areas are described below.

Area 1. Area 1 consists of a series of isolated point sources between the outside wall of the extension to Building 201 and the eastern edge of the concrete slab. This area contains the high reading of 105 μR/hr.

Area 2. An area with general elevated radiation levels is located approximately 5 feet from the southwest corner of the concrete slab. This area exhibits the characteristics of a plane source, rather than discrete points. The radioactive material in this area may be at a greater depth and/or spread over a larger area than the previously described location.

Area 3. A large area of general elevated radiation levels is located near the center of the site. This large area exhibits the characteristics of a plane source, but also contains discrete points that were easily detectable.

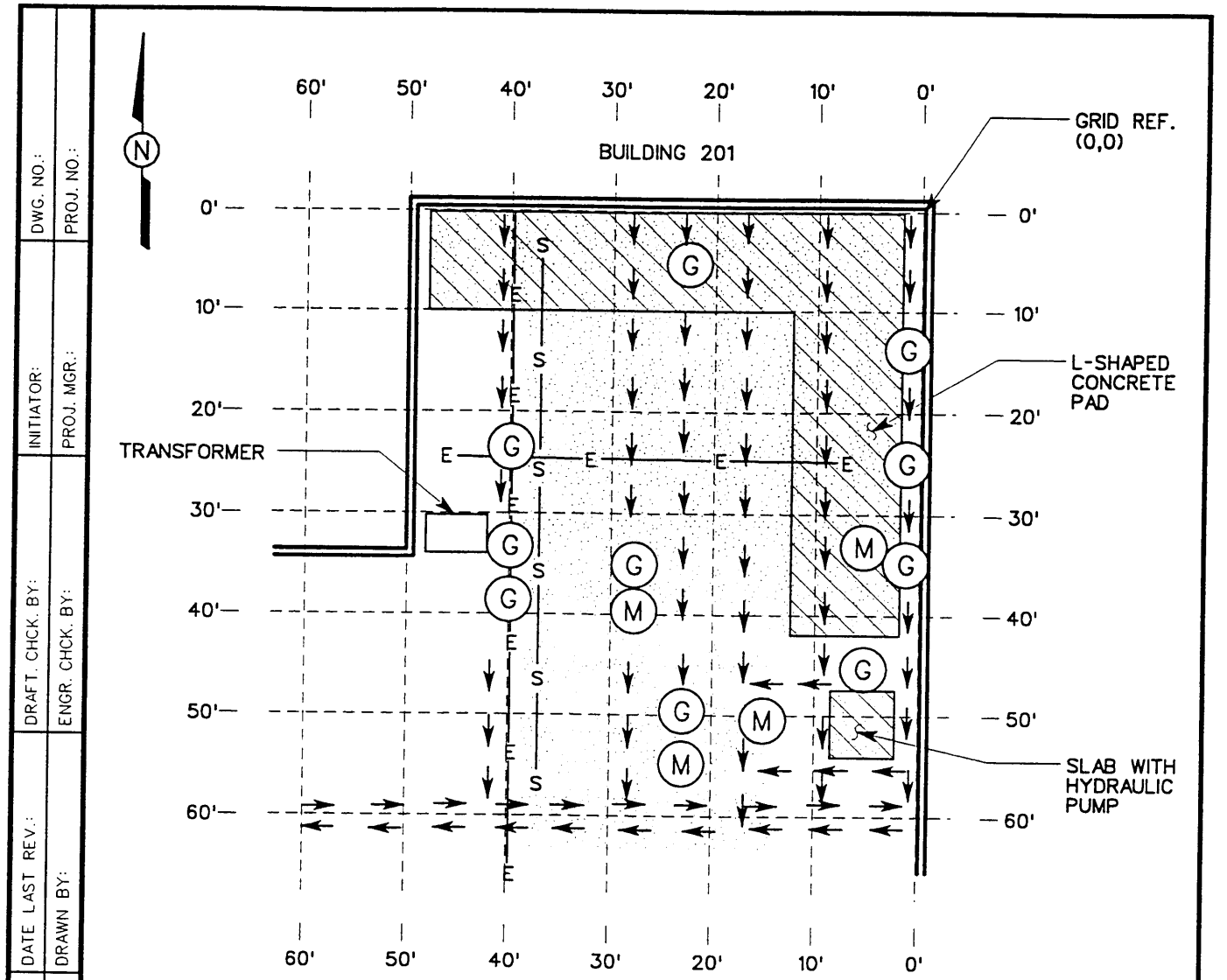
The random pattern and diversity of the "hot spots" discovered at this site is indicative of a radioactive disposal site.

Geophysical Survey Results

These results are discussed in the following paragraphs.

GPR. Several anomalies were detected at RWDS 201S when surveyed with the GPR. A survey of the area to the south and west of the L-shaped concrete slab (coincident with Area 3 above) indicates disturbed soil extending from approximately 1 to 7 feet in depth. This widespread anomaly (shown on the GPR recording in Figure 5-1) indicates a history of excavation and backfilling. The high concentration of anomalous returns suggest numerous small buried objects (rubble, etc.) and precludes precise location of individual targets. There is evidence of excavation and buried objects between the east side of the concrete slab and the wall of Building 201 (coincident with Area 1 above). A third GPR recording obtained on the 40-foot north-south reference line (shown in Figure 5-1) indicates disturbed soil extending over the entire length of the scan, as well as the buried electrical cable appearing on the Tinker AFB utility map. The estimated depth of the electric cable is 2.5 to 4 feet. A nonmetallic underground storage tank (UST) was located just south of the concrete slab and north of an old hydraulic pump station.

Magnetometer. Total magnetic field gradiometer data were collected over an 11- by 20-meter grid covering the site. Magnetic anomalies were detected at several locations. Three of the anomalies coincide with two of the areas of elevated radiation levels described above. The estimated depths of the anomalies range from 3 to 7 feet. The magnetic anomalies coincide with anomalies detected during the GPR survey.



STARTING DATE: 03/28/94 | DATE LAST REV.: | DRAFT. CHCK. BY: | INITIATOR: | DWG. NO.:
DRAWN BY: L. STOUT | DRAWN BY: | ENGR. CHCK. BY: | PROJ. MGR.: | PROJ. NO.:

FILENAME: G:\TINKER\40983202.095

FIGURE 5-1
SKETCH MAP OF
GEOPHYSICAL SURVEY
AREA AT RWDS 201S

TINKER AFB
OKLAHOMA

EM Conductivity. An EM conductivity survey was conducted at RWDS 201S, but the data collected are of questionable value. The instrument readings were erratic due to the nearness of the building, an electric transformer, and an underground electrical cable. The data collected could not be interpreted in a reliable manner.

Radioanalytical Results on Soil. During the intrusive survey, continuous core from a total of six soil borings, including one at a background location, were field screened for radioactivity (alpha, beta, and gamma) and sampled for laboratory analysis. The most active portions of each screened core were analyzed by the Air Force's Armstrong Laboratory for Ra-226, gross alpha, and gross beta. Armstrong Laboratory also performed a gamma-spec analysis on 16 subsurface soil core samples from the borings and one surface soil grab sample from the maximum hot spot identified during the surficial survey. Results from radiologic analyses are presented in Table 5-1. Radionuclides screened in the soil gamma-spec include actinium (Ac)-228, bismuth (Bi)-212, Bi-214, lead (Pb)-212, Ra-226, titanium (Ti)-208, potassium (K)-40, thorium (Th)-234, and cesium (Cs)-137.

As illustrated in Table 5-1, of the 10 radionuclides cited in Armstrong Laboratory's analysis of core soil samples, the vast majority were below detection limits. With the exception of Ra-226, its daughter Bi-214, and naturally occurring K-40 and Th-234, all radionuclides were present at levels well below 0.5 picocuries per gram (pCi/g). Significant Ra-226 concentrations were found in only two samples, one from the first core (0 to 1 foot) collected from boring 201S-B01. Radium in this sample measured 45.5 pCi/g. The other radium-contaminated sample was from the hot spot grab, which measured 25.7 pCi/g. The two EcoTek confirmatory analyses, which are presented in Table 5-2, fit the Armstrong results. They also show that the soil core samples are not significantly radioactive.

Radioanalytical Results on Groundwater. Armstrong's radioanalytical results for groundwater (Table 5-3) also show no direct evidence of radium contamination. With the exception of K-40, which occurs naturally, and Pb-212 found at levels of 84 pCi/L and 119 pCi/L in 201S-B04 and 201S-B06, respectively, all radionuclides were below or near detection limits. Pb-212, a daughter of Th-228, is not related to Ra-226; this radionuclide probably is naturally occurring.

Groundwater was resampled and reanalyzed after the monitoring wells were developed. This was done for three reasons: (1) concentrations of Ra-226 and total alpha in groundwater were initially found by Armstrong to be above the regulatory standard of 5 pCi/L and 15 pCi/L,

Table 5-1

Radioanalytical Results for Soil[a] (pCi/g) SWMU-20, RWDS 201S, Tinker AFB

Location	Depth Interval (ft)	Core No.	Gross Alpha	Gross Beta	Ac-228	Bi-212	Bi-214	Pb-212	Pb-214	Ra-226	Ti-208	K-40	Th-234	Cs-137
201S-B01	0-1	1	107.1	58.1	<0.7	<1.75	2.1	0.23	0.13	45.4[b]	<1.4	--	--	--
	6-7	2	14.7	16.7	<0.47	<0.94	0.35	0.38	<1.9	1.2	<0.88	9.6	--	--
201S-B02	2-4	1	20.8	16.1	<0.46	<0.86	<0.35	0.2	<1.9	1.1	<0.91	11	2.2	--
	8-9	2	6.6	14.3	<0.47	<0.92	<0.37	0.3	<2.0	0.9	<0.9	--	1.7	--
	10-11	3	7.4	6.3	<0.29	<0.73	<0.33	<0.16	<1.70	<1.3	<0.81	3.3	--	--
201S-B03	1-2	1	17.9	15.1	<0.51	<1.0	<0.38	0.29	<2.0	0.85	<0.98	10.9	--	--
	6-7	2	16.3	16	<0.6	<1.0	0.2	0.4	<0.002	1.1	1.2	--	2.6	--
	11-14	3	6.7	4.1	<0.4	<0.7	<0.3	<0.2	<0.002	<1.4	<0.8	--	--	--
201S-B04	1-2	1	11.9	16.7	<0.32	<0.84	<0.37	<0.19	<2.0	<1.6	<0.96	--	--	--
	7-8	2	9.1	16.1	<0.45	<0.85	<0.34	0.39	<1.8	1.	1.6	10.3	2.2	--
201S-B05	2-3	1	20.4	12.9	<0.42	<1.2	<0.51	<0.27	<2.6	<2.1	<1.2	--	--	--
	8-10	2	18.8	15.9	<0.46	<0.85	<0.35	0.34	<1.8	1.3	<0.88	9.1	--	--
	13-14	3	7.5	8.5	<0.39	<0.69	<0.31	0.16	<1.7	0.77	<0.81	8	--	--
201S-B06	1-2	1	18.4	23	<0.4	<0.9	0.4	0.2	<0.002	1.5	<0.9	--	--	0.003
	2-3	2	12	22.8	<0.4	<0.9	0.21	0.3	<0.002	1.82	<0.8	--	1.92	--
	8-9	3	<9.1	5.5	<0.3	<0.8	<0.3	<0.1	<0.002	<1.23	<0.8	--	--	--
Max Hot Spot Grab	GS[c]	--	104.1	29.5	<0.6	<1.3	1.3	0.4	<0.002	25.7[b]	2	--	--	0.1

[a]Analysis by Armstrong Laboratory at Tinker AFB (June, 1992);
Method EPA 900.0 for Gross Alpha and Beta
Method EPA 903 (Gamma Spec) for Radionuclides
[b]This concentration exceeds 5 pCi/g EPA guideline for radium in surface soil within 15 cm (6 inches) of ground surface.
[c]GS: Ground Surface (not cored)

Table 5-2

Confirmatory Radioanalytical Results (Soil and Groundwater)[a] SWMU-20, RWDS 201S, Tinker AFB

Analyte	201S-1 (2-3') Soil (pCi/g)	201S-6 (2-3') Soil (pCi/g)	Open Borehole Groundwater (pCi/L)
K-40	10	11	800
Tl-208	0.36	0.41	30
Bi-212	0.81	0.67	NA
Pb-212	1.1	1.2	78
Ra-223	0.37	0.33	NA
Ra-224	3.6	4.2	130
Ra-226	0.82	0.88	35
Ac-228	1.1	1.1	78
Pa-234	NA	3.7	NA
U-235	0.17	0.073	NA
Th-234	0.95	1.9	NA
Th-232	0.57	0.64	46

[a]Analysis by EcoTek, LSI; Atlanta, Georgia (June, 1992).
NA - Not Applicable.

Table 5-3

Radioanalytical Results for Groundwater (pCi/L) SWMU-20, RWDS 201S, Tinker AFB

Location	Gross Alpha	Gross Beta	Ac-228	Bi-212	Bi-214	Pb-212	Pb-214	Ra-226	Ti-208	K-40
201S-B02[a]	26.1[b]	<46.2	<232	<762	<151	<63.1	<0.8	<769	<407	2000
201S-MW2[c]	<7.4	<16.8	--	--	--	--	--	<0.09	--	--
201S-MW2[d]	5	27	--	--	--	--	--	<0.6	--	--
201S-MW2[e]	3	25	--	--	--	--	--	--	--	--
201S-B03[a]	34.9[b]	<42.9	<286	<680	<146	<59.3	<0.75	<830	<407	2300
201S-MW3[c]	4.8±2.7	8.4±4.2	--	--	--	--	--	1.08	--	--
201S-MW3[d]	13	62	--	--	--	--	--	<0.6	--	--
201S-MW3[e]	5	27	--	--	--	--	--		--	--
201S-B04[a]	339.7[b]	152.2	<240	<680	<160	84	<0.85	<780	<390	1500
201S-B05[a]	192[b]	61	0.23	<0.80	<0.17	0.14	<0.9	<0.83	<0.46	--
201S-MW5[c]	12.0±4.2	10.6±4.5	--	--	--	--	--	0.25	--	--
201S-MW5[d]	10	83	--	--	--	--	--	<0.6	--	--
201S-MW5[c]	5	28	--	--	--	--	--	--	--	--
201S-B06[a]	25[b]	<72.6	<267	<751	<157	119	<75	<793	<432	2600
201S-B06[f]	--	--	78	--	--	78	--	35[g]	30	800
A1-201SA[c]	4.3±3.4	11.9±5.2	--	--	--	--	--	0.38	--	--
B1-210WA[c]	4.7±2.6	<6.9	--	--	--	--	--	0.07±0.2	--	--
C1-201NS[c]	4.8±2.9	8.3±4.3	--	--	--	--	--	0.61	--	--
D1-201NE[c]	8.6±5.3	11.9±7.7	--	--	--	--	--	0.59±0.4	--	--

[a]Analysis by Armstrong Laboratory at Tinker AFB (June, 1992) on groundwater sampled from open boreholes.
[b]Gross Alpha concentration above 15 pCi/L EPA MCL (1991).
[c]Analysis by Armstrong Laboratory; San Antonio, Texas (October, 1993)(on unfiltered groundwater from completed piezometer.
[d]Analysis by Controls for Environmental Pollution (CEP), Inc.; Santa Fe, NM (December, 1993) on unfiltered groundwater from completed piezometer.
[e]Final analysis by CEP of gross alpha performed on filtered samples from completed piezometers.
[f]Analysis by EcoTek LSI; Atlanta, GA (July, 1992) on groundwater sampled from open boreholes.
[g]Radium-226 concentration above 5 pCi/L EPA MCL (1992).

respectively; (2) initial groundwater sampling was done in the newly drilled, uncompleted boreholes; (3) the location of the highest radium concentration reported by Armstrong was at the upgradient 201S-B04 location. The total alpha results in groundwater, which measured as high as 195 pCi/L by Armstrong (well above EPA standards of 15 pCi/L), were later attributed to running analyses on unfiltered samples.

Ra-226 in groundwater was detected in a one sample (201S-B06) by EcoTek at a level of 35 pCi/L. However, groundwater with elevated radium was not found when samples from the properly completed and purged monitoring wells were analyzed. These samples yielded Ra-226 concentrations below a 0.6 pCi/L detection limit. Similarly, gross alpha on filtered samples dropped well below the EPA standard of 15 pCi/L. The gross alpha in these samples measured from 3 to 5 pCi/L. Table 5-4 lists the relevant MCLs and action standards for soil and groundwater as they are currently set by EPA.

Additional monitoring wells have been installed downgradient of the site. Well numbers 2-27, 2-29A, and 2-29B were installed during the investigation of the four fuel sites. Monitoring wells 2-27B and 2-29B were screened in the USZ, and well 2-29A was screened in the LSZ. Groundwater from these wells was analyzed for radiological components (Table 5-5). The radium-226 concentration in the analyzed samples ranged from 0.3 to 2.32 pCi/L. (The proposed MCL for radium-226/228 is 20 pCi/L.) The gross alpha in these samples ranged from 2.7 to 9.5 pCi/L (MCL for alpha is 15 pCi/L).

Surface Survey Results. The highest areas of contamination were in the central and eastern portions of the site. In these areas, the SPA-6 probe recorded over 3,000 counts per minute (cpm).

The highest areas of contamination were in the central and eastern portions of the site. In these areas, the SPA-6 probe recorded over 3,000 cpm.

The highest counts recorded in the survey measured 9,400 cpm in the southern portion of the central strip of contamination that is west of the east wing of the concrete pad. The "max hot spot grab" sample was collected from this area and analyzed by Armstrong (see Table 5-1). Their gamma-spec radioanalysis of this sample detected Ra-226 at a concentration of 25.7 pCi/g. The three hand-auger borings also were located in hot spots delineated by the survey. These holes were logged to determine vertical extent of contamination.

Table 5-4

Regulatory Limits and Risk Parameters for Possible Constituents SWMU-20, RWDS 201S, Tinker AFB

(Page 1 of 2)

Chemical	Groundwater		Soil	Class[c]	Reference Dose (d) (mg/kg/day)		Carcinogenic Slope Factor[d] 1/(mg/kg/day)	
	MCL[a] (mg/L)	MCLG[a] (mg/L)	RFI Action Levels[b] (mg/kg)		Oral	Inhalation	Oral	Inhalation
Metals								
Arsenic	0.05	0.05	80	A	3.00×10^{-4}	--	1.75[e]	5.00×10^{1}[f]
Barium	2	2	--	D	7.00×10^{-2}	1.00×10^{-4}[f]	--	--
Cadmium	0.005	0.005	40	B1	5.00×10^{-4}	--	--	6.10×10^{0}[f]
Chromium (III)	0.1[g]	0.1[g]	--	A	1.00×10^{0}	6.00×10^{-7}[f]	--	--
Chromium (VI)	0.1[g]	0.1[g]	400	A	5.00×10^{-3}	--	--	4.10×10^{1}[f]
Lead	0.05[h]	0	--	B2	--	--	--	--
Mercury	0.002	0.002	20	D	3.00×10^{-4}	9.00×10^{-5}[f]	--	--
Selenium	0.05	0.05	--	D	5.00×10^{-3}	--	--	--
Silver	0.1[i]	--	200	D	5.00×10^{-3}	--	--	--
Radionuclides								
Radium-226/-228	5 pCi/L[j]	0 pCi/L	5 pCi/g[k,l]	A	--	--	6.60×10^{-10}[m,n]	4.00×10^{-9}[k]
Gross Alpha	15 pCi/L	--	--	--	--	--	--	--
Beta	4 mrems/yr	--	--	--	--	--	--	--

Table 5-4

(Page 2 of 2)

Chemical	Groundwater		Soil		Reference Dose (d) (mg/kg/day)		Carcinogenic Slope Factor[d] 1/(mg/kg/day)	
	MCL[a] (mg/L)	MCLG[a] (mg/L)	RFI Action Levels[b] (mg/kg)	Class[c]	Oral	Inhalation	Oral	Inhalation
Organic Chemicals[o,p]								
TPH	--	--	--	--	--	--	--	--
Benzene	0.005	--	--	A	--	--	2.90×10^{-2}	--
Toluene	1	1	20,000	D	2.00×10^{-1}	2.00×10^{0}	--	--
Xylenes (total)	10	10	200,000	D	2.00×10^{0}	9.00×10^{-2}[f]	--	--

[a]U.S. Environmental Protection Agency, 1992, National Primary Drinking Water Regulations, 40 CFR 141, July 1, 1992.
[b]U.S. Environmental Protection Agency, 1990, Corrective Action for Solid Waste Management Units at Hazardous Waste Management Facilities; Proposed Rule, Federal Register, July 27, 1990, pages 30798-30884.
[c]A, B, and C represent class A, B, and C carcinogens, respectively. D represents a systematic toxicant.
[d]IRIS (Integrated Risk Information System) On Line - U.S. Environmental Protection Agency.
[e]Calculated from the Drinking Water Unit Risk Level reported in IRIS (0.00005 1/µg/L).
[f]Halliburton NUS, 1992, Crutcho and Kufman Creeks and Tributaries of Elm Creek Final Remedial Investigation Report: Volume 1, Table 6-1, October 1992.
[g]Values are for total chromium.
[h]U.S. Environmental Protection Agency, 1991, Maximum Contaminant Level Goals and National Primary Drinking Water Regulations for Lead and Copper; Final Rule, 56 Federal Register 110, June 7, 1991, pages 26460-26564.
[i]Secondary Level (nonenforceable).
[j]The new proposed MCL for radium-226/-228 is 20 pCi/L.
[k]5 pCi/g averaged over the first 15 cm of soil below land surface; 15 pCi/g averaged over 15-cm-thick layers of soil more than 15 cm below the surface.
[l]U.S. Environmental Protection Agency, 1992, EPA Standards for Protection Against Uranium Mill Tailings, 40 CFR 192, July 1, 1992.
[m]Lifetime cancer risk per unit uptake (l/[pCi]); values are for radium-226 including daughter products.
[n]The ground external radiation slope factor for radium-226 (including daughter products) is 6.00×10^{-6} 1/yr per (pCi/g) expressed as the cancer risk per annum based on concentration.
[o]In addition to the standards provided here, the Oklahoma Resources Board has adopted General Numeric Criteria for benzene (0.2 µg/L), toluene (0.5 (µg/L), and xylenes (µg/L), which are used as indicators of groundwater contamination for the purpose of requiring corrective action.
[p]Oklahoma Water Quality Standards, 1988, Oklahoma Water Resources Board Authority 83 O.S, Supplement 1988 Sections 926.3, 926.6, and 1085.2 adopted by Oklahoma Water Resources Board, February 14, 1989.

Table 5-5

Radiological Sample Results for Groundwater Downgradient of SWMU-20, RWDS 201S Tinker AFB

	2-27	2-29A	2-29B
Gross Alpha (pCi/L)	9.5 ± 3.2	2.7 ± 1.1	6.4 ± 2.1
Gross Beta (pCi/L)	8.1 ± 4.7	9.7 ± 2.2	3.4 ± 2.2
Radium-226 (pCi/L)	0.46 ± 0.25	0.3 ± 0.24	2.32 ± 0.58

Another high count area is present in the northern portion of the narrow strip of soil between the wall of Building 201 bordering the east side of the site and the eastern leg of the concrete pad. The maximum level measured in this locality was 7,100 cpm. Several core holes were drilled along the concrete pad to check for contamination below it. None of these holes contained elevated readings.

The area containing the highest count rates (greater than 3,000 cpm) covers about 560 square feet (ft^2) (52 square meters [m^2]) on the gridded plot made during the survey. The 60 m^2 source area defined for RESRAD modeling was based on this area.

RCRA Metals Results for Soils and Groundwater. No unusually high concentrations of RCRA metals were detected in any of the soil samples. As depicted in Table 5-6, for soils with EPA Action Levels, none of the soils exceeded those levels. Elevated barium concentrations are not unusual for these types of soils, which are derived from Permian Redbed formations. It is unlikely that barium at the site is above background.

Unlike the soil, however, all eight RCRA metals are present in the USZ of the groundwater at levels which exceed their MCLs. The analysis was performed on filtered samples from open boreholes. Table 5-7 presents the results of this analysis. Given the low concentrations of RCRA metals in soil, these elevated values are not likely to be originating from on site. These concentrations are thought to be typical for groundwater in the industrial portions of Tinker AFB.

Organic Constituents in Groundwater. Both the USZ and LSZ exhibit signs of contamination (Table 5-8). Chlorinated organic compounds were detected in the samples collected from the USZ wells 2-27B and 2-29B. The sample from well 2-27B contained detectable amounts of chlorobenzene (21 µg/L), trichloroethene (12 µg/L), vinyl chloride (490 µg/L), and cis-1,2-dichloroethene (190 µg/L) for a chlorinated organic compound total of 713 µg/L. The sample from well 2-29B also contained detectable amounts of chlorobenzene (58 µg/L), vinyl chloride (310 µg/L), and cis-1,2-dichloroethene (9 µg/L). The chlorinated organic compound total for this sample was 377 µg/L.

A sample collected from well 2-29A completed in the LSZ contained three chlorinated organic hydrocarbons at significant concentrations. These compounds included: chlorobenzene, trichloroethene, and vinyl chloride at 40 µg/L, 93 µg/L, and 7.5 µg/L, respectively.

Table 5-6

RCRA Metal in Soil[a]
(mg/kg)
SWMU-20, RWDS 201S, Tinker AFB

Location	Depth Interval (ft)	Arsenic	Barium[+]	Cadmium	Chromium	Lead	Mercury	Selenium	Silver
201S-B01	0-1	<2.52	0.44[•]	<0.14	<0.30	<2.07	0.16	<3.70	<0.59
	6-7	7.27	196[•]	<0.12	19	11.5	0.04	<2.91	<0.46
201S-B02	3-4	9.45	128	0.14	23.9	12.3	0.05	<2.95	<0.40
	10	4.49	27.9	<0.12	14.1	7.38	0.03	<2.62	<0.36
	12	<1.58	10.3	0.14	3.62	<1.85	0.03	<2.91	<0.40
201S-B03	1.2	7.73	188	<0.,12	21.3	12.9	0.05	2.76	<0.36
	7-10	10.6	322	<0.12	23.2	12.2	0.04	<2.71	<0.37
	12.3	4.23	59.4	0.16	9.94	2.52	0.06	<2.63	<0.36
201S-B04	5	12.7	156	<0.13	28.1	13.8	0.06	<2.92	<0.40
	10	<1.44	425	<0.12	11.9	5.88	0.03	<2.64	<0.36
	11-12	2.34	12.2	0.16	6.59	<1.68	0.03	<2.64	<0.36
201S-B05	2-3	8.91	148	<0.12	18.8	9.89	0.04	<2.64	<0.36
	8-10	<1.44	15.6	<0.12	8.09	<1.68	0.03	<2.64	<0.36
	12	8.83	2160	<0.12	18.4	10.2	0.04	<2.62	<0.36
201S-B06	0-2	9.88	266[•]	2.53	29.6	77.6	0.36	<3.52	<0.56
	8-9.5	11.7	1320[•]	<0.12	19.9	23.9	0.05	<3.00	<0.48
	12	2	582[•]	<0.12	8.73	3.91	0.03	<2.92	<0.46
SS Rinsate	--	<1.69	0.35[•]	<0.10	<0.20	<1.39	0.05	<2.48	<0.40
RFI Action Level[b]	--	80	NA	40	400	NA	20	NA	200

[a]Analysis for EcoTek LSI; ICP/CVAA (SE-846, Method 6010).
[b]EPA, 1990, Corrective Action for Solid Waste Management Units at Hazardous Waste Management Facilities; Proposed Rule, Federal Register, July 27, 1990, Pages 30798-30884.
[+]The duplicate analysis not within control limits.
[•]The matrix spike sample recovery was outside of control limits.

Table 5-7

RCRA Metal in Groundwater[a]
(mg/L)
SWMU-20, RWDS 201S, Tinker AFB

Analyte	201S-B02	201S-B03	201S-B04	201S-B05	MCL[b]
Arsenic	80.2	41.1	50.7	106	0.05
Barium	6970	4880	4300	4530	2.0
Cadmium	1.7	1.83	2.52	5.54	0.005
Chromium	566	415	163	414	0.1
Lead	266	173	43	157	0.05
Mercury*	0.22	0.18	0.22	0.31	0.02
Selenium*	<22.0	<22.0	<22.0	27.2	0.05
Silver	<3.00	6.07	7.33	4.65	0.05

[a]Analysis by EcoTek LSI; ICP/CVAA (SW-846, Methods 7470, 7471) on filtered samples from open borehole.
[b]EPA, 1992, National Primary Drinking Water Regulations, 40 CFR 141, July 1, 1992.
*The matrix spike sample recovery was outside of control limit.

Table 5-8

Organic Constituents in Groundwater
SWMU-20, RWDS 201S, Tinker AFB

	USZ		LSZ
Well ID: Sample ID:	2-27B A2048	2-29B A2062	2-29A A2057
Parameters (μg/L)			
1,2-Dichlorobenzene	3.5 J	3.7 J	2.8 J
1,4-Dichlorobenzene	ND[a]	3.7 J	ND
Chlorobenzene	21	58	40
Ethyl benzene	2.6 J	ND	ND
Trichloroethene	12	ND	93
Vinyl chloride	490 D	310 D	7.5 J
bis(2-ethylhexyl)phthalate	ND	ND	1.5 J
cis-1,2-dichloroethene	190	9.0	ND

[a]ND - Not detected.
J - Concentration is an estimated value.
D - Compound identified at a secondary dilution factor.

Geotechnical Results on Soil. In addition to the intrusive sampling for chemical and radiologic analysis, geotechnical sampling and analysis was also conducted as a part of the intrusive survey. This was performed to provide site-specific input to the U.S. Department of Energy's Residual Radioactive Materials (RESRAD) modeling. Sampling for geotechnical analysis consisted of collecting one undisturbed Shelby tube soil sample at locations immediately adjacent to each of four borings: 201S-02, -03, -04, and -06. The Shelby tubes were used to sample soil at depths ranging from 3 to 7 feet below ground surface so that the entire soil horizon was adequately evaluated. Table 5-9 summarizes the results of these analyses. The most relevant and useful results from this effort are quantification of grain size distribution of the soil, and the direct evaluation of soil permeability. Overall, laboratory results showed that soil underlying RWDS 201S is homogeneous. Grainsize distribution in the soil averaged 11 percent sand, 54 percent silt, and 35 percent clay (per American Association of State Highway Officials [AASHO] system). Matrix permeabilities ranged from 1.2×10^{-7} to 1.3×10^{-8} cm/s, and averaged 4.0×10^{-8} cm/s, based on constant head permeability tests.

Table 5-9

Geotechnical Analysis on Soil[a]
SWMU-20, RWDS 201S, Tinker AFB

					Atterberg Limit						
Location	Depth Interval (ft)	Natural Moisture Content (%)	Unit Dry Weight (pcf)	pH	Liquid (%)	Plastic (%)	Loss on Ignition (%)	Specific Gravity	Porosity	Resistivity (cm/ohms)	Permeability (cm/s)
201S-B02	4-6	23	101	7.45	57	18	3.4	2.47	0.37	1450	1.3×10^{-8}
201S-B03	5-7	25	98	7.01	47	18	4.3	2.52	0.38	3250	1.2×10^{-7}
201S-B04	5-7	18	109	7.07	71	21	4.5	2.49	0.28	1060	1.6×10^{-8}
201S-B06	3-5	19	104	6.80	58	16	4.9	2.48	0.36	2050	1.4×10^{-8}

[a]Analysis by BBC&M Engineering, Inc., Dublin, Ohio (July, 1992). Tests performed on Shelby tube samples; methods per ASTM.

6.0 Baseline Risk Assessment/Potential Receptors

A human health risk assessment (Battelle, 1994) has been performed for RWDS 201S. This risk assessment, which includes an evaluation of human receptors, is summarized in Section 6.1. A specific ecological search has not been performed for this site. Section 6.2 describes the data available to begin identification of potential ecological receptors.

6.1 Human Health Risk Assessment

An intrusive survey was performed on the site and the results of that survey were used to conduct a risk assessment evaluating the threat to human health caused by the presence of radium waste. The intrusive survey failed to confirm the presence of any radioactively-contaminated soil, waste materials, or groundwater in the subsurface. However, a gamma-ray survey of surficial soil, a limited amount of surficial sampling, and gamma logging of soil cores and hand-augered holes indicated that surficial contamination may exist at the site (Battelle, 1994).

Analysis by Armstrong Laboratory of surficial soil samples collected by Battelle during the investigation measured a concentration of 45.5 pCi/g Ra-226. That result was assumed to be a conservative indication of the source concentration. The surficial gamma-ray survey delineated a potential contaminant source area of 60 m^2 at the site. Hand augering within this area implied that contamination extends no more than 0.25 meters below ground surface. This information was used with the U.S. Department of Energy's RESRAD code to perform pathway analysis and risk assessment over a 1,000-year period, and to determine dose restricting levels for soil cleanup. During modeling, cleanup standards were determined that assured that the maximum dose of 25 millirems per year (mrem/yr), as set by the USAF Radioisotope Committee, was not exceeded.

Output from RESRAD indicates that the existing source causes a maximum dose of 190 mrem/yr (equivalent to an incremental lifetime cancer risk [ILCR] of 2.18×10^{-3}, which occurs at time zero (time of the investigation). Pathways evaluated include external radiation from surface soil, inhalation of airborne Ra-226 from soil dust, ingestion of foods (vegetables and livestock) raised on contaminated soil, and ingestion of groundwater (drinking water contaminated by leaching). The primary pathway is direct external exposure to humans living on site (the model assumes a resident family farm scenario). The dose drops as time progresses and reaches about 11 mrem/yr after 300 years. This reduction in dose is primarily due to removal of much of the source by erosion (assuming a 0.0005 meters per hour (m/hr)

erosion rate). However, after 1,000 years, leaching radium breaks through into the saturated zone, elevating the total dose to 40 mrem/yr (ILCR = 1.175 x 10^4). Soil removal or dilution must lower the soil concentration to 8 pCi/g to assure that dose does not exceed the 25 mrem/yr limit. EPA radium regulations are 5 pCi/g for surfical soil contamination (0 to 15 cm below ground surface). If sufficient radium-contaminated soil is removed from the site to reach this EPA level, the total dose will drop below 25 mrem/yr, meeting the USAF Radioisotope Committee dose standard.

It was recommended in the report that, prior to developing and implementing any remedial strategy, radium distribution in surficial soils be better determined by surveying with an alpha-sensitive detector and by doing more laboratory analysis of surficial soil. The report also recommended that a radon survey should be conducted to further support the interpretation that no radium is buried at the site. These types of further characterization could confirm that much less contamination is present than was initially suspected or assumed for risk modeling purposes (Battelle, 1994).

6.2 Ecological Receptors

Tinker AFB lies within a grassland ecosystem, which is typically composed of grasses, forbes, and riparian (i.e., trees, shrubs, and vines associated with water courses) vegetation. This ecosystem has generally experienced fragmentation and disturbances as result of urbanization and industrialization at and near the Base. While no threatened or endangered plant species occur on the Base, the Oklahoma penstemon (*Penstemon oklahomensis*), identified as a rare plant under the Oklahoma Natural Heritage Inventory Program, thrives in several locations on Base. Tinker AFB policy considers rare species as if they were threatened or endangered and provides the same level of protection for these species.

In general, wildlife on the Base is typically tolerant of human activities and urban environments. No federal threatened or endangered species have been reported at the Base. However, one specie found on the Base, the Texas horned lizard (*Phrynosoma cornutum*), is a Federal Category 2 candidate specie and under review for consideration to be listed as threatened or endangered. Air Force policy (AFR 126-1) considers candidate species as threatened or endangered and provides the same level of protection.

The Oklahoma Department of Wildlife Conservation also lists several species within the state as Species of Special Concern. Information on these species suggests declining populations but information is inadequate to support listing, and additional monitoring of populations is

needed to determine the species status. These species also receive protection by Tinker AFB as threatened or endangered species. Of these species, the Swainson's hawk (*Buteo swainsoni*) and the burrowing owl (*Athene cunicularia*) have been sighted on Tinker AFB. The Swainson hawk, a summer visitor and prairie/meadow inhabitant, has been encountered Basewide. The burrowing owl has been known to inhabit the Air Field at the Base.

7.0 Action Levels

An "action level" is defined by EPA in proposed rule 40 CFR 264.521 (55 FR 30798; 7/27/90), "Corrective Action for Solid Waste Management Units (SWMU) at Hazardous Waste Management Facilities," as a health- and environment-based level, determined by EPA to be an indicator for protection of human health and the environment. In the preamble to this proposed rule, the focus of the RFI phase is defined as "characterizing the actual environmental problems at the facilities." As part of this characterization, a comparison of the contaminant concentrations to certain action levels should be made to determine if a significant release of hazardous constituents has occurred. This comparison is then used to determine if further action or corrective measures are required for a SWMU or an AOC. The preamble to the proposed rule states that the concept of action levels was introduced because of the need for "a trigger that will indicate the need for a Corrective Measures Study (CMS) and below which a CMS would not ordinarily be required" (55 FR 30798; 7/27/90). If constituent concentrations exceed certain action levels at a SWMU or an AOC, further action or a CMS may be warranted; if constituent concentrations are below action levels, a finding of no further action may be warranted. This chapter of the report presents the initial analytical data as compared to certain potential action levels.

Action levels are concentrations of contaminants at or below which exposure to humans or the environment should not produce acute or chronic effects.

The action level information is presented in this chapter so that a constituent concentration at a sample location can be compared with its potential action level. Only constituents identified in the analysis are listed in the SWMU-20, RWDS 201S table. Table 7-1 shows the action levels for soil, water, and air as published in federal or state regulations, policies, guidance documents, or proposed rules.

The action levels listed in Table 7-1 are:

- ***SWMU Corrective Action Levels (CAL)*** - The first set of action levels provided in the table are those taken from the proposed rule (40 CFR 264.521) and provided as Appendix A to the rule as "Examples of Concentrations Meeting Criteria for Action Levels." These levels are health-risk based and are provided

Table 7-1

Action Levels
SWMU-20, RWDS 201S, Tinker AFB

Parameters	SWMU CAL[a]			MCL[b]
	Soil (mg/kg)	Water (mg/L)	Air (ug/m^3)	Water (mg/L)
Organics				
Acetone	8000	4.0		
Carbon Tetrachloride	5.0	0.0003	0.03	0.005
Methyl Ethyl Ketone	4000	2.0	300	
Methylene Chloride	90	0.005	0.3	0.005
Radiometrics				
Gross Alpha				15 pCi/L
Radium-226/Radium-228				20 pCi/L
Radon				300 pCi/L

[a]CAL - Corrective Action Levels
[b]MCL - Maximum Contaminant Levels

as specific examples of levels below which corrective action would not be required.

- ***Maximum Contaminant Levels (MCL)*** - These values are provided from 40 CFR Subpart G, Sections 141.60 through 0.63 as promulgated under the Safe Drinking Water Act. These levels are designated for water media only.

- ***USGS Background*** - These values are provided from the USGS report titled "Elemental Composition of Surficial Materials from Central Oklahoma" (USGS, 1991). These values represent the levels of metals which naturally occur in Central Oklahoma soils.

- ***Background*** - These levels are provided where background could be determined. Where available, background concentrations are listed for metals in soil samples taken on site, which were thought to be unaffected by releases from a unit.

- ***National Ambient Air Quality Standards (NAAQS)*** - These standards are published in 40 CFR Part 50 under the Clean Air Act and apply to point sources that emit a limited number of constituents to the air. The constituents regulated are nitrogen dioxide, sulphur dioxide, carbon monoxide, lead, ozone, and particulate matter. Currently, it is assumed that none of the SWMUs or AOCs emit these compounds in regulated quantities and no air samples have been taken which would allow for a valid comparison.

- ***Water Quality Standards (WQS)*** - The WQS are the standards for surface water quality as established by the State of Oklahoma. These standards apply to point source discharges to surface waters and have been listed for those units adjacent to surface water.

Table 7-1 also gives a brief comparative evaluation of the data collected and the related action levels. The data for each detected compound are compared with the appropriate action level in order to identify those constituents (compounds) with concentrations exceeding the action levels. This identification of the compounds above the action levels provides an indication of a potential environmental problem at a specific site. In addition, this information indicates whether there is a need for conducting a CMS so that a corrective action can be implemented/undertaken at the site.

For constituents that have a SWMU CAL and an MCL for water, the MCL will be used for the comparison. Also, constituents that do not have a USGS background value will be compared to the site background value if available.

The data included in Table 7-1 are representative of the data presented in Chapter 5.0. For each soil boring, a range was identified and used in the comparison to the action levels.

Evaluation of the soil data for RWDS 201S shows a detection of lead in the composite soil sample. This detection is below the USGS background concentration. No groundwater samples were taken at the RWDS 201S site.

Evaluation of the soil data for RWDS-201S shows none of the constituents detected exceed the action levels or background values for soil. Several inorganic constituents exceeded MCLs in the groundwater. These constituents are arsenic, barium, cadmium, chromium, lead, and mercury. Gross alpha was also detected above MCLs in the groundwater.

8.0 Summary and Conclusions

RWDS 201S is located in the north end of the south alcove in Building 201. Interviews and records searches indicated that approximately 10 yd^3 of radium-bearing waste composed of radium-painted dials and radium paint solids may be disposed of in RWDS 201S. However, the intrusive survey portion of this study generated the following significant results.

- Although interviews, records searches, and geophysical surveys led previous researchers to conclude that there are likely to be significant inventories of radium-contaminated wastes buried on site, no signs of subsurface contamination were detected by Battelle at the locations identified in risk assessment (Battelle, 1994). It is possible that the interviewed personnel were mistaken about the site's history. Subsurface geophysical surveys are generally not very accurate in clay-rich soils like those present at this site. At this time, it is uncertain if buried wastes are truly present; however, subsurface data that have been collected appear to indicate that no waste is present.

- There are areas of elevated gamma activity on the site's surface. Results from two soil samples indicate that these hot spots contain radium. Vertical surveying or profiling of the hot spots indicates that contamination only extends 6 to 8 inches below ground surface.

- A review of regulatory guidelines for radium concentrations in soils done during this study indicates that EPA requires near-surface radium concentrations to be less than 5 pCi/g. RESRAD modeling shows that if the site is cleaned up to 5 pCi/g, doses to humans that might live on this land some time after closure would not exceed the USAF Radioisotope Committee 25 mrem/yr limit.

9.0 Recommendations

This RFI Summary Report was prepared to determine and document whether sufficient investigations at RWDS 201S have been performed to meet the permit requirements. Review of available documents and evaluation of data reported in this report indicate that the main focus of previous investigations at this site have involved mainly the analysis of radioactive constituents. However, hazardous waste constituents have not been addressed. Also, based on the documents reviewed, data collected at this site are limited. Additional investigations are necessary to confirm the presence or absence of hazardous waste constituents at the site. In addition, the nature and extent of contamination, if any, should be determined.

In view of these deficiencies, several additional investigations are recommended during the Phase II RFI. Specific sampling needs to meet the objectives of the additional investigations will be presented in the work plan and sampling plan for the Phase II RFI. At a minimum, the following recommendations should be implemented:

- Obtain soil samples for VOC and SVOC analyses.
- Obtain groundwater samples for VOC and SVOC analyses.

In addition, to fully evaluate the extent of soil contamination at this site it is recommended that site-specific soil background samples be collected during the Phase II RFI. This additional information along with the USGS background values should be used in the Phase II report to distinguish site-related from background concentrations in a statistically significant manner. During the development of the Phase II RFI work plan, the number of background samples to be collected, the location of the soil borings, and the soil analysis to be performed on the samples should be determined for EPA approval.

10.0 References

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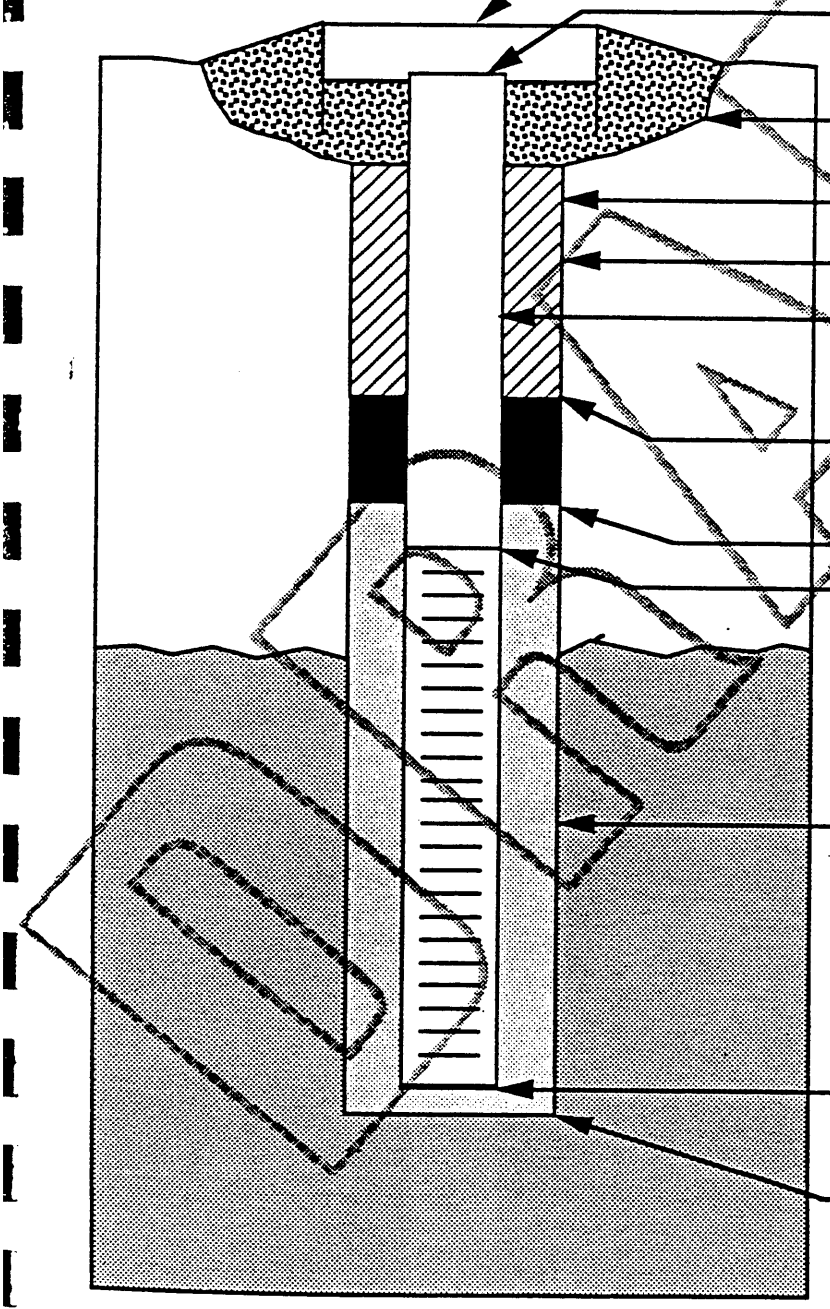
APPENDIX A
SOIL BORING DIAGRAMS

PIEZOMETER COMPLETION DIAGRAM

Project	Intrusive Survey	Location	RWDS 20S	Driller	PSI, Inc.
Project No.	G986138	Boring	20S-MW2	Drilling Method	HSA
Elevation		Date	6/3/92	Development Method	hand bailed



Elevation of Flush Mount: _____

Elevation of Riser Top: _____

Type of Surface Seal: Cement (RediMix)

Type of Backfill: Grout w/ 4% Bentonite

Diameter of Hole: 6.5 inches

Riser Pipe I.D.: 2.0 inches

Type of Riser Pipe: PVC

Elevation/Depth Top of Seal: 1.0 ft.

Type of Seal: Bentonite pellets

Elevation/Depth Top of Sand: 3.0 ft.

Elevation/Depth Top of Screen: 4.8 ft.

Type of Screen: 10 slot PVC

Slot Size x Length: 10 slots/inch 0.01 in

I.D. Screen: 2.0 ft. inch

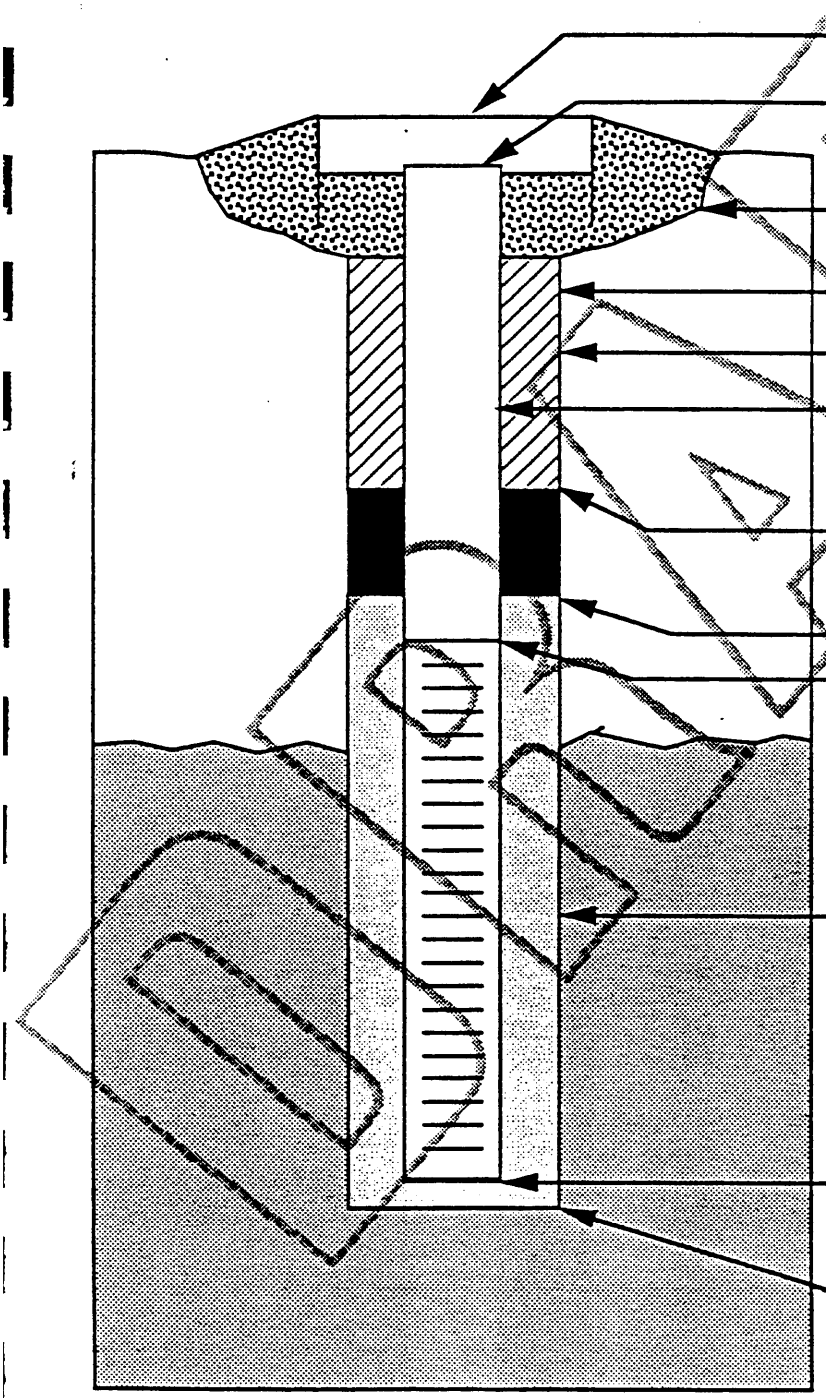
Type of Sand Pack: 10/20 silica (CSSI)

Elevation/Depth Bottom of Screen: 14.8 ft.

Elevation/Depth Bottom of Hole: 15.0 ft.

PIEZOMETER COMPLETION DIAGRAM

Project	Intrusive Survey	Location	RWDS 2015	Driller	PSI, Inc.
Project No.	G986138	Boring	2015-MW3	Drilling Method	HSA
Elevation		Date	6/3/92	Development Method	bailed



Elevation of Flush Mount: _____

Elevation of Riser Top: _____

Type of Surface Seal: Cement (RediMix)

Type of Backfill: Grout w/ 5% Bentonite

Diameter of Hole: 6.5 inches

Riser Pipe I.D.: 2.0 inches

Type of Riser Pipe: PVC

Elevation/Depth Top of Seal: 1.0 ft.

Type of Seal: Bentonite pellets

Elevation/Depth Top of Sand: 3.0 ft.

Elevation/Depth Top of Screen: 4.7 ft.

Type of Screen: PVC

Slot Size x Length: 10 slots/in. ; 0.01 in.

I.D. Screen: 2.0 inches

Type of Sand Pack: 10/20 silica (CSSI)

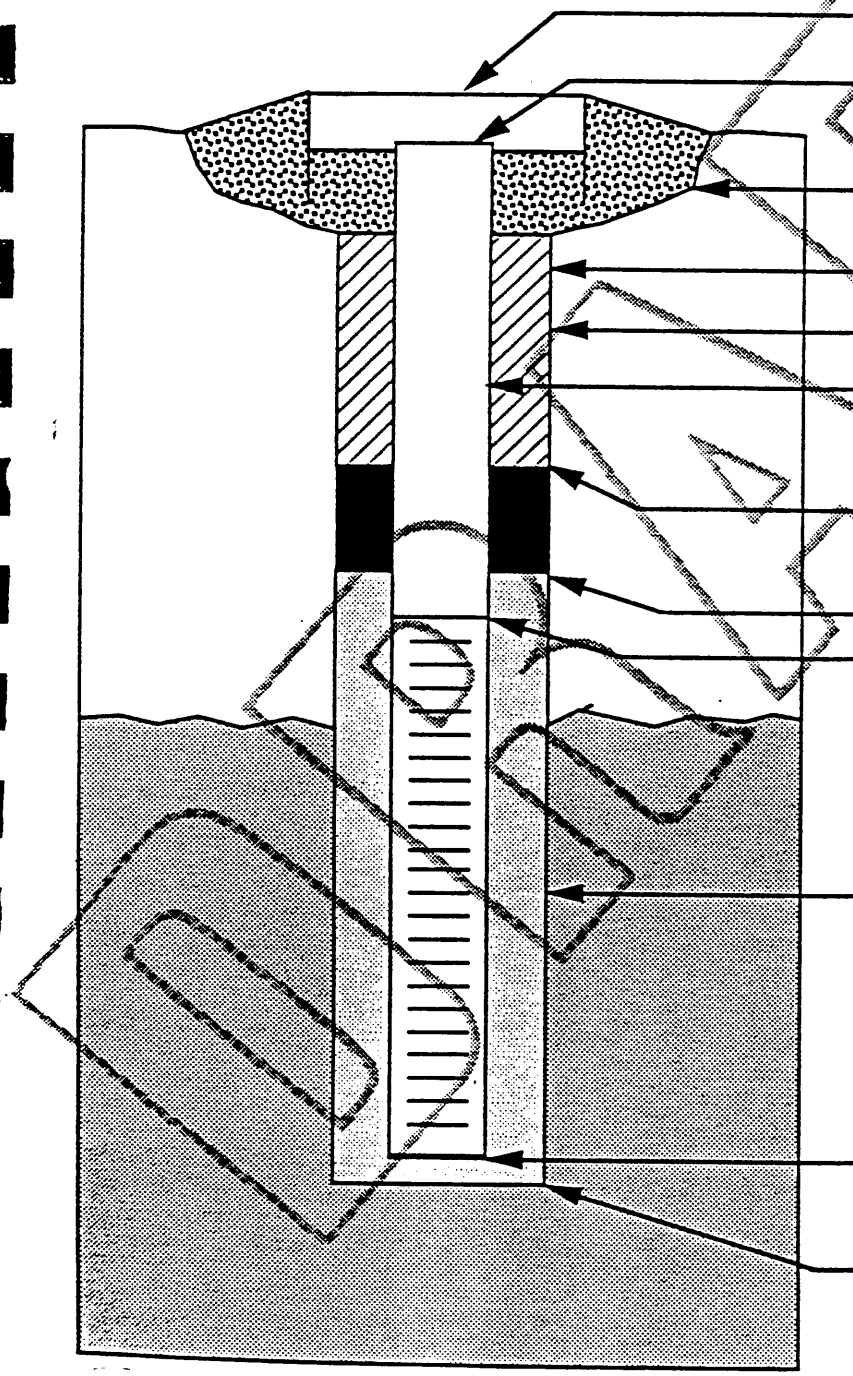
Elevation/Depth Bottom of Screen: 14.7 ft.

Elevation/Depth Bottom of Hole: 14.9 ft.

ATTACHMENT #11

PIEZOMETER COMPLETION DIAGRAM

Project: Intrusive Survey
Location: RWDS 2015
Driller: PSI, Inc.
Project No.: G986138
Boring: 2015-MW5
Drilling Method: HSA
Elevation: _____
Date: 6/3/92
Development Method: hand bailed



Elevation of Flush Mount: _____
Elevation of Riser Top: _____
Type of Surface Seal: Cement (RediMix)
Type of Backfill: Grout w/ 4% Bentonite
Diameter of Hole: 6.5 inches
Riser Pipe I.D.: 2.0 inches
Type of Riser Pipe: PVC
Elevation/Depth Top of Seal: 1.0 ft.
Type of Seal: Bentonite pellets
Elevation/Depth Top of Sand: 2.0 ft.
Elevation/Depth Top of Screen: 2.5 ft.
Type of Screen: PVC
Slot Size x Length: 10 slots/in.; 0.01 in.
I.D. Screen: 2.0 inches
Type of Sand Pack: 10/20 silica (CSSI)
Elevation/Depth Bottom of Screen: 12.5 ft.
Elevation/Depth Bottom of Hole: 12.6 ft.

Final Report
Phase I RCRA Facility Investigation for Appendix I Sites
VOLUME IX

SWMU-21, Radioactive Waste Disposal Site 62598

Department of the Air Force
Oklahoma City Air Logistics Center
Tinker Air Force Base, Oklahoma

September 1994

Table of Contents - RFI Summary Report

Table of Contents *(Continued)*

List of Tables

List of Figures

List of Acronyms

AFB	Air Force Base
AOC	area of concern
CAL	Corrective Action Levels
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CDM	CDM Federal Programs Corporation
CFR	Code of Federal Regulations
CMS	Corrective Measures Study
cm/s	centimeters per second
DERP	Defense Environmental Restoration Program
DOD	U.S. Department of Defense
EID	Engineering Installation Division
EM	electromagnetic
EPA	U.S. Environmental Protection Agency
ES	Engineering Science
ft/ft	foot per foot
GPR	ground penetrating radar
HSWA	Hazardous and Solid Waste Amendment
IRP	Installation Restoration Program
LSZ	lower saturated zone
µR/hr	microroentgen per hour
MCL	maximum concentration level
MHz	megahertz
msl	mean sea level
NAAQS	National Ambient Air Quality Standards
NCP	National Oil and Hazardous Substances Contingency Pollution Act
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
PA/SI	preliminary assessment/site investigation
RCRA	Resource Conservation and Recovery Act
RI/FS	remedial investigation/feasibility study
RFI	RCRA Facility Investigation
ROD	Record of Decision
RWDS	radioactive waste disposal site
SARA	Superfund Amendments and Reauthorization Act

List of Acronyms *(Continued)*

SWMU	solid waste management unit
TSD	treatment, storage, and disposal (facility)
USACE	U.S. Army Corps of Engineers
USC	U.S. Code
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USZ	upper saturated zone
UWBZ	upper water bering zone
WQS	Water Quality Standards
yd^3	cubic yards

Executive Summary

This report provides a summary of the various investigations that have been conducted at the Solid Waste Management Unit (SWMU)-21 Radioactive Waste Disposal Site 62598 (RWDS 62598), Tinker Air Force Base (AFB), Oklahoma. The report has been prepared to determine and document whether sufficient investigations at RWDS 62598 have been performed to meet regulatory requirements. Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County. The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. The Base encompasses 5,000 acres.

Background. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon™, jet fuels, and radium paints.

In 1984, Congress amended the Resource Conservation and Recovery Act (RCRA) with the Hazardous and Solid Waste Amendments (HSWA), which allow the Environmental Protection Agency (EPA) to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989, Tinker AFB submitted its Part B permit application for renewal of its operating RCRA Hazardous Waste Storage facility permit. The final RCRA HSWA permit issued on July 1, 1991, requires Tinker AFB to investigate all SWMUs and areas of concern (AOC) and to perform corrective action at those identified as posing a threat to human health of the environment. The permit specifies that a RCRA Facility Investigation (RFI) be conducted for 43 identified SWMUs and two AOCs on the Base. This document has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for RWDS 62598.

Source Description. RWDS 62598 is located north of Crutcho Creek, east of Landfill No. 3 (SWMU-5), and west of Reserve Road. This site reportedly contained a lead distillation unit (still) with radium paint solids; however, there was a nonconfirmed report that the still may have been removed from this site and shipped off site. Before the removal action, this site was marked with a concrete monument and a radiation warning sign. The original

marker was destroyed and the current monument was installed in 1972 at the approximate location of the original marker.

Site Investigations

NonIntrusive Survey Results. The investigation of RWDS 62598 included several nonintrusive survey techniques in an attempt to characterize the extent of contamination present at this site. For the radiation surveys, an 80 feet by 80 feet area, centered on the concrete monument, was divided into a 2.5- by 2.5-foot grid system within 10 feet of the monument, and expanded to 5-foot by 5-foot grids for the remainder of the area. Background gamma radiation exposure level in the site vicinity ranged from 7.0 microroentgen per hour (μR/hr) to 8.0 μR/hr. The site's gamma radiation exposure level was equal to or below the general background level. No elevated gamma radiation exposure level were detected on the ground surface at RWDS 62598.

The ground penetrating radar (GPR) survey of this site was impeded by soil piles scattered across the site. These piles altered and limited the direction of scan paths emitted by the GPR antenna. However, one anomaly was detected approximately two feet southeast of the concrete monument. The anomaly exhibited the characteristics of a burial pit, 1 to 6 feet deep.

A total magnetic field gradiometer survey revealed one significant magnetic anomaly. The location of this anomaly correlated with the anomaly detected during the GPR survey, and exhibited the characteristics of a buried ferromagnetic object at 3 to 6 feet depth. The topographic variations and contrasting properties of the soil piles created large variation in the magnetic baseline which may have masked small magnetic anomalies.

An induced electromagnetic (EM) conductivity survey was conducted over RWDS 62598; however, no significant anomalies were detected.

Removal Action. RWDS 62598 was excavated with the objective of either finding and removing a lead still or providing additional evidence to support the report that a still had previously been removed and shipped off site. Nothing was found at the site, and following a confirmatory survey by personnel from Armstrong Laboratory, Brooks AFB, the excavation was backfilled. Analysis of soils sampled from the excavation revealed radiological and chemical test results to be sufficiently low to allow the soils to remain in situ.

One objective of the work performed at RWDS 62598 was to recover a lead still reported to be buried at the site in the 1950s. The lead still reported to be buried at the site in the 1950s was not found despite the careful exhumation of soils. Therefore, Tinker AFB conducted a records search as an additional safety precaution. An interview with the individual who built the still provided size information; it was concluded that the object was too large to have been missed during the careful exhumation of RWDS 62598. The records search was not able to conclusively verify off-site shipment. However, the records search does conclude that a shipping arrangement between Tinker AFB and Canadian Radium and Uranium Corporation in Mt. Kisco, New York, was in place at the time and that the still was most likely shipped off site for disposal or resource recovery.

Conclusions. None of the investigations at the site resulted in any significant findings. The lead still suspected to be on site was determined to be too large to have been missed during the careful excavation of RWDS 62598. Although there is no record of off-site shipment, it is likely that the still was shipped off site for resource recovery.

Recommendations. Based on the documents reviewed, there is limited data available for adequate characterization of this site. For instance, previous investigations have mainly focused on the analysis of radioactive waste constituents. No hazardous waste constituents have been addressed. Therefore, it is recommended that additional investigations be conducted during the Phase II RFI. Specific data needs to determine the nature and extent of contamination will be presented in the work plan and sampling plan developed during the Phase II RFI. At a minimum, the following recommendations should be implemented:

- Obtain soil samples for VOC, SVOC, and metals analyses.
- Collect site-specific soil background samples to be used in addition to USGS soil data to distinguish site-related from background concentrations in a statistically significant manner during the Phase II investigation.
- Obtain groundwater samples for VOC, SVOC, metals, and inorganic parameters analyses.

1.0 Introduction

1.1 Purpose and Scope

This document has been prepared in response to the U.S. Department of the Air Force, Tinker Air Force Base (AFB), Oklahoma request for a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Summary Report for solid waste management unit (SWMU)-21, Radioactive Waste Disposal Site (RWDS) 62598.

The objective of this RFI Summary Report is to provide Tinker AFB with one comprehensive report that summarizes the various investigations that have occurred at RWDS 62598 since the first environmental investigation was initiated on Base in 1981. The purpose of this comprehensive summary document is to:

- Characterize the site (Environmental Setting).
- Define the source (Source Characterization).
- Define the degree and extent of contamination (Contamination Characterization).
- Identify potential receptors.
- Identify all action levels for the protection of human health and the environment.

Additionally, this document briefly describes the procedures, methods, and results of all previous investigations (removal actions and baseline risk assessment) that relate to SWMU-21 and contaminant releases, including information on the type and extent of contamination at the site, and actual or potential receptors. Where previous investigations, reports, or studies were not comprehensive and did not furnish the information required to determine the nature and extent of contamination, future work that can be conducted to complete the investigation has been recommended.

1.2 Preface

In 1980, Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to address the cleanup of hazardous waste disposal sites across the country. CERCLA gave the president authority to require responsible parties to remediate the sites or to undertake response actions through use of a fund (the Superfund). The president, through Executive Order 12580, delegated the U.S. Environmental Protection Agency (EPA) with the responsibility to investigate and remediate private party hazardous waste disposal sites that created a threat to human health and the environment. The president delegated responsibility for investigation and cleanup of federal facility disposal sites to the various federal agency heads. The Defense Environmental Restoration Program (DERP) was formally

established by Congress in Title 10 U.S. Code (USC) 2701-2707 and 2810. DERP provides centralized management for the cleanup of U.S. Department of Defense (DOD) hazardous waste sites consistent with the provisions of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] 300), and Executive Order 12580. To support the goals of DERP, the Installation Restoration Program (IRP) was developed to identify, investigate, and clean up contamination at installations.

Under the Air Force IRP, Tinker AFB began a Phase I study similar to a preliminary assessment/site investigation (PA/SI) in 1981 (Engineering Science [ES], 1982). This study helped locate 14 sites that needed further investigation. A Phase II study was performed in 1983 (Radian Corporation [Radian], 1985a,b).

In 1986, Congress amended CERCLA through the SARA. SARA waived sovereign immunity for federal facilities. This act gave EPA authority to oversee the cleanup of federal facilities and to have the final authority for selecting the remedial action at federal facilities placed on the National Priorities List (NPL) if the EPA and the relevant federal agency cannot concur in the selection. Congress also codified DERP (SARA Section 211), establishing a fund for the DOD to remediate its sites because the Superfund is not available for the cleanup of federal facilities. DERP specifies the type of cleanup responses that the fund can be used to address.

In response to SARA, the DOD realigned its IRP to follow the investigation and cleanup stages of the EPA:

- PA/SI
- Remedial investigation/feasibility study (RI/FS)
- Record of Decision (ROD) for selection of a remedial action
- Remedial design/remedial action.

In 1984, Congress amended RCRA with the Hazardous and Solid Waste Amendments (HSWA) which allow the EPA to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989 Tinker AFB submitted its Part B permit application for renewal of its operating RCRA hazardous waste storage facility permit.

EPA, in the Hazardous Waste Management Permit for Tinker AFB, dated July 1, 1991, identified 43 SWMUs and two areas of concern (AOC) on Tinker AFB that need to be addressed. This permit requires Tinker AFB to investigate all SWMUs and AOCs and to perform corrective action at those identified as posing a threat to human health or the environment. This RFI Summary Report has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for RWDS 62598 and to document all determinations.

1.3 Facility Description

Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County (Figure 1-1) with its approximate geographic center located at 35° 25' latitude and 97° 24' longitude (U.S. Geological Survey [USGS], 1978). The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. An additional area east of the main Base is used by the Engineering Installation Division (EID) and is known as Area D. The Base encompasses approximately 5,000 acres. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon^{TM}, jet fuels, and radium paints. Wastes that are currently generated are managed at two permitted hazardous waste storage facilities. However, prior to enactment of RCRA, industrial wastes were discharged into unlined landfills and waste pits, streams, sewers, and ponds. Past releases from these landfills, pits, etc., as well as from underground tanks, have occurred. As a result, there are numerous sites of soil, groundwater, and surface water contamination on the Base.

The various reports generated as a result of investigative activities conducted at RWDS 62598 have been reviewed and evaluated in terms of the sites' status under RCRA regulations. A summary based on the review of these reports for RWDS 62598 is presented in the following chapters and sections. In addition, recommendations for additional work is given at the end of the summary report.

STARTING DATE: 03/17/94	DATE LAST REV.:	DRAFT. CHCK. BY:G. PACHECO	INITIATOR: C. WALLACE
DRAWN BY:P.O. TERRY	DRAWN BY:	ENGR. CHCK. BY: C. WALLACE	PROJ. MGR.:J. TAYLOR

DWG. NO.:

PROJ. NO.:

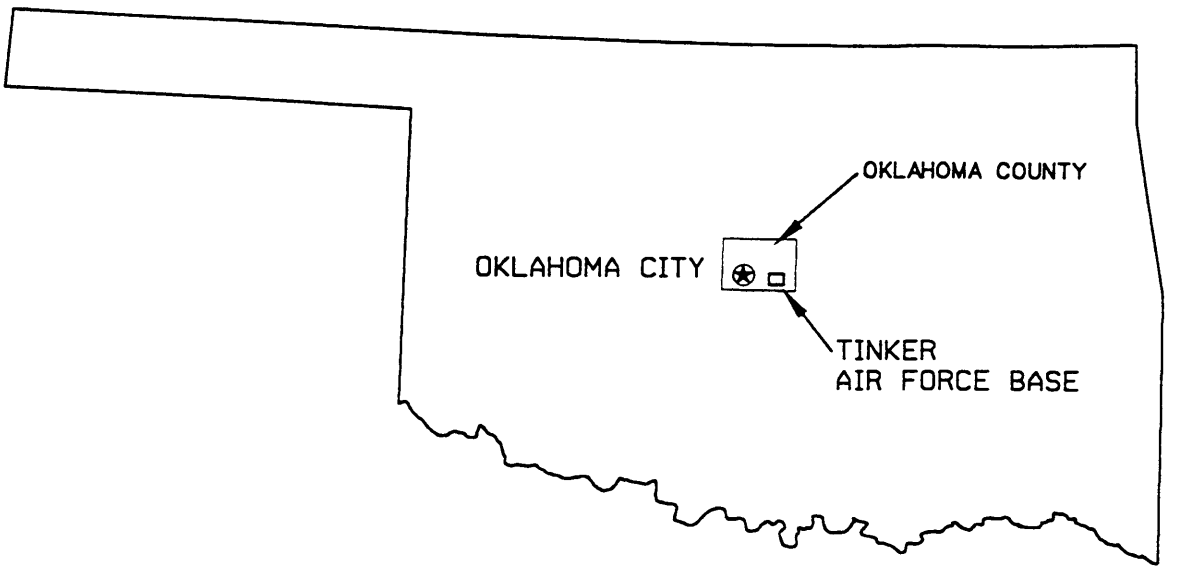


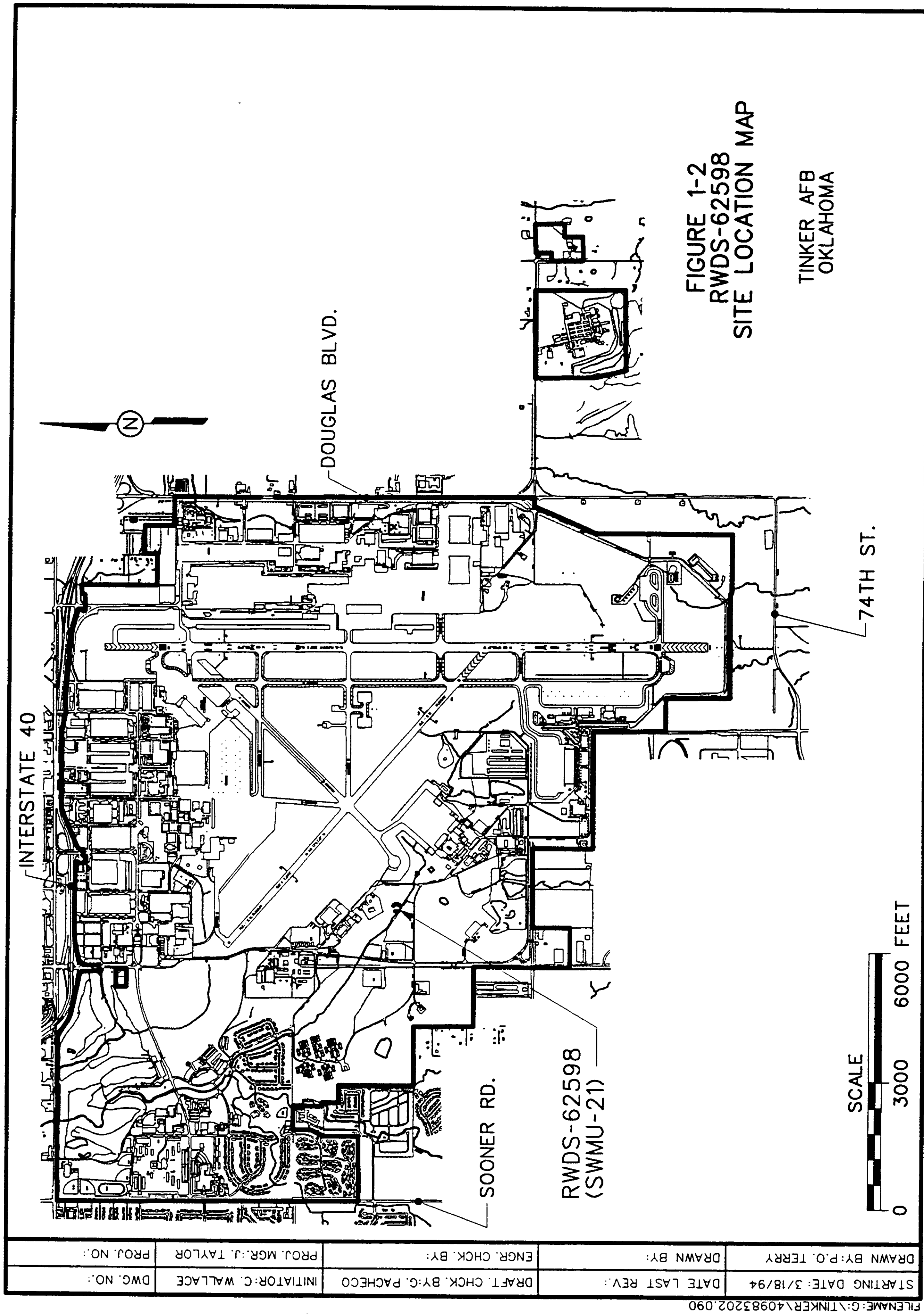
FIGURE 1-1
TINKER AIR FORCE BASE
OKLAHOMA
STATE INDEX MAP

PREPARED FOR
TINKER AFB
OKLAHOMA

3/23/94 POT
FILENAME: G:\TINKER\40983202.075

1.4 Site Description

RWDS 62598 is located north of Crutcho Creek, east of Landfill 3 (SWMU-5), and west of Reserve Road as shown on Figure 1-2. Prior to the 1991 removal action, this site was marked with a concrete monument and a radiation warning sign (CDM Federal Programs Corporation (CDM), 1992). This site reportedly contained a lead distillation unit with radium paint solids.


INTERSTATE 40
DOUGLAS BLVD.
74TH ST.
SOONER RD.
RWDS-62598
(SWMU-21)
SCALE
0
3000
6000 FEET
FIGURE 1-2
RWDS-62598
SITE LOCATION MAP
TINKER AFB
OKLAHOMA
DRAWN BY: P.O. TERRY
STARTING DATE: 3/18/94
DRAWN BY:
DATE LAST REV.:
ENGR. CHCK. BY:
DRAFT. CHCK. BY: G. PACHECO
PROJ. MGR.: J. TAYLOR
INITIATOR: C. WALLACE
PROJ. NO.:
DWG. NO.:
FILENAME: G:\TINKER\40983202.090

2.0 Background

2.1 Site Operations and History

Tinker AFB was originally known as the Midwest Air Depot and began operations in July 1941. The site was activated March 1942. During World War II, the depot was responsible for reconditioning, modifying, and modernizing aircraft, vehicles, and equipment.

Radium-coated dials were used in the instrumentation panels of planes during the 1940s and 1950s. The radium paint was stripped from the dials with acetone or methylethylketone. This resulted in a radium paint and solvent solution. Initially, this waste was sent to Canadian Radium and Uranium Corporation located in Mt. Kisco, New York.

However, this practice was discontinued in 1951 to save money. After 1952, this type of waste was processed on Base. A lead still was constructed to volatilize the solvents from the solution. This volatilization allowed the bulk of the waste to be minimized so that a new still was only expected to be required every 4 to 5 years. The still was made from a sheet of lead shaped into a tube approximately 12 to 18 inches in diameter and about 18 inches high with a bottom soldered on. When the still became radioactively "hot," a top was soldered on and the still was buried (U.S. Corps of Engineers [USACE], 1989). The term "hot" reportedly refers to unacceptable readings from a Geiger counter used to survey the still for safety (no reference has been found that indicates what constituted "unacceptable readings").

The Chief of Bioengineering at Tinker AFB from 1950 to 1956 (who was also the base Radiological Officer) confirmed the lead still was buried at the location of RWDS 62598 (Figure 2-1) in 1955. He stated that he believes this was the only still buried on Tinker AFB. He indicated that the still was buried 3 to 4 feet deep but could be as deep as 6 feet. The Phase II report by Chem-Nuclear Environmental Services (Chem-Nuclear, 1990) identified an Air Force document stating the still had been removed from this site and suggesting that a buried object does not exist at RWDS 62598. A record search conducted in 1989 did not confirm such a removal (USACE, 1989). No information has been found that describes the fate of any subsequent radium stills, if any.

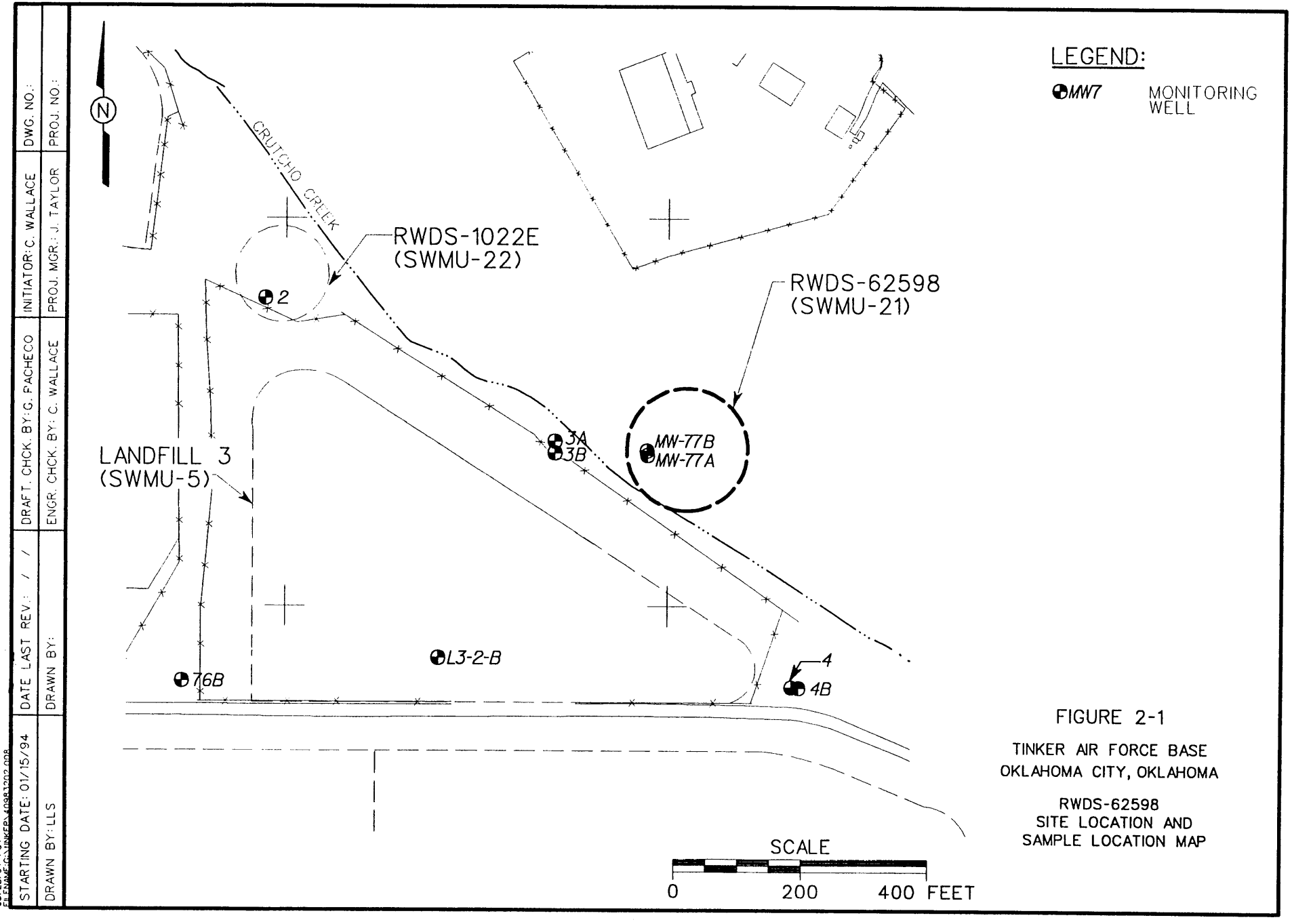


FIGURE 2-1

TINKER AIR FORCE BASE
OKLAHOMA CITY, OKLAHOMA

RWDS-62598
SITE LOCATION AND
SAMPLE LOCATION MAP

2.2 Summary of Previous Investigations

The RWDS 62598 Phase II investigations consisted of extensive surface radiological and geophysical surveys. The Air Force specifically directed that no intrusive sampling was permitted during this phase of the investigation. As a result, all surveys were designed to be nonintrusive in nature, and were restricted to activities on or above the ground surface (Chem-Nuclear, 1990).

This section explains the methodology of the RWDS 62598 investigative surveys, and provides a basic description of the equipment used to perform the surveys. The results of these surveys are summarized in Section 5.1.

Radiological Survey Equipment and Technique. The radiological survey consisted primarily of ground surface radiation surveys using an Eberline ESP-2 with a SPA-3 probe (2-by-2-inch sodium iodine crystal) in the ratemeter mode. At any location with surface radiation levels above background, on-contact readings were taken with an Eberline RM-20 instrument with an HP-260 probe, in order to confirm the absence of surface contamination.

The RWDS Phase I research indicated that the RWDS 62598 site contained radium-contaminated objects and/or residue. Among other radioactive decay particles, radium emits gamma rays during the decay process. Since the contaminated object was suspected to be buried at a significant depth, the soil above the object would attenuate all except the gamma radiation before it reaches the surface. The gamma radiation would also be subject to some degree of attenuation, thereby lowering its energy. The SPA-3 probe was chosen for the radiological surveys due to its sensitivity to low-energy gamma rays (Chem-Nuclear, 1990).

In order to ensure a thorough radiological survey, the site was sectioned off into grids. The site was then surveyed grid by grid, independent of, and unbiased by, previous radiological surveys.

All radiation survey readings were recorded on the survey logs/grid maps in microroentgen per hour (μR/hr). In general, all readings were taken on-contact with the ground surface. There were no locations with on-contact readings in excess of eight μR/hr.

Geophysical Survey Equipment and Technique. Following the previously described surface radiation surveys, RWDS 62598 was subjected to a series of nonintrusive geophysical surveys. The lateral and/or vertical variations mapped by geophysical techniques can provide

a model for the geologic environment of the investigated site, as well as delineate cultural or synthetic variations in the materials present beneath the surface. The geophysical surveys were conducted in an attempt to correlate inconsistencies in the subsurface physical properties with information available on and above the surface.

An inconsistency in the subsurface properties detected as the result of a geophysical survey is referred to as an "anomaly." Since the RWDS Phase I research revealed that RWDS 62598 was associated with excavation and subsequent burial activities, and was suspected to contain radium-contaminated metals and a metallic container, the geophysical survey techniques were designed with emphasis on the detection of metallic and soil density variation anomalies (Chem-Nuclear, 1990).

At RWDS 62598, several types of geophysical survey equipment were utilized in order to measure different physical properties. The following is a basic description of the geophysical survey equipment used during this investigation, and the physical properties that they exploit.

Ground Penetrating Radar. Ground penetrating radar (GPR) is a system which transmits high-frequency electromagnetic (EM) energy into the earth and detects return energy reflected from subsurface structural interfaces or buried objects. GPR is useful in detecting and mapping near-surface structures, soil-unit interfaces, and buried natural or man-made objects. It is especially useful in the location of utility lines, underground storage tanks, and buried waste containers, which are not readily detectable by other geophysical methods by virtue of their physical properties or nearby interference (such as power lines, metal fences, buildings, etc.).

Three different GPR antennas were utilized during the course of the RWDS 62598 investigations in order to maximize the resolution and/or depth of the subsurface search. The highest frequency of EM energy utilized was 500 megahertz (MHz). This offered the best resolution of near surface anomalies, but its depth of search was limited to approximately 3 feet. The middle frequency employed was 300 MHz, which increased the effective search depth, but sacrificed the degree of resolution between various anomalies. The lowest frequency of EM energy used was 80 MHz. This low-frequency energy maximized the effective search depth, but offered the least amount of resolution.

The GPR geophysical survey was performed in an attempt to examine the variation of soil density characteristic to sites subject to previous excavation. It is also effective in detecting voids created by containers.

Induction Em Conductivity (EM-31 and EM-34). The induction EM method measures the apparent conductivity of the subsurface environment. The conductivity is a function of the properties of the materials it contains, such as soil or rock type, moisture content, metallic properties, organic or inorganic concentrations, permeability, and porosity.

Both the EM-31 and the EM-34 instruments were used for these geophysical surveys. The EM-34 has a greater effective search depth than the EM-31 due to the greater distance between the transmitter and receiver poles. The EM-31 and EM-34 instruments measure the subsurface conductivity by radiating an EM field which induces eddy currents in the earth. The magnitude of these eddy currents is proportional to the conductivity of the material through which they flow. The induced currents generate secondary magnetic fields, which intercept the receiver coil of the instrument. The instrument processes the received signal and produces an output voltage related to the conductivity of the subsurface material. The varying output voltages for different locations are recorded in a data storage device during the actual survey process. Upon completion of the survey, the data can be transferred for automated or manual interpretation.

EM conductivity geophysical surveys were performed in an attempt to examine the conductivity properties of the metallic objects reported to be the source of the radioactive contamination site.

Total Magnetic Field Gradiometer (Magnetometer). The total magnetic field intensity method measures the cumulative perturbation of the earth's magnetic field. Magnetic field perturbations are a function of the properties of the subsurface materials, such as soil or rock type, buried debris, or any accumulation or aggregation of ferromagnetic materials.

The magnetometer measures the total magnetic field intensity at two sensor heights and records the readings in a data storage device during the course of the survey. Upon completion of the survey, the data can be transferred for automated or manual interpretation.

A magnetometer geophysical survey was performed in an attempt to exploit the magnetic properties of ferrous materials which may be associated with the radium-contaminated objects, or their containers, buried at the disposal site.

2.3 Current Regulatory Status

The IRP has been ongoing at Tinker AFB since the early 1980s. IRP studies on the Base were conducted according to IRP guidance, which is essentially the same as EPA's guidance for conducting RI/FS under CERCLA. All investigation and removal actions have been closely monitored and approved by the EPA.

Since receiving the Hazardous Waste Management Permit on July 1, 1991, many of the IRP sites have come under the jurisdiction of the RCRA permits branch of EPA. As such, they have been identified as SWMUs; however, a large amount of work has already been performed at most of these sites under the IRP. Additional investigation at the SWMUs will be performed under the IRP.

3.0 Environmental Setting

3.1 Topography and Drainage

3.1.1 Topography

Regional/Tinker AFB. The topography of Oklahoma City and surrounding area varies from generally level to gently rolling in appearance. Local relief is primarily the result of dissection by erosional activity or stream channel development. At Oklahoma City, surface elevations are typically in the range of 1,070 to 1,400 feet mean sea level (msl). At Tinker AFB, ground surface elevations vary from 1,190 feet msl near the northwest corner where Crutcho Creek intersects the Base boundary to approximately 1,320 feet msl at Area D (EID).

Site. RWDS 62598 is located north of Crutcho Creek, east of Landfill 3 and west of Reserve Road. Surface elevations in the vicinity of RWDS 62598 range from about 1,217 to 1,220 feet msl and are relatively flat.

3.1.2 Surface Drainage

Regional/Tinker AFB. Drainage of Tinker AFB land areas is accomplished by overland flow of runoff to diversion structures and then to area surface streams, which flow intermittently. The northeast portion of the Base is drained primarily by unnamed tributaries of Soldier Creek, which is itself a tributary of Crutcho Creek. The north and west sections of the Base, including the main instrument runway, drain to Crutcho Creek, a tributary of the North Canadian River. Two small unnamed intermittent streams crossing installation boundaries south of the main instrument runway generally do not receive significant quantities of Base runoff due to site grading designed to preclude such drainage. These streams, when flowing, extend to Stanley Draper Lake, approximately one-half mile south of the Base.

Site. Surface drainage in the vicinity of RWDS 62598 is towards Crutcho Creek, which is adjacent to RWDS 62598 on its southwest side.

3.2 Geology

3.2.1 Regional/Tinker AFB Geology

Tinker AFB is located within the Central Redbed Plain Section of the Central Lowland physiographic province, which is tectonically stable. No major fault or fracture zones have been mapped near Tinker AFB. The major lithologic units in the area of the Base are relatively flat-lying and have a regional westward dip of about 0.0076 foot per foot (ft/ft) (Bingham and Moore, 1975).

Geologic formations that underlie Tinker AFB include, from oldest to youngest, the Wellington Formation, Garber Sandstone, and the Hennessey Group; all are Permian in age.

All geologic units immediately underlying Tinker AFB are sedimentary in origin. The Garber Sandstone and Wellington Formation are commonly referred to as the Garber-Wellington Formation due to strong lithologic similarities. These formations are characterized by fine-grained, calcareously-cemented sandstones interbedded with shale. The Hennessey Group consists of the Fairmont Shale and the Kingman Siltstone. It overlies the Garber-Wellington Formation along the eastern portion of Cleveland and Oklahoma counties. Quaternary alluvium is found in many undisturbed streambeds and channels located within the area.

Stratigraphy. Tinker AFB lies atop a sedimentary rock column composed of strata that ranges in age from Cambrian to Permian above a Precambrian igneous basement. Quaternary alluvium and terrace deposits can be found overlying bedrock in and near present-day stream valleys. At Tinker AFB, Quaternary deposits consist of unconsolidated weathered bedrock, fill material, wind-blown sand, and interfingering lenses of sand, silt, clay, and gravel of fluvial origin. The terrace deposits are exposed where stream valleys have downcut through older strata and have left them topographically above present-day deposits. Alluvial sediments range in thickness from less than a foot to nearly 20 feet.

Subsurface (bedrock) geologic units which outcrop at Tinker AFB and are important to understanding groundwater and contaminant concerns at the Base consist of, in descending order, the Hennessey Group, the Garber Sandstone, and the Wellington Formation (Table 3-1). These bedrock units were deposited during the Permian Age (230 to 280 million years ago) and are typical of redbed deposits formed during that period. They are composed of a conformable sequence of sandstones, siltstones, and shales. Individual beds are lenticular and vary in thickness over short horizontal distances. Because lithologies are similar and because

Table 3-1

Major Geologic Units in the Vicinity of Tinker AFB (Modified from Wood and Burton, 1968)

(Page 1 of 2)

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
QUATERNARY	PLEISTOCENE AND RECENT	Alluvium	0-70	Unconsolidated and interfingering lenses of sand, silt, clay, and gravel in the flood plains and channels of stream	Moderately permeable. Yields small to moderate quantities of water in valleys of larger streams. Water is very hard, but suitable for most uses, unless contaminated by industrial wastes or oil field brines.
		Terrace deposits	0-100	Unconsolidated and interfingering lenses of sand, silt, gravel, and clay that occur at one or more levels above the flood plains of the principal streams.	Moderately permeable. Locally above the water table and not saturated. Where deposits have sufficient saturated thickness, they are capable of yielding moderate quantities of water to wells. Water is moderately hard to very hard, but less mineralized than water in other aquifers. Suitable for most uses unless contaminated by oil field brines.

Table 3-1

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
PERMIAN	LOWER PERMIAN	Hennessey Group (includes Kingman Siltstone and Fairmont Shale)	700	Deep-red clay shale containing thin beds of red sandstone and white or greenish bands of sandy or limey shale. Forms relatively flat to gently rolling grass-covered prairie.	Poorly permeable. Yields meager quantities or very hard, moderately to highly mineralized water to shallow domestic and stock wells. In places water contains large amounts of sulfate.
		Garber Sandstone	500±	Deep-red clay to reddish-orange, massive and cross-bedded fine-grained sandstone interbedded and interfingered with red shale and siltstone	Poorly to moderately permeable. Important source of groundwater in Cleveland and Oklahoma counties. Yields small to moderate quantities of water to deep wells; heavily pumped for industrial and municipal uses in the Norman and Midwest City areas. Water from shallow wells hard to very hard; water from deep wells moderately hard to soft. Lower part contains water too salty for domestic and most industrial uses.
		Wellington Formation	500±	Deep-red to reddish-orange massive and cross-bedded fine-grained sandstone interbedded with red, purple, maroon, and gray shale. Base of formation not exposed in the area.	

of a lack of fossils or key beds, the Garber Sandstone and the Wellington Formation are difficult to distinguish and are often informally lumped together as the Garber-Wellington Formation. Together, they are about 900 feet thick at Tinker AFB. The interconnected, lenticular nature of sandstones within the sequence forms complex pathways for groundwater movement.

The surficial geology of the north section of the Base is dominated by the Garber Sandstone, which outcrops across a board area of Oklahoma County. Generally, the Garber outcrop is covered by a veneer of soil and/or alluvium up to 20 feet thick. To the south, the Garber Sandstone is overlain by outcropping strata of the Hennessey Group, including the Kingman Siltstone and the Fairmont Shale (Bingham and Moore, 1975). Drilling information obtained as a result of geotechnical investigations and monitoring well installation confirms the presence of these units.

Depositional Environment. The Permian-age strata presently exposed at the surface in central Oklahoma were deposited along a low-lying north-south oriented coastline. Land features included meandering to braided sediment-loaded streams that flowed generally westward from highlands to the east (ancestral Ozarks). Sand dunes were common, as were cut-off stream segments that rapidly evaporated. The climate was arid and vegetation sparse. Off shore the sea was shallow and deepened gradually to the west. The shoreline's position varied over a wide range. Isolated evaporitic basins frequently formed as the shoreline shifted.

Across Oklahoma, this depositional environment resulted in an interfingering collage of fluviatile and wind-blown sands, clays, shallow marine shales, and evaporite deposits. The overloaded streams and evaporitic basins acted as sumps for heavy metals such as iron, chromium, lead, and barium. Oxidation of iron in the arid climate resulted in the reddish color of many of the sediments. Erosion and chemical breakdown of granitic rocks from the highlands resulted in extensive clay deposits. Evaporite minerals such as anhydrite ($CaSO_4$), barite ($BaSO_4$), and gypsum ($CaSO_4 \cdot 2H_2O$) are common.

Around Tinker AFB, the Hennessey Group represents deposition in a tidal flat environment cut by shallow, narrow channels. The Hennessey Group is comprised predominantly of red shales which contain thin beds of sandstone (less than 10 feet thick) and siltstone. In outcrop, "mudball" conglomerates, burrow surfaces, and dessication cracks are recognized. These units

outcrop over roughly the southern half of the Base, thickening to approximately 70 feet in the southwest from their erosional edge (zero thickness) across the central part of Tinker AFB.

In contrast, the Garber Sandstone and the Wellington Formation around Tinker AFB consist of an irregularly-interbedded system of lenticular sandstones, siltstones, and shales deposited either in meandering streams in the upper reaches of a delta or in a braided stream environment. Outcrop units north of Tinker AFB exhibit many small to medium channels with cut and fill geometries consistent with a stream setting. Sandstones are typically cross-bedded. Individual beds range in thickness from a few inches to approximately 50 feet and appear massive, but thicker units are often formed from a series of "stacked" thinner beds. Geophysical and lithologic well logs indicate that from 65 to 75 percent of the Garber Sandstone and the Wellington Formation are composed of sandstone at Tinker AFB. The percentage of sandstone in the section decreases to the north, south, and west of the Base. These sandstones are typically fine to very fine grained, friable, and poorly cemented. However, where sandstone is cemented by red muds or by secondary carbonate or iron cements, local thin "hard" intervals exist along disconformities at the base of sandstone beds. Shales are described as ranging from clayey to sandy, are generally discontinuous, and range in thickness from a few inches to approximately 40 feet.

Stratigraphic Correlation. Correlation of geologic units is difficult due to the discontinuous nature of the sandstone and shale beds. However, cross-sections (Figure 3-1) demonstrate that two stratigraphic intervals can be correlated over large sections of the Base in the conceptual model. These intervals are represented on geologic cross-sections A-A' and B-B' (Figures 3-2 and 3-3). Section A-A' is roughly a dip section and B-B' is approximately a strike section. The first correlatable interval is marked by the base of the Hennessey Group and the first sandstone at the top of the Garber Sandstone. This interval is mappable over the southern half of Tinker AFB. The second interval consists of a shale zone within the Garber Sandstone which, in places, is comprised of a single shale layer and, in other places, of multiple shale layers. This interval is more continuous than other shale intervals and in cross-sections appears mappable over a large part of the Base. It is extrapolated under the central portion of Tinker AFB where little well controls exists.

Structure. Tinker AFB lies within a tectonically stable area; no major near-surface faults or fracture zones have been mapped near the Base. Most of the consolidated rock units of the Oklahoma City area dip westward at a low angle. A regional dip of 0.0057 to 0.0076 ft/ft in

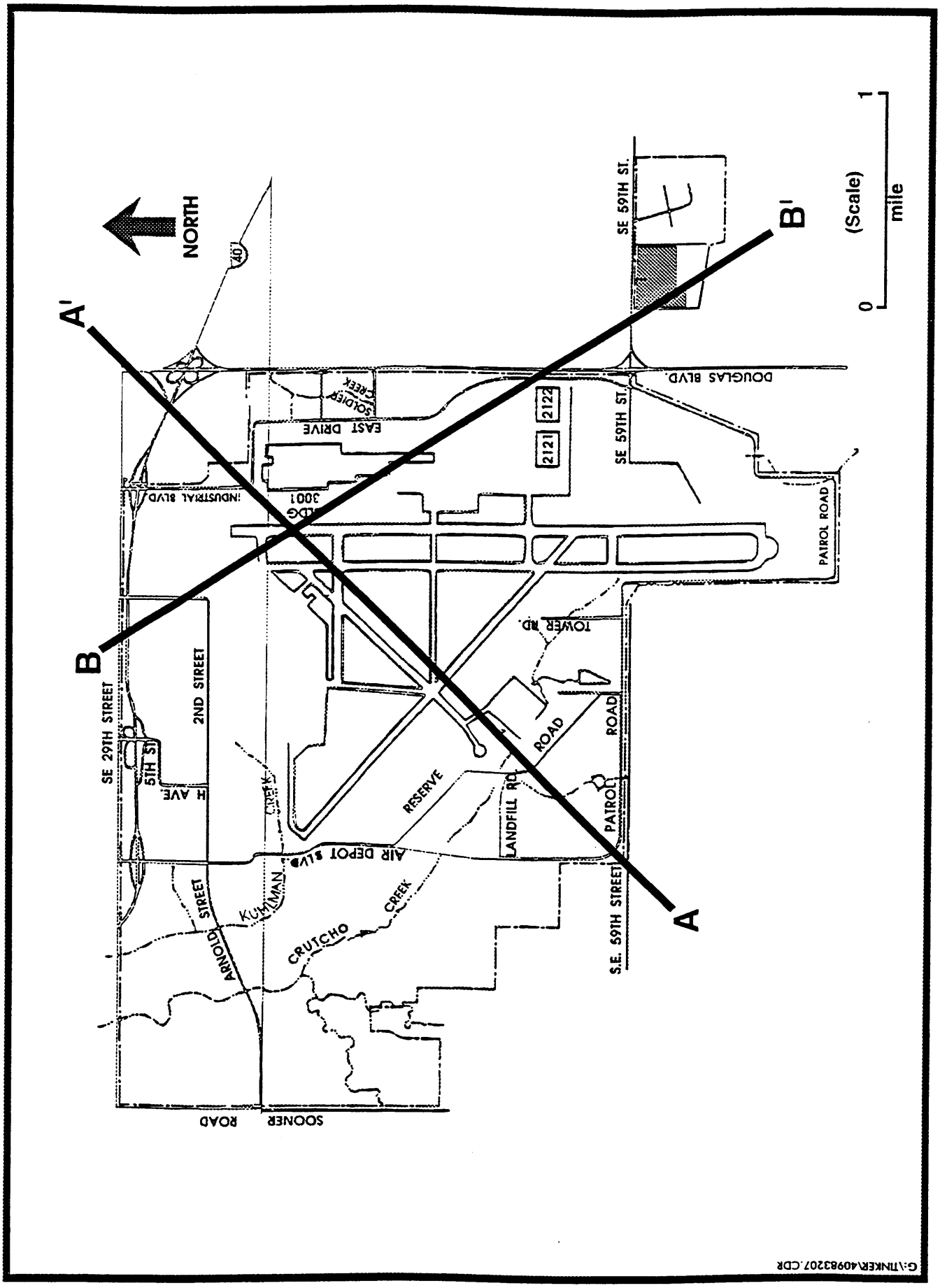


FIGURE 3-1 TINKER AFB GEOLOGIC CROSS SECTION LOCATION MAP

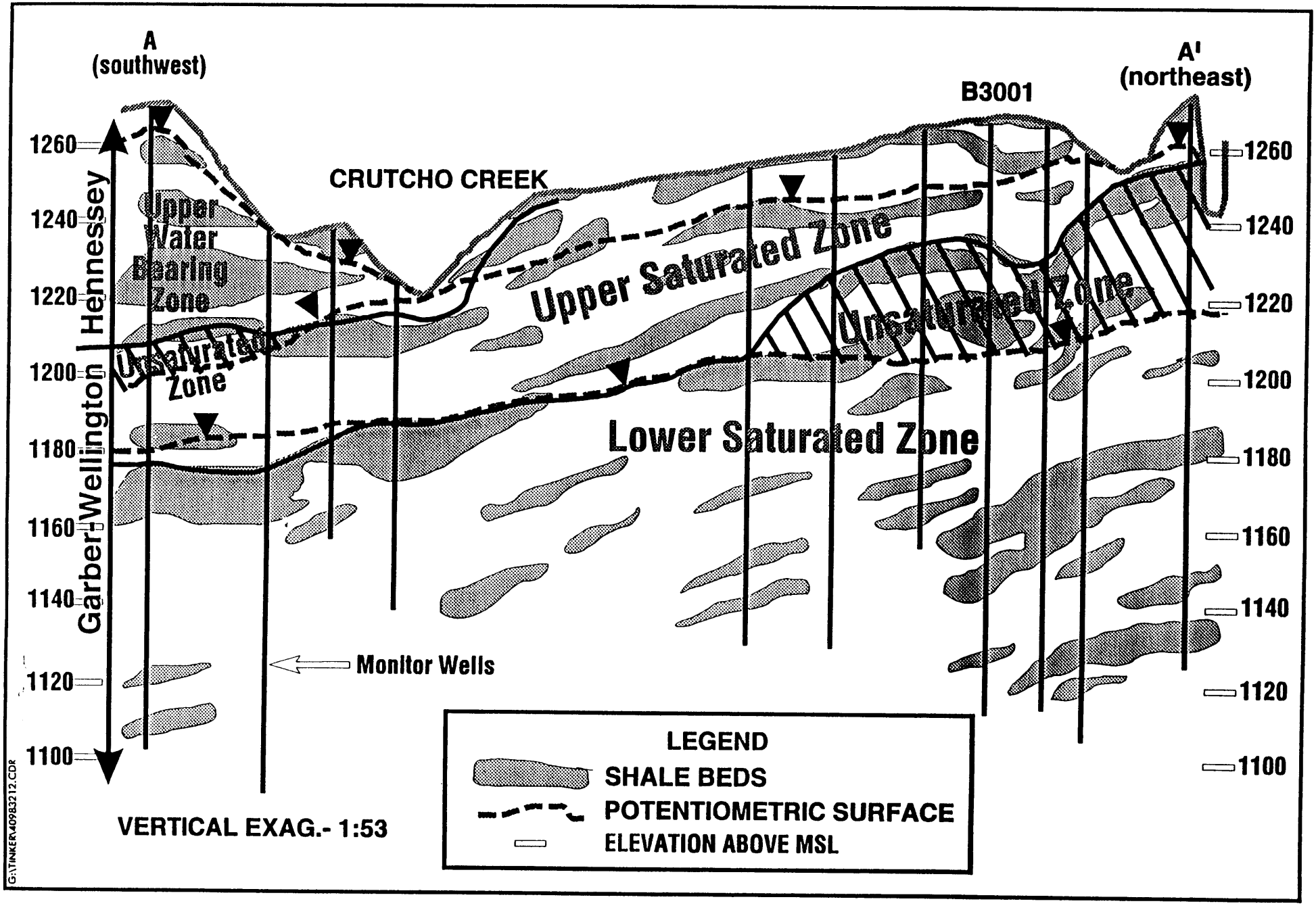


FIGURE 3-2 TINKER AFB GEOLOGIC CROSS SECTION A-A'

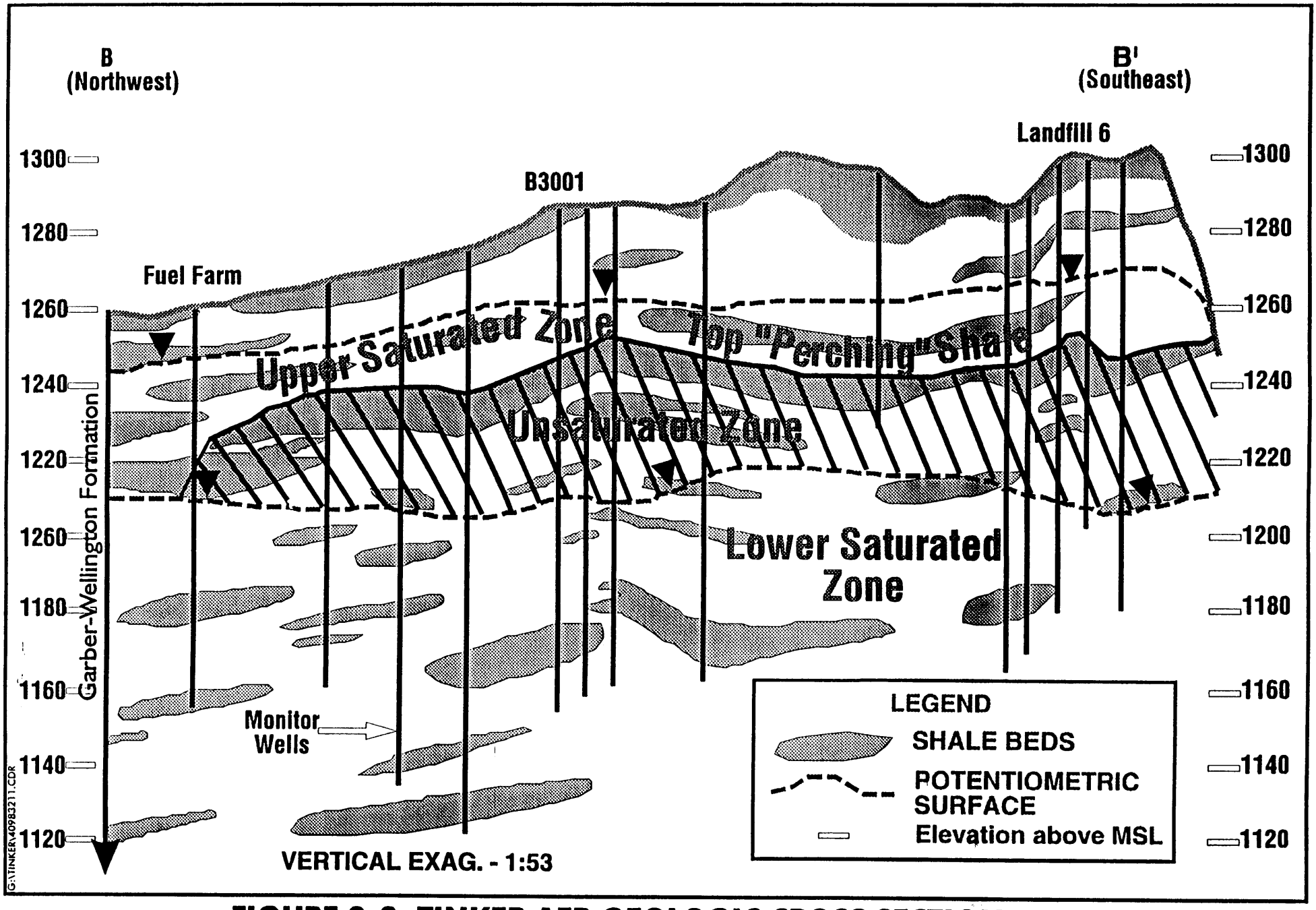


FIGURE 3-3 TINKER AFB GEOLOGIC CROSS SECTION B-B'

a generally westward direction is supported by stratigraphic correlation on geologic cross-sections at Tinker AFB. Bedrock units strike slightly west of north.

Although Tinker AFB lies in a tectonically stable area, regional dips are interrupted by buried structural features located west of the Base. A published east-to-west generalized geologic cross-section, which includes Tinker AFB, supports the existence of a northwest-trending structural trough or syncline located near the western margin of the base. The syncline is mapped adjacent to and just east of a faulted anticlinal structure located beneath the Oklahoma City Oil Field. The fault does not appear to offset Permian-age strata. There are indications that the syncline may act as a "sink" for some regional groundwater (southwest flow) at Tinker AFB before it continues to more distant discharge points.

3.2.2 Site Geology

RWDS-62598 is located near the contact between the Hennessey Group and the Garber-Wellington Formation. Alluvial deposits (sands, silts, and clays) of varying thickness exist in the shallow subsurface of the RWDS-62598 area, extending from the surface down to a depth of approximately 15 feet below grade.

3.3 Hydrology

3.3.1 Regional/Tinker AFB Hydrology

The most important source of potable groundwater in the Oklahoma City metropolitan area is the Central Oklahoma aquifer system. This aquifer extends under much of central Oklahoma and includes water in the Garber Sandstone and Wellington Formation, the overlying alluvium and terrace deposits, and the underlying Chase, Council Grove, and Admire Groups. The Garber Sandstone and the Wellington Formation portion of the Central Oklahoma aquifer system is commonly referred to as the "Garber-Wellington aquifer" and is considered to be a single aquifer because these units were deposited under similar conditions and because many of the best producing wells are completed in this zone. On a regional scale, the aquifer is confined above by the less permeable Hennessey Group and below by the Late Pennsylvanian Vanoss Group.

Tinker AFB lies within the limits of the Garber-Wellington Groundwater Basin. Currently, Tinker derives most of its water supply from this aquifer and supplements the supply by purchasing from the Oklahoma City Water Department. The nearby communities of Midwest City and Del City derive water supplies from both surface sources and wells tapping the

aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by a municipal distribution system also depend on the Garber-Wellington aquifer. Communities presently depending upon surface supplies (such as Oklahoma City) also maintain a well system drilled into the Garber-Wellington as a standby source of water in the event of drought.

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 AFB is located in an aquifer outcrop area, the Base is considered to be situated in a recharge zone.

According to Wood and Burton (1968) and Wickersham (1979), the quality of groundwater 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.

Tinker AFB presently obtains its water supplies from a distribution system comprised of 29 water wells constructed along the east and west Base boundaries and by purchase from the Oklahoma City Water Department. All Base wells are finished into the Garber-Wellington aquifer. Base wells range from 700 to 900 feet in finished depth, with yields ranging from 205 to 250 gallons per minute. The wells incorporate multiple screens, deriving water supplies from sand zones with a combined thickness from 103 to 184 feet (Wickersham, 1979).

Although the variability in the geology and the recharge system at Tinker AFB makes it difficult to predict local flow paths, Central Oklahoma aquifer water table data show that regional groundwater flow under Tinker varies from west-northwest to southwest, depending on location. This theory is supported by contoured potentiometric data from base monitoring wells which show groundwater movement in the upper and lower aquifer zones to generally follow regional dip. Measured normal to potentiometric contours, groundwater flow gradients range from 0.0019 to 0.0057 ft/ft. However, because flow in the near-surface portions of the aquifer at Tinker AFB is strongly influenced by topography, local stream base-levels, complex subsurface geology, and location in a recharge area, both direction and magnitude of groundwater movement is highly variable. The interaction of these factors not only influences

regional flow but gives rise to complicated local, often transient, flow patterns at individual sites.

As a result of ongoing environmental investigations and the approximately 450 groundwater monitoring wells installed on the Base during various investigations, a better understanding of the specific hydrological framework has emerged. The current conceptual model developed by Tinker AFB (Tinker, 1993), based on the increased understanding of the hydrological framework, has been revised from an earlier model adopted by the USACE. Previous studies reported that groundwater was divided into four water-bearing zones: the perched aquifer, the top of regional aquifer, the regional aquifer, and the producing zone. In the current model, two principal water table aquifer zones and a third less extensive zone have been identified. The third is limited to the southwest quadrant. The third aquifer zone consisted of saturated siltstone and thin sandstone beds in the Hennessey Shale and equates to the upper water bearing zone (UWBZ) described by the USACE at Landfills No. 1 through 4 (SWMUs 3 through 6) (USACE, 1993). In addition, numerous shallow, thin saturated beds of siltstone and sandstone exist throughout the Base. These are of limited areal extent and are often perched.

In the current conceptual hydrologic model, an upper saturated zone (USZ) and a lower saturated zone (LSZ) are recognized in the interval from ground surface to approximately 200 feet. Below this is found the producing zone from which the Base draws much of its water supply. Figure 3-4 shows the potentiometric surface for the USZ and Figure 3-5 shows the potentiometric surface for the LSZ. The USZ exists mainly under water table (unconfined) conditions, but may be partially confined locally. Conditions in the LSZ are difficult to determine due to screen placement and overly long sandpacks below the screen interval.

The USZ is found at a depth of 5 to 70 feet below ground surface and has a saturated thickness ranging from less than 1 foot at its eastern boundary to over 20 feet in places west of Building 3001. The USZ is erosionally truncated by Soldier Creek along the northeastern margin of Tinker AFB. This aquifer zone is considered to be a perched aquifer over the eastern one-third of Tinker AFB, where it is separated from the LSZ by an underlying confining shale layer and a vadose zone. The confining interval extends across the entire Base, but the vadose zone exists over the eastern one-third of this area. The available hydrogeologic data indicate that the vadose zone does not exist west of a north-south line located approximately 500 to 1,000 feet west of the main runway; consequently, the USZ is not perched west of this line. However, based on potentiometric head data from wells

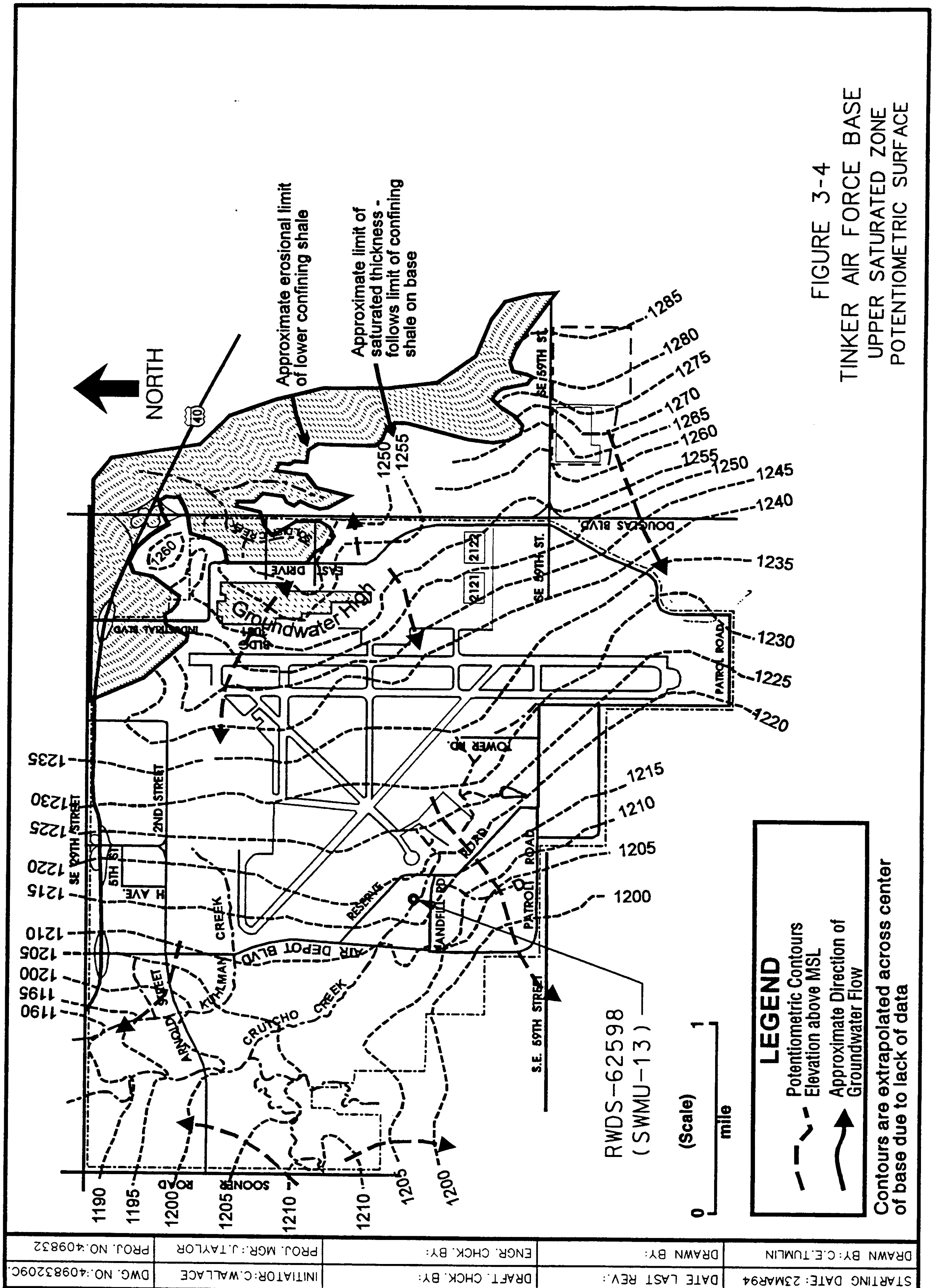
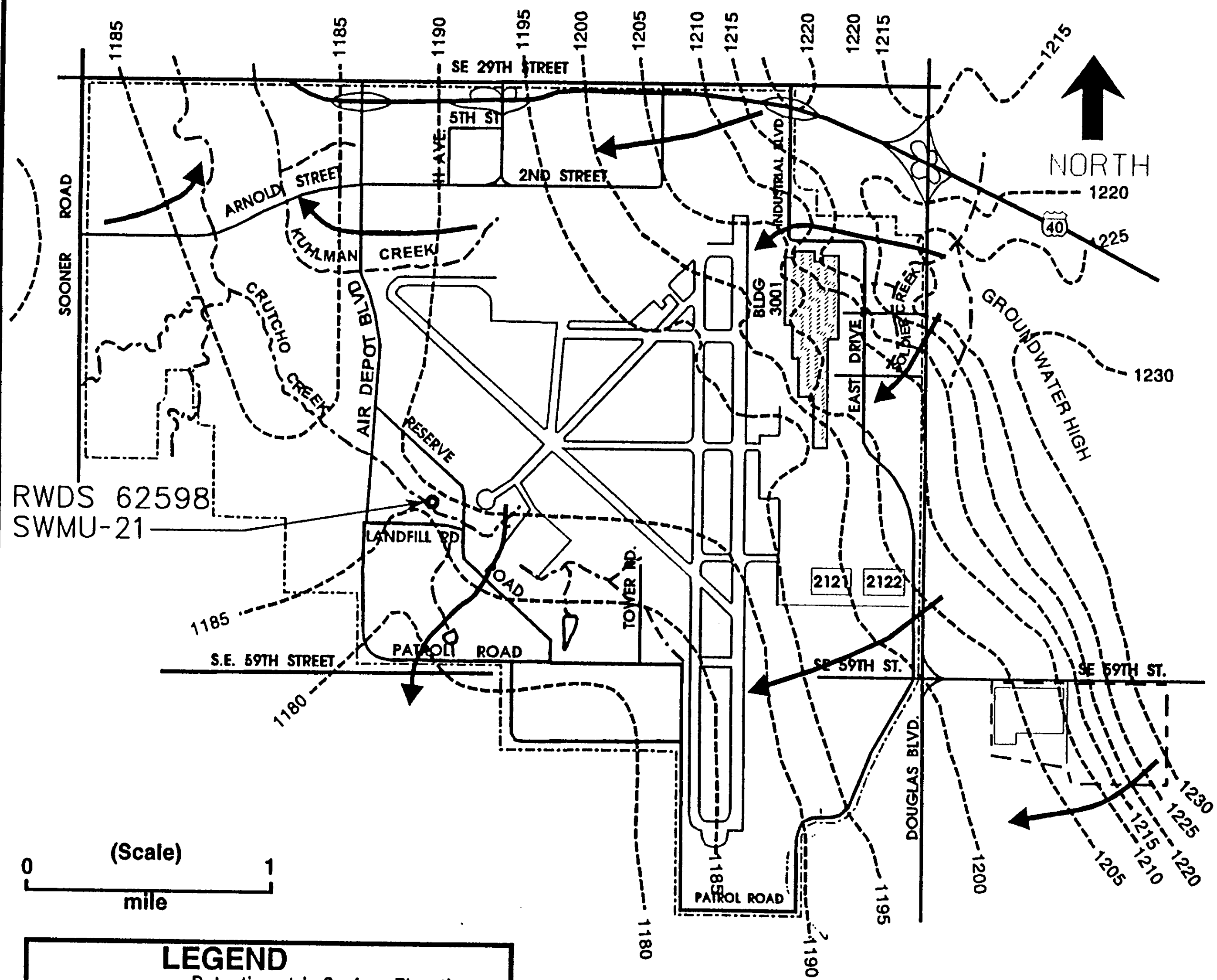


FIGURE 3-4
TINKER AIR FORCE BASE
UPPER SATURATED ZONE
POTENTIOMETRIC SURFACE



(Scale)
0 — 1
mile

LEGEND

- - - - - Potentiometric Surface Elevation above MSL

→ Approximate Direction of Groundwater Flow

Contours are extrapolated across center of base due to lack of data

FIGURE 3-5
TINKER AIR FORCE BASE
LOWER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 23MAR94	DATE LAST REV.:	DRAFT. CHCK. BY:	INITIATOR: C.WALLACE	DWG. NO.: 40983209C.
DRAWN BY: C.E.TUMLIN	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.: J.TAYLOR	PROJ. NO.: 409832

G:\TINKER\40983202C.528

screened above and below the confining shale layer, the USZ remains a discrete aquifer zone distinct from the LSZ even over the western part of the Base. In areas where several shales interfinger to form the lower confining interval rather than a single shale bed, "gaps" may occur. In general, these "gaps" are not holes in the shale, but are places where multiple shales exist that are separated by slightly more permeable strata. Hydrologic data from monitoring wells indicate that these zones allow increased downward flow of groundwater above what normally leaks through the confining layer.

The LSZ is hydraulically interconnected and can be considered one aquifer zone down to approximately 200 feet. This area includes what was referred to by the USACE as the top of regional and regional zones. Hydrogeologic data from wells screened at different depths at the same location within this zone, however, provide evidence that locally a significant vertical (downward) component of groundwater flow exists in conjunction with lateral flow. The magnitude of the vertical component is highly variable over the Base. Preliminary evidence suggests that the LSZ is hydraulically discrete from the producing zone. Due to variations in topography, the top of the lower zone is found at depths ranging from 50 to 100 feet below ground surface under the eastern parts of the Base and as shallow as 30 feet to the west. Differences in potentiometric head values found at successive depths are due to a vertical (downward) component of groundwater flow in addition to lateral flow and the presence or absence of shale layers which locally confine the aquifer system. The LSZ extends east of the Base (east of Soldier Creek) beyond the limits of the USZ where it becomes the first groundwater zone encountered in off-Base wells. Because of the regional dip of bedding, groundwater gradient, and topography, the LSZ just east of the Base is generally encountered at depths less than 20 feet.

3.3.2 Site Hydrology

The groundwater beneath RWDS 62598 exists in two zones. The uppermost zone is called the USZ. This zone is hydraulically connected to Crutcho Creek. RWDS 62598 is approximately 100 feet northeast of Landfill 3. The deepest hydrogeologic zone at the site is the LSZ.

The USZ and the LSZ are separated by a low permeability shale layer. This shale interval, which is part of the Hennessey Group, varies in thickness and pinches out north of Landfill Road underneath Landfill 3. The shale interval acts as the lower confining bed for the USZ and, therefore, perches the USZ. This shale interval is the second mappable layer discussed earlier under the section on stratigraphic correlation. The landfill trenches are set within and

underlain by clay. The clay is a low-permeability layer, but it does not present as much of a barrier as the shale layer to the south. Average permeabilities for the clay and shale layers were reported to be 1.4×10^{-8} centimeters per second (cm/s) and 3×10^{-9} cm/s, respectively.

The USZ is a sandstone layer across the site. PVC pipes set in the Landfill 3 trenches have water levels corresponding to the USZ. The flow of the USZ moves toward Crutcho Creek from a local potentiometric high under Landfill 3 and southwest on the southern side of the high. The USZ sandstone was encountered at a depth between 15 and 30 feet below grade and ranged in thickness from a few feet to as much as 25 feet. The USZ is underlain by a substantial layer of shale and siltstone ranging in thickness from 8 to 25 feet. Vertical migration of the USZ groundwater and contaminants occurs primarily by movement through preferential pathways in the formation under semiconfined and confined conditions, with the interbedded coarser-grained material acting as a conduit to the LSZ. The permeability of the USZ formation was measured to be 1.4×10^{-3} cm/s, and that of the underlying siltstone to be 3×10^{-8} cm/s. The estimated flow rate of the USZ is 113 feet per year.

The LSZ is composed primarily of interbedded shale, siltstone, and sandstone. Figures presented in the RI report (USACE, 1993) depicting potentiometric surfaces for groundwater based on 1987 and 1990 monitoring well data show groundwater flowing in different directions. The 1987 contours show the LSZ flowing in a southeast direction, while the 1990 contours indicate a southwestern flow underneath Landfill 3. The LSZ formation was encountered at depths of 50 to 70 feet below grade and extended to a maximum depth of 125 feet before encountering a lower confining unit. The permeability of the formation was measured to be 1.2×10^{-3} cm/s. The estimated flow rate of the LSZ is 48 feet per year.

3.4 Soils

Three major soil types have been mapped in the Tinker AFB area and are described in Table 3-2 (U.S. Department of Agriculture [USDA], 1969). The three soil types, the Darrell-Stephenville, Renfrow-Vernon-Bethany, and Dale-Canadian-Port, consist of sandy to fine sandy loam, silt loam, and clay loam, respectively. The Darrell-Stephenville and the Renfrow-Vernon-Bethany are primarily residual soils derived from the underlying shales of the Hennessey Group. The Dale-Canadian-Port association is predominantly a stream-deposited alluvial soil restricted to stream floodplains. The thickness of the soils ranges from 12 to 60 inches.

Table 3-2

Tinker AFB Soil Associations
(Source: USDA, 1969)

Association	Description	Thickness (in.)	Unified Classification[a]	Permeability (in./hr)
Darrell-Stephenville: loamy soils of wooded uplands	Sandy loam Sandy clay loam Soft sandstone (Garber Sandstone)	12-54	SM,ML,SC	2.0-6.30
Renfrow-Vernon-Bethany: loamy and clayey soils on prairie uplands	Silt loam - clay Clay loam Shale (Fairmont Shale)	12-60	ML,CL,MH,CH	<0.60-0.20
Dale-Canadian-Port: loamy soil on low benches near large streams	Fine sandy loam Silty clay loam Loam Clay loam	12-60	SM,ML,CL	0.05-6.30

[a]Unified classifications defined in U.S. Bureau of Reclamation, 5005-86.

4.0 Source Characterization

The anticipated source of contamination at RWDS 62598 was a lead-walled radium still. Radium-226 was an ingredient in the luminous paints used to coat instrument dials and label instrument panels of planes during the 1940s and 1950s. Acetone and methylethyketone were used to strip the radium paint from dials, resulting in a radium paint and solvent solution. Until 1951, Tinker AFB sent this radium-solvent waste to Canadian Radium and Uranium Corporation located in Mt. Kisco, New York. In 1951, this practice was discontinued as a cost-saving measure. Therefore, after 1952, this type of waste was processed on Base by volatilizing the solvents off in a lead still. When the still became radioactively "hot," a top was soldered on. The still was approximately 12 to 18 inches in diameter and about 18 inches high. It was reported that a still of this description had been buried at the location of RWDS 62598 in 1955. The Phase I report identified an Air Force document stating that the still had been removed from the site and suggesting that the lead still was no longer buried in RWDS 62598.

Radium is a metabolic analog of calcium and as such, if ingested, is deposited in the skeleton. Any radium-226 deposited in the skeleton serves a source of alpha radiation to the bone and contiguous tissues.

Radium-226 also decays to form radon-222. Since radon is a gas, it has the potential for diffusing out of the ground and becoming airborne. Radon-222 has a half-life of 3.82 days. If radon is inhaled into the lungs and under goes decay, the alpha radiation from the radon progeny will provide a radiation dose to the lungs and contiguous tissues.

5.0 Contaminant Characterization

5.1 Nonintrusive Surveys

As described in Section 2.2, the investigation of RWDS 62598 included several nonintrusive survey techniques in an attempt to characterize the extent of contamination present at this site. This section summarizes the results of these nonintrusive surveys.

For the RWDS 62598 radiation surveys, an 80- by 80-foot area, centered on the concrete monument, was divided into a 2.5- by 2.5-foot grid system within 10 feet of the monument, and expanded to 5- by 5-foot grids for the remainder of the area.

Background gamma radiation exposure level in the site vicinity ranged from 7.0 μR/hr to 8.0 μR/hr. The site's gamma radiation exposure level was equal to or below the general background level. No elevated gamma radiation exposure level were detected on the ground surface at RWDS 62598 (Chem-Nuclear, 1990).

The GPR survey of this site was impeded by soil piles scattered across the site. These piles altered and limited the direction of scan paths emitted by the GPR antenna. However, one anomaly was detected approximately 2 feet southeast of the concrete monument. The anomaly exhibited the characteristics of a burial pit, 1 to 6 feet deep.

A total magnetic field gradiometer survey was conducted at RWDS 62598 which revealed one significant magnetic anomaly. The location of this anomaly correlated with the anomaly detected during the GPR survey, and exhibited the characteristics of a buried ferromagnetic object at a depth of 3 to 6 feet. The topographic variations and contrasting properties of the soil piles created large variation in the magnetic baseline which may have masked small magnetic anomalies.

An induced electromagnetic (EM) conductivity survey was conducted over RWDS 62598; however, no significant anomalies were detected. This may be caused by the small size and/or the composition of the object associated with the anomaly detected during the GPR and magnetometer surveys. A linear anomaly indicative of a pipeline was detected running across the northeast quadrant of the surveyed area.

5.2 Intrusive Surveys

Monitoring wells 77A and 77B are located just north of Crutcho Creek between RWDS site 62598 and Landfill 3. Samples from these wells contained Radium-226 concentrations ranging from 0.68 to 5.8 pCi/L and Radium-228 concentrations from 1.9 to 3.1 pCi/L (Table 5-1). The MCL for Radium 226/228 is 20 pCi/L. The gross alpha activity for these two wells ranged from 1.8 to 35.4 pCi/L. The MCL for gross alpha is 15 pCi/L. It should be stressed that these wells are located between RWDS 62598 and Landfill 3 and any detected constituents cannot necessarily be attributed to the RWDS 62598 site without further investigation.

5.3 Removal Action

RWDS 62598 was excavated in July 1991 with the objective of either finding and removing a lead still or providing additional evidence to support the report that a still had previously been removed and shipped off site. The area at the GPR anomaly was excavated first, to a depth exceeding 6 feet. When nothing was found at that location, the area around the site marker was also excavated to a depth exceeding 6 feet.

As the excavation was advanced, the soils were screened with the hand-held survey instruments. The only anomaly encountered was a slight metallic anomaly which resulted from a secondary deposit containing naturally occurring iron which surrounded some tree roots.

The EM conductivity survey anomalies were identified as a pipeline in the survey report discussed in Section 2.2 of this document. This identification was confirmed because the pipeline was visible at the surface in the location identified by the EM survey (CDM, 1992).

No still was found at the site, and following a confirmatory survey by personnel from Armstrong Laboratory, Brooks AFB, the excavation was backfilled. Analysis of soils sampled from the excavation produced radiological and chemical test results sufficiently low to allow the soils to remain in situ (CDM, 1992).

The lead still reported to be buried at the site in the 1950s was not found despite the careful exhumation of soils. Therefore, Tinker AFB conducted a "records search" as an additional safety precaution. An interview with the individual who built the still provided size information; it was concluded that the object was too large to have been missed during the careful exhumation of RWDS 62598. The records search was not able to conclusively verify an off-site shipment. However, the records search does conclude that a shipping arrangement

Table 5-1

Radioanalytical Results for Groundwater (pCi/L) SWMU-21, RWDS 62598, Tinker AFB, Oklahoma

Sample ID	Detected Parameters (pCi/L)[a]		Gross Activity (pCi/L)	
	Ra-226	Ra-228	Alpha Activity	Beta Activity
MW-77A/12	4.10 ± 0.73 (J)[b]	1.89 ± 0.60 (J)	27.7 ± 3.8 (J)	13.8 ± 1.7 (J)
MW-77A/12 DUP	5.79 ± 0.91 (J)	3.13 ± 0.79 (J)	35.4 ± 4.9 (J)	18.4 ± 2.3 (J)
MW-77B/12	0.68 ± 0.25 (J)	U[c]	1.78 ± 0.85 (J)	3.76 ± 0.71 (J)

[a]pCi/L = picocuries per liter
[b]"J" indicates the data are estimated due to out of control QA/QC.
[c]"U" indicates sample was analyzed and not detected at the detection limit or value qualified U due to blank contamination.

between Tinker AFB and Canadian Radium and Uranium Corporation in Mt. Kisco, New York, was in place at the time and that the still was most likely shipped off site for disposal or resource recovery (CDM, 1992).

6.0 Potential Receptors

A specific potential human and ecological receptor search has not been performed for RWDS 62598. Data are available in the form of chemical analysis of groundwater, and can be used to initiate a potential receptors search. The following sections describe the data available to begin identification of potential receptors.

6.1 Human Receptors

Tinker AFB is situated on a relatively flat expanse of grassland. Prior to the development of the Base, the area was characterized by large tracts of agricultural land. The Base currently occupies approximately 5,000 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.

The Garber-Wellington aquifer, which underlies Tinker AFB, is the single most important source of potable groundwater in the Oklahoma City area. The recharge area for the Garber-Wellington aquifer covers the eastern half of Oklahoma County, including Tinker AFB. Approximately 75 percent of the Base's water supply is obtained from production wells pumping from this aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by municipal distribution systems also depend on the Garber-Wellington aquifer. Communities, such as Oklahoma City, presently depending upon surface water supplies also maintain a well system drilled into this aquifer as a standby source of water in the event of drought. Lake Stanley Draper, a local surface water supply reservoir with a small portion of its drainage basin within the boundaries of Tinker AFB, serves a significant recreational function as well.

In 1989, approximately 26,000 military and civilian personnel worked at Tinker AFB. Of these, approximately 2,722 personnel occupied on-Base housing, which consisted of 530 family housing units and seven dormitories. At that time, 1,262 of these residents were children. Military personnel and their families who reside on Base represent the nearest receptors to releases from Tinker AFB.

The current land use at and near the Base is not expected to change because the facilities have decades of useful life remaining and the Base has an important and continuing mission. However, other future land use scenarios and any human receptors associated with those scenarios may need to be considered.

6.2 Ecological Receptors

Tinker AFB lies within a grassland ecosystem, which is typically composed of grasses, forbes, and riparian (i.e., trees, shrubs, and vines associated with water courses) vegetation. This ecosystem has generally experienced fragmentation and disturbances as result of urbanization and industrialization at and near the Base. While no threatened or endangered plant species occur on the Base, the Oklahoma penstemon (*Penstemon oklahomensis*), identified as a rare plant under the Oklahoma Natural Heritage Inventory Program, thrives in several locations on Base. Tinker AFB policy considers rare species as if they were threatened or endangered and provides the same level of protection for these species.

In general, wildlife on the Base is typically tolerant of human activities and urban environments. No federal threatened or endangered species have been reported at the Base. However, one specie found on the Base, the Texas horned lizard (*Phrynosoma cornutum*), is a Federal Category 2 candidate specie and under review for consideration to be listed as threatened or endangered. Air Force policy (AFR 126-1) considers candidate species as threatened or endangered and provides the same level of protection.

The Oklahoma Department of Wildlife Conservation also lists several species within the state as Species of Special Concern. Information on these species suggests declining populations but information is inadequate to support listing, and additional monitoring of populations is needed to determine the species status. These species also receive protection by Tinker AFB as threatened or endangered species. Of these species, the Swainson's hawk (*Buteo swainsoni*) and the burrowing owl (*Athene cunicularia*) have been sighted on Tinker AFB. The Swainson hawk, a summer visitor and prairie/meadow inhabitant, has been encountered Basewide. The burrowing owl has been known to inhabit the Air Field at the Base.

7.0 Action Levels

An "action level" is defined by EPA in proposed rule 40 CFR 264.521 (55 FR 30798; 7/27/90), "Corrective Action for Solid Waste Management Units (SWMU) at Hazardous Waste Management Facilities," as a health- and environment-based level, determined by EPA to be an indicator for protection of human health and the environment. In the preamble to this proposed rule, the focus of the RFI phase is defined as "characterizing the actual environmental problems at the facilities." As part of this characterization, a comparison of the contaminant concentrations to certain action levels should be made to determine if a significant release of hazardous constituents has occurred. This comparison is then used to determine if further action or corrective measures are required for a SWMU or an AOC. The preamble to the proposed rule states that the concept of action levels was introduced because of the need for "a trigger that will indicate the need for a Corrective Measures Study (CMS) and below which a CMS would not ordinarily be required" (55 FR 30798; 7/27/90). If constituent concentrations exceed certain action levels at a SWMU or an AOC, further action or a CMS may be warranted; if constituent concentrations are below action levels, a finding of no further action may be warranted. This chapter of the report presents the initial analytical data as compared to certain potential action levels.

Action levels are concentrations of contaminants at or below which exposure to humans or the environment should not produce acute or chronic effects.

The action level information is presented in this chapter so that a constituent concentration at a sample location can be compared with its potential action level. Only constituents identified in the analysis are listed in the SWMU-21, RWDS 62598 table. Table 7-1 shows the action levels for soil, water, and air as published in federal or state regulations, policies, guidance documents, or proposed rules.

The action levels listed in Table 7-1 are:

- ***SWMU Corrective Action Levels (CAL)*** - The first set of action levels provided in the table are those taken from the proposed rule (40 CFR 264.521) and provided as Appendix A to the rule as "Examples of Concentrations Meeting Criteria for Action Levels." These levels are health-risk based and are provided

Table 7-1

Action Levels
SWMU 21, RWDS 62598, Tinker AFB

Parameters	SWMU CAL[a]			MCL[b]
	Soil (mg/kg)	Water (mg/L)	Air ($\mu g/m^3$)	Water (mg/L)
Organics				
Acetone	8000	4.0		
Carbon Tetrachloride	5.0	0.0003	0.03	0.005
Methyl Ethyl Ketone	4000	2.0	300	
Methylene Chloride	90	0.005	0.3	0.005
Radiometrics				
Gross Alpha				15 pCi/L
Radium-226/228				20 pCi/L
Radon				300 pCi/L

[a]CAL - Corrective Action Levels
[b]MCL - Maximum Contaminant Levels

as specific examples of levels below which corrective action would not be required.

- ***Maximum Contaminant Levels (MCL)*** - These values are provided from 40 CFR Subpart G, Sections 141.60 through 0.63 as promulgated under the Safe Drinking Water Act. These levels are designated for water media only.

- ***USGS Background*** - These values are provided from the USGS report titled "Elemental Composition of Surficial Materials from Central Oklahoma" (USGS, 1991). These values represent the levels of metals which naturally occur in Central Oklahoma soils.

- ***Background*** - These levels are provided where background could be determined. Where available, background concentrations are listed for metals in soil samples taken on site, which were thought to be unaffected by releases from a unit.

- ***National Ambient Air Quality Standards (NAAQS)*** - These standards are published in 40 CFR Part 50 under the Clean Air Act and apply to point sources that emit a limited number of constituents to the air. The constituents regulated are nitrogen dioxide, sulphur dioxide, carbon monoxide, lead, ozone, and particulate matter. Currently, it is assumed that none of the SWMUs or AOCs emit these compounds in regulated quantities and no air samples have been taken which would allow for a valid comparison.

- ***Water Quality Standards (WQS)*** - The WQS are the standards for surface water quality as established by the State of Oklahoma. These standards apply to point source discharges to surface waters and have been listed for those units adjacent to surface water.

Table 7-1 also gives a brief comparative evaluation of the data collected and the related action levels. The data for each detected compound are compared with the appropriate action level in order to identify those constituents (compounds) with concentrations exceeding the action levels. This identification of the compounds above the action levels provides an indication of a potential environmental problem at a specific site. In addition, this information indicates whether there is a need for conducting a CMS so that a corrective action can be implemented/undertaken at the site.

8.0 Summary and Conclusions

8.1 Summary

RWDS 62598 is located north of Crutcho Creek, east of Landfill 3, south of Facility 1025, and west of Reserve Road. It was reported that a lead still containing radium paint had been disposed of at this site. Radium-coated dials were used in the instrument panels of the planes during the 1940s and 1950s. The radium paint was stripped from the dials with acetone or methylethylketone. This resulted in a radium paint and solvent solution. Initially this waste was sent to Canadian Radium and Uranium Corporation in Mt. Kisco, New York but that was discontinued in 1951 to save money. After 1952, as a cost saving measure, this type of waste was disposed of on Base. A lead still was constructed to volatilize the solvents from the solution. This allowed the bulk of the waste to be minimized so that a new still was only required every 4 to 5 years. The lead was shaped into a tube with a bottom soldered on. The still was approximately 12 to 18 inches in diameter and approximately 18 inches high. When the still became radioactively "hot," a top was soldered on and the still was buried.

Previous Investigations. The Phase I report identified an Air Force document stating that the still had been removed from this site and suggesting that a buried object does not exist at RWDS 62598 (USACE, 1989).

Nonintrusive radiation surveys did not detect any radiation levels above background. The GPR survey of this site detected one anomaly that exhibited the characteristics of a burial pit, 1 to 6 feet deep. A total magnetic field gradiometer survey was also performed, revealing one significant magnetic anomaly that correlated with the anomaly detected during the GPR survey and exhibited the characteristics of a buried ferromagnetic object at 3 to 6 feet.

Removal Action. RWDS 62598 was excavated with the objective of either finding and removing the lead still or providing additional evidence to support the report that the still had previously been removed and shipped off site. The area at the GPR anomaly was excavated first, to a depth exceeding 6 feet. When nothing was found at that location, the area around the site marker was also excavated to a depth exceeding 6 feet.

As the excavation was advanced, the soils were screened with the hand-held survey instruments. The only anomaly encountered was a slight metallic anomaly which resulted from a secondary deposit containing naturally occurring iron which surrounded some tree roots.

No still was found at the site, and following a confirmatory survey by personnel from Armstrong Laboratory, Brooks AFB, the excavation was backfilled. Analysis of soils sampled from the excavation produced radiological and chemical test results sufficiently low to allow the soils to remain in situ.

8.2 Conclusions

It was concluded that the lead still was too large to have been missed during the careful exhumation of RWDS 62598. The records search was not able to conclusively verify an off-site shipment. However, the records search does conclude that a shipping arrangement between Tinker AFB and Canadian Radium and Uranium Corporation in Mt. Kisco, New York, was in place at the time and that the still was most likely shipped off site for disposal or resource recovery. RWDS 62598 was recommended for closure by both CDM and Environmental Management Operations (EMO) (CDM, 1992). No further investigative work is identified for closure of this site.

9.0 Recommendations

This RFI Summary Report was prepared to determine and document whether sufficient investigations at RWDS 62598 have been performed to meet the permit requirements. Review of available documents and evaluation of data reported in this report indicate that the main focus of all the previous investigations at this site have involved mainly the analysis of radioactive constituents. However, hazardous waste constituents have not been addressed. Also, based on the documents reviewed, data collected at this site are limited. Additional investigations are necessary to confirm the presence or absence of hazardous waste constituents at the site. In addition, the nature and extent of contamination, if any, should be determined.

In view of these deficiencies, several additional investigations are recommended during the Phase II RFI. Based on the location of RWDS 62598, it will be more appropriate to investigate this site as part of a group comprising several waste units in close proximity: RWDS 1022E, RWDS 1030W, Landfills 1 through 4, the SP, and FTA1. Specific sampling needs to meet the objectives of the additional investigations will be presented in the work plan and sampling plan for the Phase II RFI. At a minimum, the following recommendations should be implemented:

- Obtain soil samples for VOC and SVOC analyses.
- Obtain groundwater samples for VOC and SVOC analyses.

In addition, to fully evaluate the extent of soil contamination at this site it is recommended that site-specific soil background samples be collected during the Phase II RFI. This additional information along with the USGS background values should be used in the Phase II report to distinguish site-related from background concentrations in a statistically significant manner. During the development of the Phase II RFI work plan, the number of background samples to be collected, the location of the soil borings, and the soil analysis to be performed on the samples should be determined for EPA approval.

Spacing 1.0

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Final Report
Phase I RCRA Facility Investigation for Appendix I Sites

VOLUME IX

SWMU-22, Radioactive Waste Disposal Site 1022E

Department of the Air Force
Oklahoma City Air Logistics Center
Tinker Air Force Base, Oklahoma

September 1994

Table of Contents - RFI Summary Report

Table of Contents *(Continued)*

List of Tables

List of Figures

List of Acronyms

AFB	Air Force Base
AOC	areas of concern
CAL	Corrective Action Levels
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CDM	CDM Federal Programs Corporation
CFR	Code of Federal Regulations
CMS	Corrective Measures Study
DERP	Defense Environmental Response Program
DOD	U.S. Department of Defense
DRMO	Defense Reutilization Marketing Organization
DWS	drinking water standards
EID	Engineering Installation Division
EM	electromagnetic
EPA	U.S. Environmental Protection Agency
ES	Engineering Science
ft/ft	foot per foot
GC	gas chromatograph
GPR	ground penetrating radar
HSWA	Hazardous and Solid Waste Amendments
IRP	Installation Restoration Program
LSZ	lower saturated zone
µR/hr	microrentgen per hour
mHz	megahertz
mR	milliroentgen
mrem/yr	millirems per year
MCL	maximum concentration level
MCLG	maximum concentration level goal
mCi	millicurie
msl	mean sea level
nCi/g	nanocuries per gram
NAAQS	National Ambient Air Quality Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
NRC	Nuclear Regulatory Commission

List of Acronyms *(Continued)*

PA/SI	preliminary assessment/site investigation
pCi	picocuries
pCi/g	picocuries per gram
PID	photoionization detector
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
RD/RA	remedial design/remedial action
RIC	Radioisotope Committee (U.S. Air Force)
RI/FS	remedial investigation/feasibility study
RFI	RCRA Facility Investigation
ROD	record of decision
RWDS	radioactive waste disposal site
SARA	Superfund Amendments and Reauthorization Act
SWMU	solid waste management unit
TCLP	Toxicity Characteristic Leaching Procedure
TEDE	total effective dose equivalent
TSD	treatment, storage, and disposal (facility)
USACE	U.S. Army Corps of Engineers
USC	U.S. Code
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USZ	upper saturated zone
WQS	Water Quality Standards

Executive Summary

This report provides a summary of the various investigations that have been conducted at the Solid Waste Management Unit (SWMU)-22, Radioactive Waste Disposal Site 1022E (RWDS 1022E), Tinker Air Force Base (AFB), Oklahoma. The report has been prepared to determine and document whether sufficient investigations at RWDS 1022E have been performed to meet regulatory requirements. Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County. The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. The Base encompasses approximately 5,000 acres.

Background. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon^{TM}, jet fuels, and radium paints.

In 1984, Congress amended the Resource Conservation and Recovery Act (RCRA) with the Hazardous and Solid Waste Amendments (HSWA), which allow the Environmental Protection Agency (EPA) to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989, Tinker AFB submitted its Part B permit application for renewal of its operating RCRA Hazardous Waste Storage facility permit. The final RCRA HSWA permit issued on July 1, 1991, requires Tinker AFB to investigate all SWMUs and AOCs and to perform corrective action at those identified as posing a threat to human health or environment. The permit specifies that a RCRA Facility Investigation (RFI) be conducted for 43 identified SWMUs and two areas of concern (AOC) on the Base. Consequently, this document has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for RWDS 1022E.

Source Description. RWDS 1022E is located northwest of Landfill 3 (SWMU-5). The only marker is an unlabeled piece of angle iron. At one time a red reflector on a metal rod with two pieces of angle iron stuck in the ground at either side of the reflector was reported to have been in place at the approximate site location. There are verbal reports that a site marker was installed at the time of the burial of radioactive waste, but was later destroyed (CDM Federal Programs Corporation, 1992). The IRP Phase I records search report reported

that 8 to 10 containers of radioactive material from Building 230 were buried 30 feet deep at this site (USACE, 1989). Other reports have indicated that this material probably consisted of boxes of blocking tubes (or vacuum tubes) each containing 1 millicurie (mCi) of radium-226.

Site Investigations - Nonintrusive Surveys. The Chem-Nuclear Environmental Services survey (Chem-Nuclear, 1990), used the unlabeled piece of angle iron as the center of their survey.

Background gamma radiation exposure level in the site vicinity at the time of the survey ranged from 6.5 to 7.0 microentgen per hour (μR/hr). The site radiation levels were at or below background, with the exception of one isolated spot. This spot was an area approximately 6 inches in diameter located about 30 feet east of the center marker. Gamma radiation exposure level at ground elevation at this spot was 10.6 μR/hr. During the geophysical survey, a verification radiological survey identified another isolated area approximately 8 inches to the south of the original spot. This new area had a reading of 14.2 μR/hr. According to Chem-Nuclear, the elevated levels at the second location appeared related to the first, which still read about 10.6 uR/hr.

A ground penetrating radar (GPR) survey was conducted over RWDS 1022E. Numerous anomalies were detected indicative of small buried objects at depths ranging from 1 to 7 feet. Because of the characteristics of the soil, the GPR penetration was limited to a maximum of 7 feet. No direct correlation could be made with the detected anomalies and the area of elevated radiation levels.

An induced electromagnetic (EM) survey was conducted at RWDS 1022E, collecting data over four east-west parallel lines across the 100 by 100 feet area of interest. An anomaly covering 13 feet by 39 feet area was detected. The anomaly may be a large metallic object or a group of small metallic objects at a depth of 6 to 8 feet. A separate EM-34 survey corroborated the existence of this anomaly. This large anomaly was about 10 feet to the west of the spot with elevated radiation levels.

A total magnetic field gradiometer survey was conducted at RWDS 1022E which revealed four separate gravity anomalies. Three of these anomalies were in the area coinciding with the large EM anomaly. The estimated depths of these anomalies were 15 to 20 feet. The fourth anomaly was located approximately 32 feet to the east of the site's center mark, close to the area with the elevated radiation levels, at a depth of approximately 5 feet.

Removal Action. In July 1991, RWDS 1022E was excavated with a tracked backhoe. Following clearing of the site and setting up the controlled area, soil was removed in lifts and stockpiled on the site. Screening of each lift was performed with a metal detector, radiation survey instruments, and a photoionization detector (PID). Samples of each lift were collected from the stockpiles and were analyzed by Armstrong Laboratory's on-site laboratory for gross alpha, gross beta, gamma spectroscopy.

A small amount of radioactive waste was encountered at this site. The waste encountered consists of three small radioactive objects including the following:

1. Thorium object, 291 gram, activity 2.1 nanocuries per gram (nCi/g)
2. Thorium object, 119 grams, activity 1.7 nCi/g
3. Radium compass, 70 grams, activity 544 picocuries per gram (pCi/g).

Also encountered were 180 cubic feet (6.67 cubic yards) of organically-contaminated soils. These soils were containerized in two B-25 boxes for proper disposal by Tinker AFB through their Defense Reutilization Marketing Organization (DRMO).

Conclusions. The removal action was performed the week of July 8, 1991. RWDS 1022E was excavated to the depth required to both resolve the anomalies and to reach native (undisturbed) soils. The anomalies were accounted for by locating foil blankets at various depths of the excavation.

Following completion of the excavations, the site was cleared by Armstrong Laboratory. They conducted a confirmatory survey of the excavations and the stockpiles, finding no readings above background. The site is now covered by the RCRA cap for Landfill 3.

Recommendations. Based on the documents reviewed, there is limited data available for adequate characterization of this site. For instance, all investigations at this site have mainly focused on the analysis of radioactive waste constituents. No hazardous waste constituents have been addressed. Therefore, it is recommended that additional investigations be conducted during the Phase II RFI. Specific data needs to determine the nature and extent of contamination will be presented in the work plan and sampling plan developed during the Phase II RFI. At a minimum, the following recommendations should be implemented:

- Obtain soil samples for VOC, SVOC, and metals analyses.

- Collect site-specific soil background samples to be used in addition to USGS soil data to distinguish site-related from background concentrations in a statistically significant manner during the Phase II investigation.

- Obtain groundwater samples for VOC, SVOC, metals, and inorganic parameters analyses.

1.0 Introduction

1.1 Purpose and Scope

This document has been prepared in response to the Department of Air Force, Tinker Air Force Base (AFB), Oklahoma request for a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Summary Report for solid waste management unit (SWMU)-22, Radioactive Waste Disposal Site (RWDS) 1022E.

The objective of this RFI Summary Report is to provide Tinker AFB with one comprehensive report that summarizes the various investigations that have occurred at RWDS 1022E since the first environmental investigation was initiated on Base in 1981. The purpose of this comprehensive summary document is to:

- Characterize the site (Environmental Setting).
- Define the source (Source Characterization).
- Define the degree and extent of contamination (Contamination Characterization).
- Identify potential receptors.
- Identify all action levels for the protection of human health and the environment.

Additionally, this document briefly describes the procedures, methods, and results of all previous investigations (removal actions and baseline risk assessment) that relate to RWDS 1022E and contaminant releases, including information on the type and extent of contamination at the site, and actual or potential receptors. Where previous investigations, reports, or studies were not comprehensive and did not furnish the information required to determine the nature and extent of contamination, future work that can be conducted to complete the investigation has been recommended.

1.2 Preface

In 1980, Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to address the cleanup of hazardous waste disposal sites across the country. CERCLA gave the president authority to require responsible parties to remediate the sites or to undertake response actions through use of a fund (the Superfund). The president, through Executive Order 12580, delegated the U.S. Environmental Protection Agency (EPA) with the responsibility to investigate and remediate private party hazardous waste disposal sites that created a threat to human health and the environment. The president delegated responsibility for investigation and cleanup of federal facility disposal sites to the various federal agency heads. The Defense Environmental Restoration Program (DERP) was formally

established by Congress in Title 10 U.S. Code (USC) 2701-2707 and 2810. DERP provides centralized management for the cleanup of U.S. Department of Defense (DOD) hazardous waste sites consistent with the provisions of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] 300), and Executive Order 12580. To support the goals of DERP, the Installation Restoration Program (IRP) was developed to identify, investigate, and clean up contamination at installations.

Under the Air Force IRP, Tinker AFB began a Phase I study similar to a preliminary assessment/site investigation (PA/SI) in 1981 (Engineering Science [ES], 1982). This study helped locate 14 sites that needed further investigation. A Phase II study was performed in 1983 (Radian Corporation [Radian], 1985a,b).

In 1986, Congress amended CERCLA through the SARA. SARA waived sovereign immunity for federal facilities. This act gave EPA authority to oversee the cleanup of federal facilities and to have the final authority for selecting the remedial action at federal facilities placed on the National Priorities List (NPL) if the EPA and the relevant federal agency cannot concur in the selection. Congress also codified DERP (SARA Section 211), establishing a fund for the DOD to remediate its sites because the Superfund is not available for the cleanup of federal facilities. DERP specifies the type of cleanup responses that the fund can be used to address.

In response to SARA, the DOD realigned its IRP to follow the investigation and cleanup stages of the EPA:

- PA/SI
- Remedial investigation/feasibility study (RI/FS)
- Record of Decision (ROD) for selection of a remedial action
- Remedial design/remedial action.

In 1984, Congress amended RCRA with the Hazardous and Solid Waste Amendments (HSWA) which allow the EPA to require, as a permit condition, a facility to undertake corrective action for any release of hazardous waste or constituents from any SWMU at a treatment, storage, and disposal (TSD) facility. On January 12, 1989 Tinker AFB submitted its Part B permit application for renewal of its operating RCRA hazardous waste storage facility permit.

EPA, in the Hazardous Waste Management Permit for Tinker AFB, dated July 1, 1991, identified 43 SWMUs and two areas of concern (AOC) on Tinker AFB that need to be addressed. This permit requires Tinker AFB to investigate all SWMUs and AOCs and to perform corrective action at those identified as posing a threat to human health or the environment. This RFI Summary Report has been prepared to determine whether sufficient investigations have been conducted to meet the permit requirements for RWDS 1022E and to document all determinations.

1.3 Facility Description

Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan area, in Oklahoma County (Figure 1-1) with its approximate geographic center located at 35° 25' latitude and 97° 24' longitude (U.S. Geological Survey [USGS], 1978). The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. An additional area east of the main Base is used by the Engineering Installation Division (EID) and is known as Area D. The Base encompasses approximately 5,000 acres. Tinker AFB began operations in 1942 and serves as a worldwide repair depot for a variety of aircraft, weapons, and engines. These activities require the use of hazardous materials and result in the generation of hazardous wastes. These wastes have included spent organic solvents, waste oils, waste paint strippers and sludges, electroplating wastewaters and sludges, alkaline cleaners, acids, Freon^{TM}, jet fuels, and radium paints. Wastes that are currently generated are managed at two permitted hazardous waste storage facilities. However, prior to enactment of RCRA, industrial wastes were discharged into unlined landfills and waste pits, streams, sewers, and ponds. Past releases from these landfills, pits, etc., as well as from underground tanks, have occurred. As a result, there are numerous sites of soil, groundwater, and surface water contamination on the Base.

The various reports generated as a result of investigative activities conducted at the RWDS 1022E have been reviewed and evaluated in terms of the sites' status under RCRA regulations. A summary based on the review of these reports for RWDS 1022E is presented in the following chapters and sections. In addition, recommendations for additional work is given at the end of the summary report.

1.4 Site Description

RWDS 1022E is located northwest of Landfill No. 3 (SWMU-5), as shown on Figures 1-2 and 1-3. The U.S. Army Corps of Engineers (USACE, 1989) records search report stated that

STARTING DATE: 03/17/94	DATE LAST REV.:	DRAFT. CHCK. BY:G. PACHECO	INITIATOR: C. WALLACE	DWG. NO.:
DRAWN BY:P.O. TERRY	DRAWN BY:	ENGR. CHCK. BY: C. WALLACE	PROJ. MGR.J. TAYLOR	PROJ. NO.:

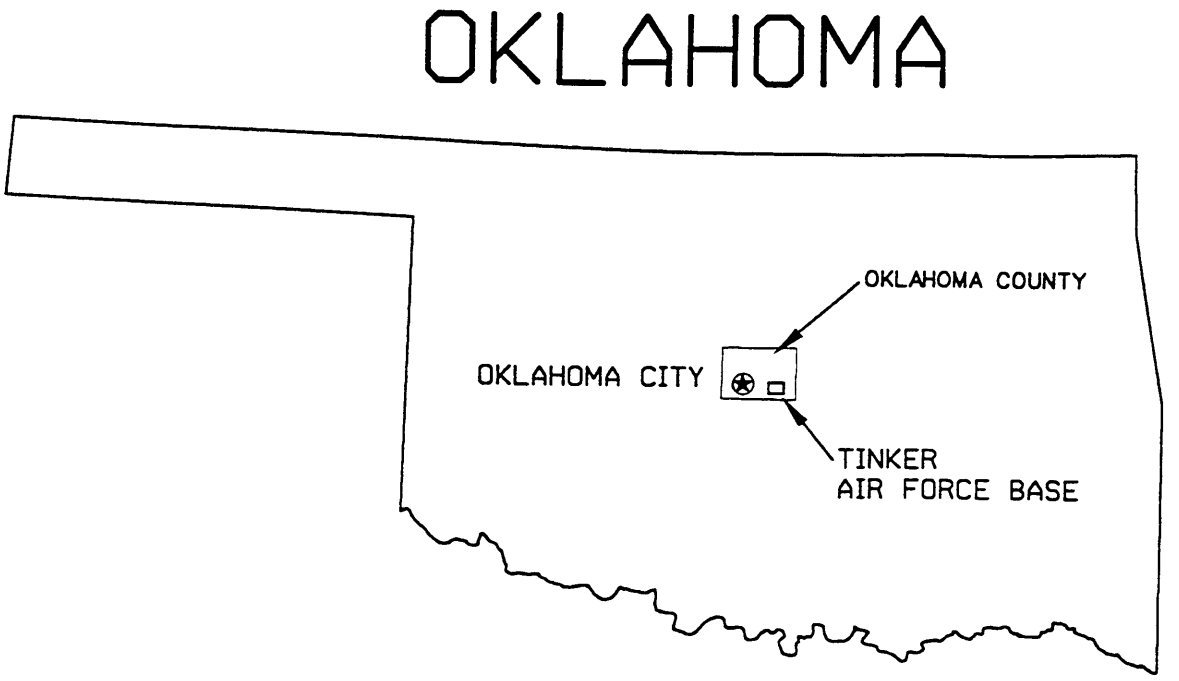


FIGURE 1-1
TINKER AIR FORCE BASE
OKLAHOMA
STATE INDEX MAP

PREPARED FOR
TINKER AFB
OKLAHOMA

3/23/94 POT
FILENAME: G:\TINKER\40983202.075

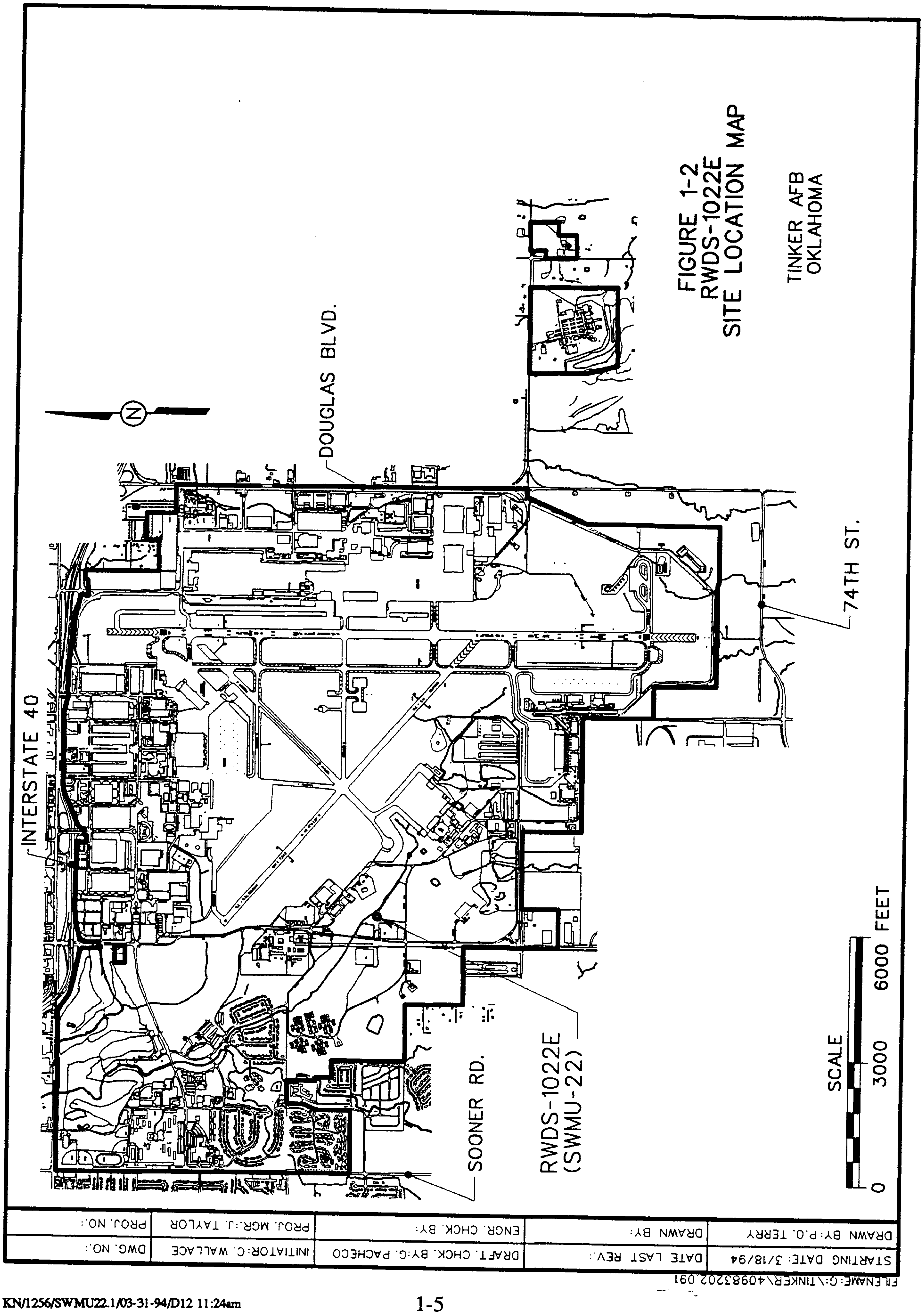


FIGURE 1-2
RWDS-1022E
SITE LOCATION MAP
TINKER AFB
OKLAHOMA
INTERSTATE 40
DOUGLAS BLVD.
74TH ST.
SOONER RD.
RWDS-1022E
(SWMU-22)
N
SCALE
0
3000
6000 FEET
STARTING DATE: 3/18/94
DRAWN BY: P.O. TERRY
DATE LAST REV.:
DRAWN BY:
DRAFT. CHCK. BY: G. PACHECO
ENGR. CHCK. BY:
INITIATOR: C. WALLACE
PROJ. MGR.: J. TAYLOR
DWG. NO.:
PROJ. NO.:
FILENAME: G:\TINKER\40983202.091

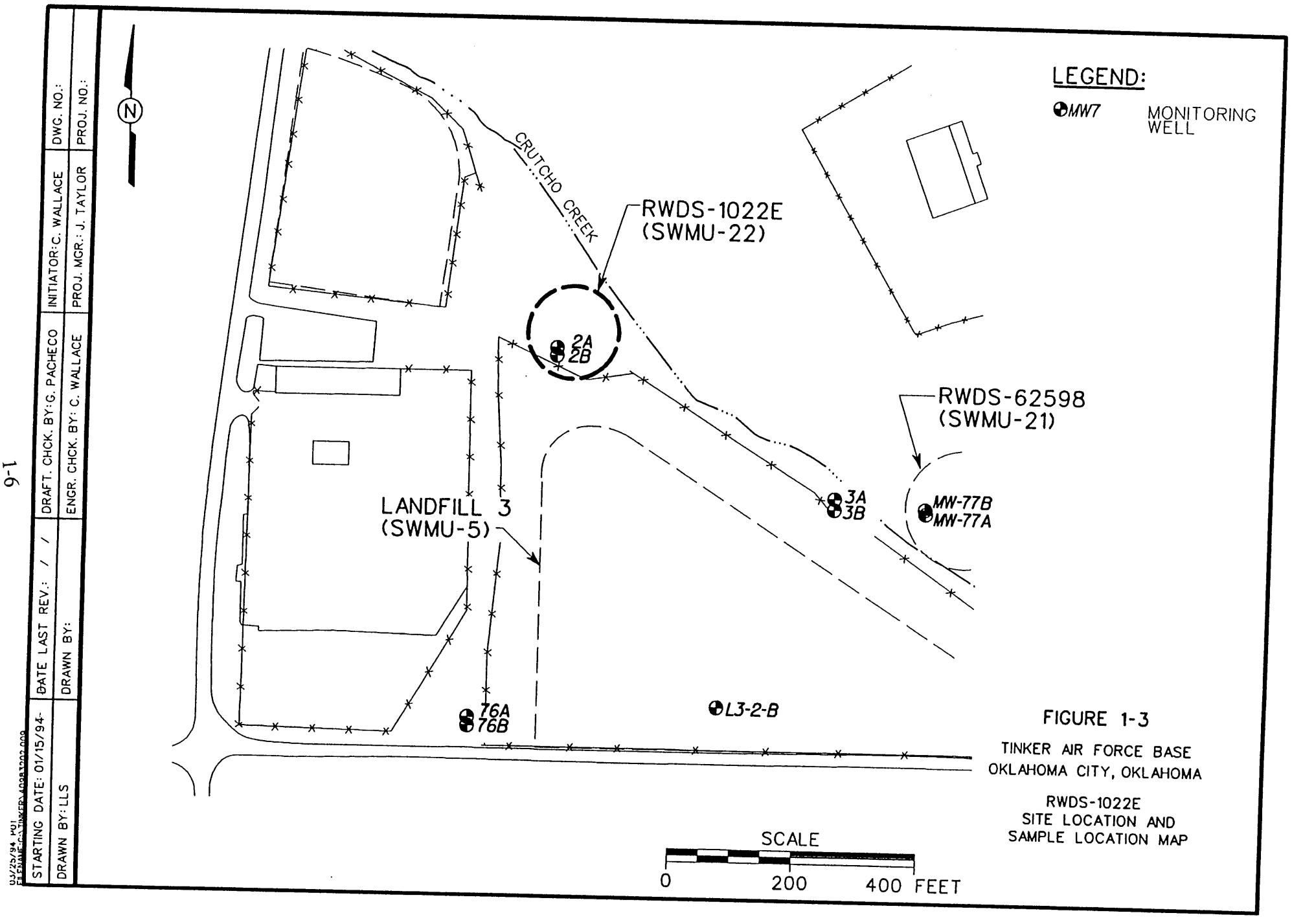


FIGURE 1-3

TINKER AIR FORCE BASE
OKLAHOMA CITY, OKLAHOMA

RWDS-1022E
SITE LOCATION AND
SAMPLE LOCATION MAP

eight to ten containers of radioactive material from Building 230 were buried 30 feet deep at this site. Other reports have indicated that this material probably consisted of boxes of blocking tubes (or vacuum tubes) each containing 1 millicurie(mCi) of radium-226. Prior to the removal action, an unlabeled piece of angle iron marked the position believed to be the center of the site (Chem-Nuclear Environmental Services [Chem-Nuclear], 1990). After the removal action, RWDS 1022E was covered by the cap placed over the adjacent landfill.

2.0 Background

2.1 Site Operations and History

Tinker AFB was originally known as the Midwest Air Depot and began operations in July 1941. The site was activated March 1942. During World War II, the depot was responsible for reconditioning, modifying, and modernizing aircraft, vehicles, and equipment.

RWDS 1022E was reported to be the burial site of eight to ten containers of radioactive material that may have consisted of blocking tubes (vacuum tubes), each containing 1 mCi of radium-226.

2.2 Summary of Previous Investigations

The RWDS record search performed by the USACE in 1989 revealed information on two previous radiological surveys and an ongoing groundwater investigation.

Radiological Surveys. A survey with beta/gamma radioactivity detector equipment in November 1971 detected a value of 0.03 milliroentgen (mR/hr) which is slightly above the background value of .02 mR/hr. On September 23, 1988, the Tinker Radiation Officer performed a survey that detected a value of .02 mR/hr 5 feet west of the angle iron marker.

Groundwater Investigations. As part of the ongoing investigations of SWMUs 3 through 6, several monitoring wells have been installed in the RWDS 1022E area. Also, borings were drilled into the landfill trenches and solid waste and leachate samples were taken for analysis. Monitoring well 2 (which is very close to the site) did not indicate any radioactive contamination when tested in 1986, although several other monitoring wells in this area did indicate radioactivity over background. Testing results from the leachate in trench boring 3-3 (which is also very close to the site) indicated that the gross alpha was below detection limits, but the gross beta was 80 picocuries per liter (pCi/L) with a 15 plus or minus counting error. Background for beta is 9 pCi/L, as calculated in the Tinker AFB IRP groundwater assessment (CDM Federal Programs Corporation [CDM], 1993).

RWDS Phase II Investigations. The RWDS Phase II investigations consisted of extensive surface radiological and geophysical surveys (Chem-Nuclear, 1990). The Air Force specifically directed that no intrusive sampling was permitted during this phase of the investigation.

As a result, all surveys were designed to be nonintrusive in nature, and were restricted to activities on or above the ground surface.

This section explains the methodology of the RWDS investigative surveys, and provides a basic description of the equipment used to perform the surveys.

Radiological Survey Equipment and Technique. The radiological surveys consisted primarily of ground surface radiation surveys using an Eberline ESP-2 with a SPA-3 probe (2-inch-by-2-inch NaI crystal) in the ratemeter mode. At any location with surface radiation levels above background, on-contact readings were taken with an Eberline RM-20 instrument with an HP-260 probe, in order to confirm the absence of surface contamination.

Based on the RWDS Phase I research, RWDS 1022E contained radium contaminated objects. Among other radioactive decay particles, radium emits gamma rays during the decay process. Since the contaminated objects were suspected to be buried at a significant depth, the soil above the objects would attenuate all except the gamma radiation before it reached the surface.

The gamma radiation is also subject to some degree of attenuation, thereby lowering its energy. The SPA-3 probe was chosen for the radiological surveys due to its sensitivity to low energy gamma rays.

In order to ensure a thorough radiological survey, the site was sectioned off into grids of appropriate size. The site was then surveyed grid by grid, independent of, and unbiased by, previous radiological surveys.

All radiation survey readings were recorded on the survey logs/grid maps in microroentgen per hour (μR/hr). In general, all readings were taken on-contact with the ground surface. The locations with on-contact readings in excess of 16 μR/hr were designated as "hot spots" and physically marked on site with a flagged wooden stake. The level of 16 μR/hr was chosen for two reasons:

- It was greater than twice background (background levels were in the range of 6.0 to 7.0 μR/hr)

- It was approximately 10 μR/hr above background. For those grids where no "hot spots" were detected, the highest level for that grid was recorded. For grids which contained an area of readings in excess of 16 μR/hr, but could not be

traced to a single point, the general area reading was recorded for those grids (or portion thereof).

Geophysical Survey Equipment and Technique. Following the previously described surface radiation surveys, RWDS 1022E was subjected to a series of nonintrusive geophysical surveys. The lateral and/or vertical variations mapped by geophysical techniques can provide a model for the geologic environment of the investigated site, as well as delineate cultural or synthetic variations in the materials present beneath the surface. The geophysical surveys were conducted in an attempt to correlate inconsistencies in the subsurface physical properties with information available on and above the surface.

An inconsistency in the subsurface properties detected as the result of a geophysical survey is referred to an "anomaly." Since the RWDS Phase I research revealed that RWDS 1022E was associated with excavation and subsequent burial activities, and probably contained radium contaminated metals and/or metallic containers, the geophysical survey techniques were designed with emphasis on the detection of metallic and soil density variation anomalies.

RWDS 1022E was subjected to various types of geophysical surveys which were independent of the preceding radiological survey. Because this site contained elevated radiation levels at the surface, additional concentrated geophysical surveys were conducted, in the vicinity of the "hot spot(s)," to maximize the probability of detecting an anomaly which could be related to the elevated radiation level(s).

At RWDS 1022E, several types of geophysical survey equipment were utilized in order to measure different physical properties. The following is a basic description of the geophysical survey equipment used during this investigation, and the physical properties that they exploit.

Ground Penetrating Radar. Ground penetrating radar (GPR) is a system which transmits high-frequency electromagnetic (EM) energy into the earth and detects return energy reflected from subsurface structural interfaces or buried objects. GPR is useful in detecting and mapping near-surface structures, soil-unit interfaces, and buried natural or man-made objects. It is especially useful in the location of utility lines, underground storage tanks, and buried waste containers, which are not readily detectable by other geophysical methods by virtue of their physical properties or nearby interference (such as power lines, metal fences, buildings, etc.).

Three different GPR antennas were utilized during the course of the RWDS 1022E investigations in order to maximize the resolution and/or depth of the subsurface search. The highest frequency of EM energy utilized was 500 megahertz (MHz). This offered the best resolution of near surface anomalies, but its depth of search was limited to approximately 3 feet. The middle frequency employed was 30 MHz, which increased the effective search depth, but sacrificed the degree of resolution between various anomalies. This low frequency energy maximized the effective search depth, but offered the least amount of resolution.

The GPR geophysical survey was performed in an attempt to examine the variation of soil density characteristic to sites subject to previous excavation. It is also effective in detecting voids created by containers.

Induction Electromagnetic Conductivity (EM-31 and EM-34). The induction EM method measures the apparent conductivity of the subsurface environment. The conductivity is a function of the properties of the materials it contains, such as soil or rock type, moisture content, metallic properties, organic or inorganic concentrations, permeability, and porosity.

Both the EM-31 and the EM-34 instruments were used for these geophysical surveys. The EM-34 has a greater effective search depth than the EM-31 due to the greater distance between the transmitter and receiver poles. The EM-31 and EM-34 instruments measure the subsurface conductivity by radiating an electromagnetic field which induces eddy currents in the earth. The magnitude of these eddy currents is proportional to the conductivity of the material through which they flow. The induced currents generate secondary magnetic fields, which intercept the receiver coil of the instrument. The instrument processes the received signal and produces an output voltage related to the conductivity of the subsurface material. The varying output voltages for different locations are recorded in a data storage device during the actual survey process. Upon completion of the survey, the data can be transferred for automated or manual interpretation.

EM conductivity geophysical surveys were reported in an attempt to examine the conductivity properties of the metallic objects reported to be the source of the radioactive contamination at the site.

Total Magnetic Field Gradiometer (Magnetometer). The total magnetic field intensity method measures the cumulative perturbation of the earth's magnetic field. Magnetic field

perturbations are a function of the properties of the subsurface materials, such as soil or rock type, buried debris, or any accumulation or aggregation of ferromagnetic materials.

The magnetometer measures the total magnetic field intensity at two sensor heights and records the readings in a data storage device during the course of the survey. Upon completion of the survey, the data can be transferred for automated or manual interpretation.

A magnetometer geophysical survey was performed in an attempt to exploit the magnetic properties of ferrous materials which may be associated with the radium contaminated objects, or their containers, buried at the disposal sites.

Removal Action. The objective of the 1991 removal action at RWDS 1022E was to either locate and exhume radioactive waste reported to have been buried at the site or to show that the waste did not currently exist at the site.

2.3 Current Regulatory Status

The IRP has been ongoing at Tinker AFB since the early 1980s. IRP studies on the Base were conducted according to IRP guidance, which is essentially the same as EPA's guidance for conducting RI/FS under CERCLA. All investigation and removal actions have been closely monitored and approved by the EPA.

Since receiving the Hazardous Waste Management Permit on July 1, 1991, many of the IRP sites have come under the jurisdiction of the RCRA permits branch of EPA. As such, they have been identified as SWMUs; however, a large amount of work has already been performed at most of these sites under the IRP. Additional investigation at the SWMUs will be performed under the IRP.

3.0 Environmental Setting

3.1 Topography and Drainage

3.1.1 Topography

Regional/Tinker AFB. The topography of Oklahoma City and surrounding area varies from generally level to gently rolling in appearance. Local relief is primarily the result of dissection by erosional activity or stream channel development. At Oklahoma City, surface elevations are typically in the range of 1,070 to 1,400 feet mean sea level (msl). At Tinker AFB, ground surface elevations vary from 1,190 feet msl near the northwest corner where Crutcho Creek intersects the Base boundary to approximately 1,320 feet msl at Area D (EID).

Site. After the removal action was completed for RWDS 1022E the site was covered by the cap from the adjacent Landfill 3. This cap has a 3 to 5 percent slope toward the west.

3.1.2 Surface Drainage

Regional/Tinker AFB. Drainage of Tinker AFB land areas is accomplished by overland flow of runoff to diversion structures and then to area surface streams, which flow intermittently. The northeast portion of the Base is drained primarily by unnamed tributaries of Soldier Creek, which is itself a tributary of Crutcho Creek. The north and west sections of the Base, including the main instrument runway, drain to Crutcho Creek, a tributary of the North Canadian River. Two small unnamed intermittent streams crossing installation boundaries south of the main instrument runway generally do not receive significant quantities of Base runoff due to site grading designed to preclude such drainage. These streams, when flowing, extend to Stanley Draper Lake, approximately one-half mile south of the Base.

Site. Surface drainage in the area of RWDS 1022E is influenced by the RCRA cap for Landfill 3 that extends over RWDS 1022E. The cap has a 3 to 5 percent slope and was installed after the removal action for RWDS 1022E was completed. The cap is an engineered cap with a membrane liner. The drainage of the cap above the RWDS 1022E site is towards the west.

3.2 Geology

3.2.1 Regional/Tinker AFB Geology

Tinker AFB is located within the Central Redland Plain Section of the Central Lowland physiographic province, which is tectonically stable. No major fault or fracture zones have been mapped near Tinker AFB. The major lithologic units in the area of the Base are relatively flat-lying and have a regional westward dip of about 0.0076 foot per foot (ft/ft) (Bingham and Moore, 1975).

Geologic formations that underlie Tinker AFB include, from oldest to youngest, the Wellington Formation, Garber Sandstone, and the Hennessey Group; all are Permian in age.

All geologic units immediately underlying Tinker AFB are sedimentary in origin. The Garber Sandstone and Wellington Formation are commonly referred to as the Garber-Wellington Formation due to strong lithologic similarities. These formations are characterized by fine-grained, calcareously-cemented sandstones interbedded with shale. The Hennessey Group consists of the Fairmont Shale and the Kingman Siltstone. It overlies the Garber-Wellington Formation along the eastern portion of Cleveland and Oklahoma counties. Quaternary alluvium is found in many undisturbed streambeds and channels located within the area.

Stratigraphy. Tinker AFB lies atop a sedimentary rock column composed of strata that ranges in age from Cambrian to Permian above a Precambrian igneous basement. Quaternary alluvium and terrace deposits can be found overlying bedrock in and near present-day stream valleys. At Tinker AFB, Quaternary deposits consist of unconsolidated weathered bedrock, fill material, wind-blown sand, and interfingering lenses of sand, silt, clay, and gravel of fluvial origin. The terrace deposits are exposed where stream valleys have downcut through older strata and have left them topographically above present-day deposits. Alluvial sediments range in thickness from less than a foot to nearly 20 feet.

Subsurface (bedrock) geologic units which outcrop at Tinker AFB and are important to understanding groundwater and contaminant concerns at the Base consist of, in descending order, the Hennessey Group, the Garber Sandstone, and the Wellington Formation (Table 3-1). These bedrock units were deposited during the Permian Age (230 to 280 million years ago) and are typical of redbed deposits formed during that period. They are composed of a conformable sequence of sandstones, siltstones, and shales. Individual beds are lenticular and vary in thickness over short horizontal distances. Because lithologies are similar and because

Table 3-1

Major Geologic Units in the Vicinity of Tinker AFB (Modified from Wood and Burton, 1968)

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
QUATERNARY	PLEISTOCENE AND RECENT	Alluvium	0-70	Unconsolidated and interfingering lenses of sand, silt, clay, and gravel in the flood plains and channels of stream	Moderately permeable. Yields small to moderate quantities of water in valleys of larger streams. Water is very hard, but suitable for most uses, unless contaminated by industrial wastes or oil field brines.
		Terrace deposits	0-100	Unconsolidated and interfingering lenses of sand, silt, gravel, and clay that occur at one or more levels above the flood plains of the principal streams.	Moderately permeable. Locally above the water table and not saturated. Where deposits have sufficient saturated thickness, they are capable of yielding moderate quantities of water to wells. Water is moderately hard to very hard, but less mineralized than water in other aquifers. Suitable for most uses unless contaminated by oil field brines.

Table 3-1

System	Series	Stratigraphic Unit	Thickness (feet)	Description and Distribution	Water-Bearing Properties
PERMIAN	LOWER PERMIAN	Hennessey Group (includes Kingman Siltstone and Fairmont Shale)	700	Deep-red clay shale containing thin beds of red sandstone and white or greenish bands of sandy or limey shale. Forms relatively flat to gently rolling grass-covered prairie.	Poorly permeable. Yields meager quantities or very hard, moderately to highly mineralized water to shallow domestic and stock wells. In places water contains large amounts of sulfate.
		Garber Sandstone	500±	Deep-red clay to reddish-orange, massive and cross-bedded fine-grained sandstone interbedded and interfingered with red shale and siltstone	Poorly to moderately permeable. Important source of groundwater in Cleveland and Oklahoma counties. Yields small to moderate quantities of water to deep wells; heavily pumped for industrial and municipal uses in the Norman and Midwest City areas. Water from shallow wells hard to very hard; water from deep wells moderately hard to soft. Lower part contains water too salty for domestic and most industrial uses.
		Wellington Formation	500±	Deep-red to reddish-orange massive and cross-bedded fine-grained sandstone interbedded with red, purple, maroon, and gray shale. Base of formation not exposed in the area.	

of a lack of fossils or key beds, the Garber Sandstone and the Wellington Formation are difficult to distinguish and are often informally lumped together as the Garber-Wellington Formation. Together, they are about 900 feet thick at Tinker AFB. The interconnected, lenticular nature of sandstones within the sequence forms complex pathways for groundwater movement.

The surficial geology of the north section of the Base is dominated by the Garber Sandstone, which outcrops across a board area of Oklahoma County. Generally, the Garber outcrop is covered by a veneer of soil and/or alluvium up to 20 feet thick. To the south, the Garber Sandstone is overlain by outcropping strata of the Hennessey Group, including the Kingman Siltstone and the Fairmont Shale (Bingham and Moore, 1975). Drilling information obtained as a result of geotechnical investigations and monitoring well installation confirms the presence of these units.

Depositional Environment. The Permian-age strata presently exposed at the surface in central Oklahoma were deposited along a low-lying north-south oriented coastline. Land features included meandering to braided sediment-loaded streams that flowed generally westward from highlands to the east (ancestral Ozarks). Sand dunes were common, as were cut-off stream segments that rapidly evaporated. The climate was arid and vegetation sparse. Off shore the sea was shallow and deepened gradually to the west. The shoreline's position varied over a wide range. Isolated evaporitic basins frequently formed as the shoreline shifted.

Across Oklahoma, this depositional environment resulted in an interfingering collage of fluviatile and wind-blown sands, clays, shallow marine shales, and evaporite deposits. The overloaded streams and evaporitic basins acted as sumps for heavy metals such as iron, chromium, lead, and barium. Oxidation of iron in the arid climate resulted in the reddish color of many of the sediments. Erosion and chemical breakdown of granitic rocks from the highlands resulted in extensive clay deposits. Evaporite minerals such as anhydrite ($CaSO_4$), barite ($BaSO_4$), and gypsum ($CaSO_4 \cdot 2H_2O$) are common.

Around Tinker AFB, the Hennessey Group represents deposition in a tidal flat environment cut by shallow, narrow channels. The Hennessey Group is comprised predominantly of red shales which contain thin beds of sandstone (less than 10 feet thick) and siltstone. In outcrop, "mudball" conglomerates, burrow surfaces, and dessication cracks are recognized. These units

outcrop over roughly the southern half of the Base, thickening to approximately 70 feet in the southwest from their erosional edge (zero thickness) across the central part of Tinker AFB.

In contrast, the Garber Sandstone and the Wellington Formation around Tinker AFB consist of an irregularly-interbedded system of lenticular sandstones, siltstones, and shales deposited either in meandering streams in the upper reaches of a delta or in a braided stream environment. Outcrop units north of Tinker AFB exhibit many small to medium channels with cut and fill geometries consistent with a stream setting. Sandstones are typically cross-bedded. Individual beds range in thickness from a few inches to approximately 50 feet and appear massive, but thicker units are often formed from a series of "stacked" thinner beds. Geophysical and lithologic well logs indicate that from 65 to 75 percent of the Garber Sandstone and the Wellington Formation are composed of sandstone at Tinker AFB. The percentage of sandstone in the section decreases to the north, south, and west of the Base. These sandstones are typically fine to very fine grained, friable, and poorly cemented. However, where sandstone is cemented by red muds or by secondary carbonate or iron cements, local thin "hard" intervals exist along disconformities at the base of sandstone beds. Shales are described as ranging from clayey to sandy, are generally discontinuous, and range in thickness from a few inches to approximately 40 feet.

Stratigraphic Correlation. Correlation of geologic units is difficult due to the discontinuous nature of the sandstone and shale beds. However, cross-sections (Figure 3-1) demonstrate that two stratigraphic intervals can be correlated over large sections of the Base in the conceptual model. These intervals are represented on geologic cross-sections A-A' and B-B' (Figures 3-2 and 3-3). Section A-A' is roughly a dip section and B-B' is approximately a strike section. The first correlatable interval is marked by the base of the Hennessey Group and the first sandstone at the top of the Garber Sandstone. This interval is mappable over the southern half of Tinker AFB. The second interval consists of a shale zone within the Garber Sandstone which, in places, is comprised of a single shale layer and, in other places, of multiple shale layers. This interval is more continuous than other shale intervals and in cross-sections appears mappable over a large part of the Base. It is extrapolated under the central portion of Tinker AFB where little well controls exists.

Structure. Tinker AFB lies within a tectonically stable area; no major near-surface faults or fracture zones have been mapped near the Base. Most of the consolidated rock units of the Oklahoma City area dip westward at a low angle. A regional dip of 0.0057 to 0.0076 ft/ft in

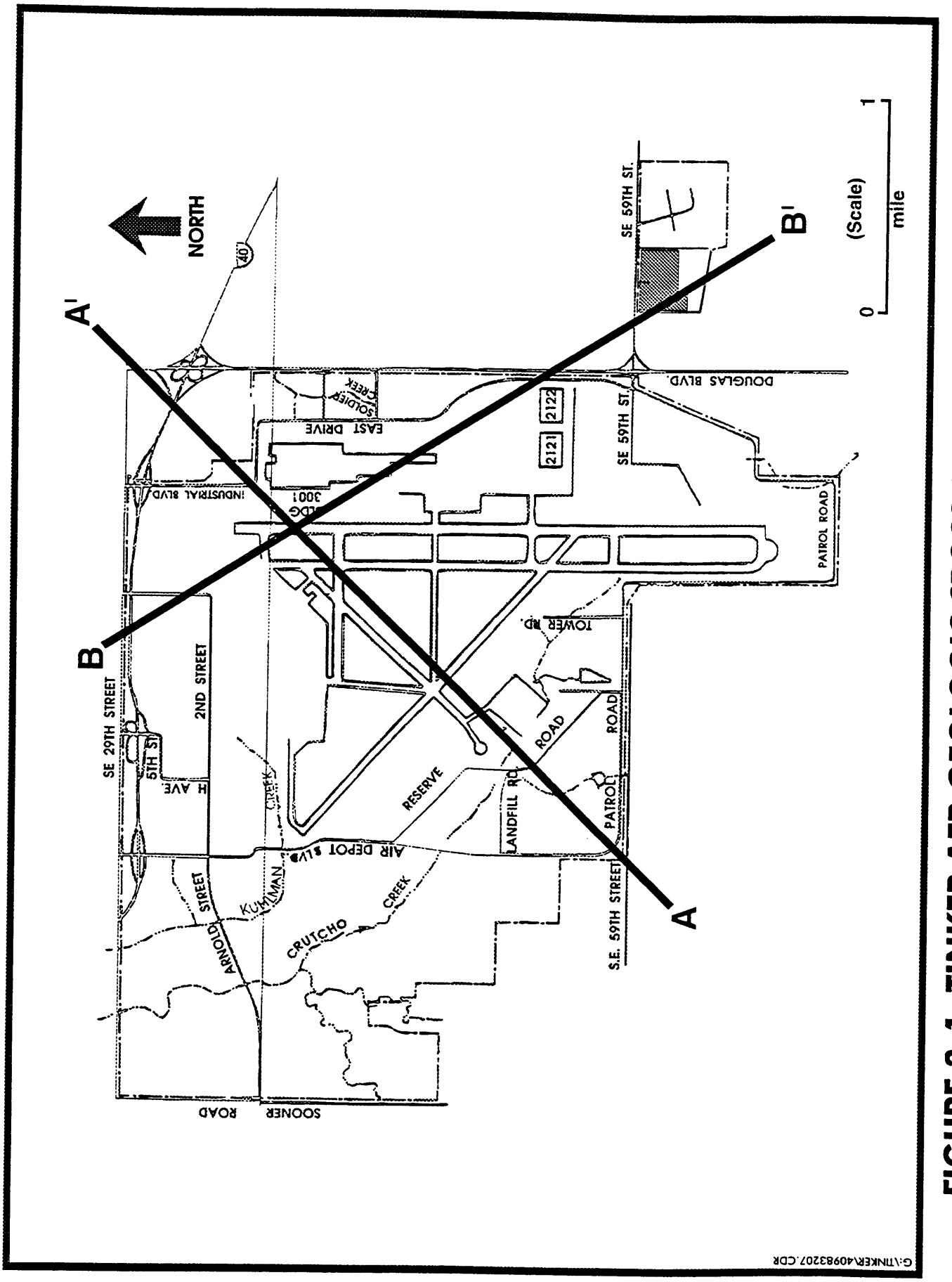


FIGURE 3-1 TINKER AFB GEOLOGIC CROSS SECTION LOCATION MAP

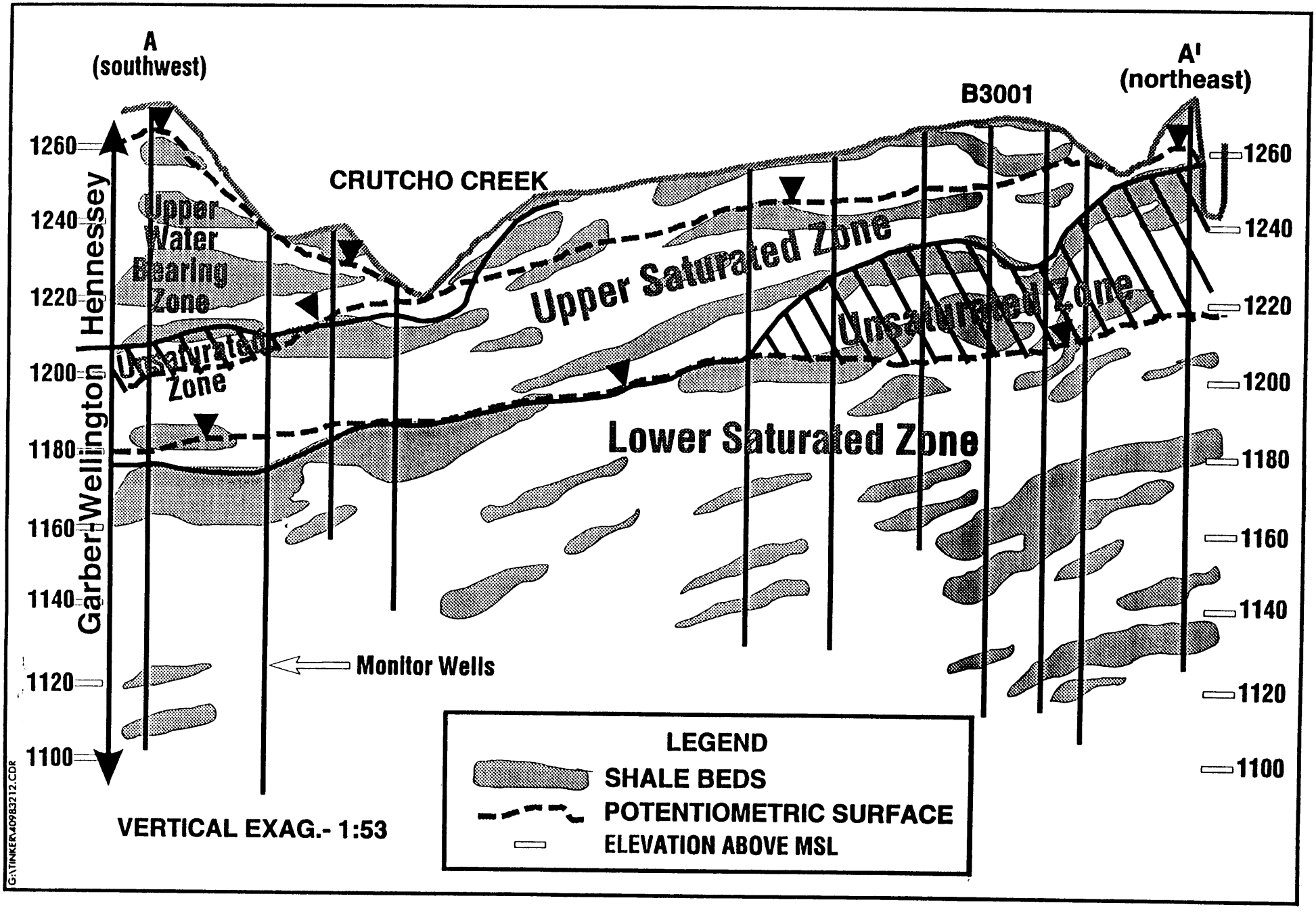


FIGURE 3-2 TINKER AFB GEOLOGIC CROSS SECTION A-A'

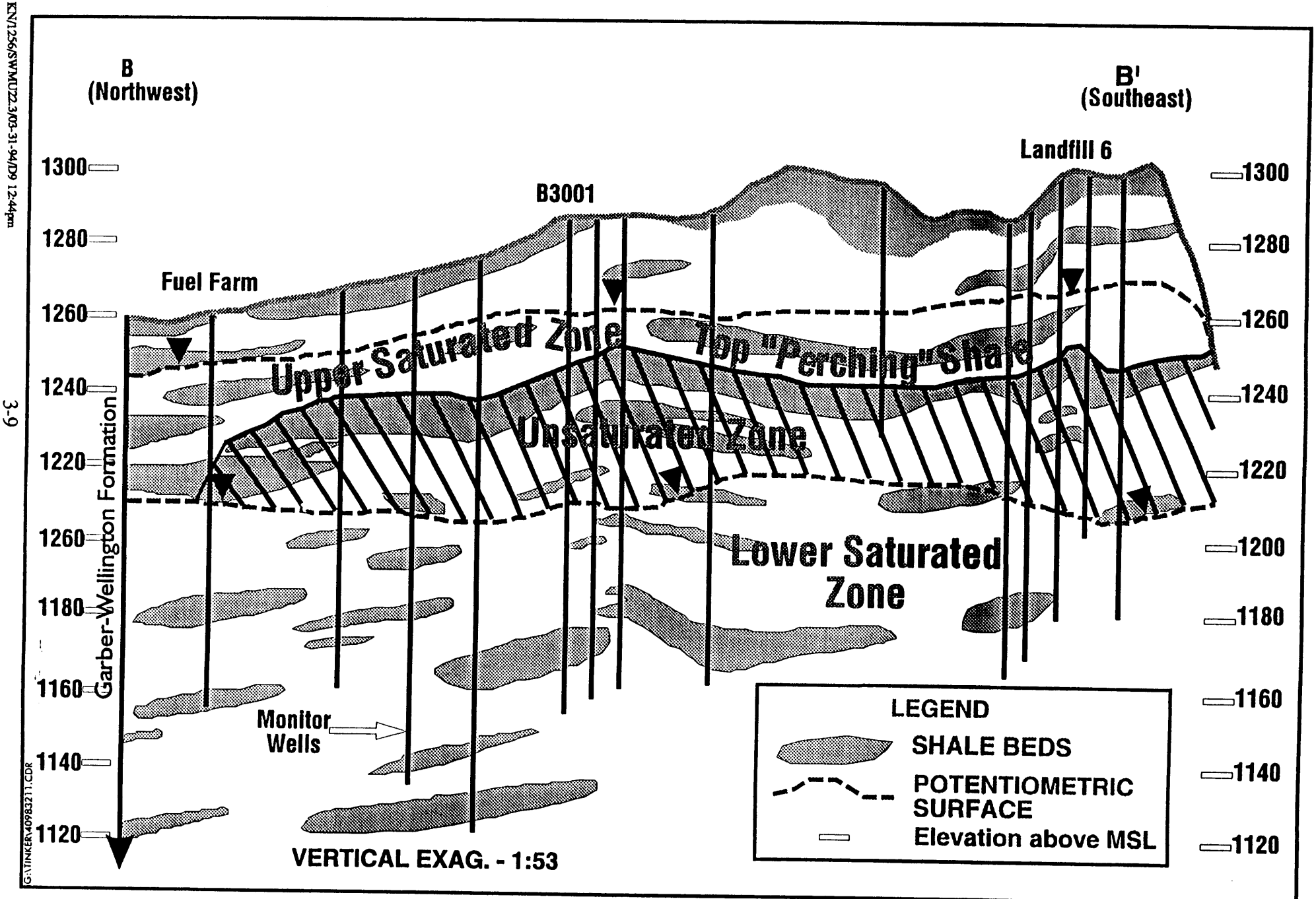


FIGURE 3-3 TINKER AFB GEOLOGIC CROSS SECTION B-B'

a generally westward direction is supported by stratigraphic correlation on geologic cross-sections at Tinker AFB. Bedrock units strike slightly west of north.

Although Tinker AFB lies in a tectonically stable area, regional dips are interrupted by buried structural features located west of the Base. A published east-to-west generalized geologic cross-section, which includes Tinker AFB, supports the existence of a northwest-trending structural trough or syncline located near the western margin of the base. The syncline is mapped adjacent to and just east of a faulted anticlinal structure located beneath the Oklahoma City Oil Field. The fault does not appear to offset Permian-age strata. There are indications that the syncline may act as a "sink" for some regional groundwater (southwest flow) at Tinker AFB before it continues to more distant discharge points.

3.2.2 Site Geology

RWDS 1022E is located just south of the contact between the Hennessey Group and the Garber-Wellington Formation. Alluvial deposits of the Hennessey Group (silts and clays) of varying thickness exist in the shallow subsurface of the RWDS 1022E area, extending from the surface down to a depth of approximately 15 feet below grade.

3.3 Hydrology

3.3.1 Regional/Tinker AFB Hydrology

The most important source of potable groundwater in the Oklahoma City metropolitan area is the Central Oklahoma aquifer system. This aquifer extends under much of central Oklahoma and includes water in the Garber Sandstone and Wellington Formation, the overlying alluvium and terrace deposits, and the underlying Chase, Council Grove, and Admire Groups. The Garber Sandstone and the Wellington Formation portion of the Central Oklahoma aquifer system is commonly referred to as the "Garber-Wellington aquifer" and is considered to be a single aquifer because these units were deposited under similar conditions and because many of the best producing wells are completed in this zone. On a regional scale, the aquifer is confined above by the less permeable Hennessey Group and below by the Late Pennsylvanian Vanoss Group.

Tinker AFB lies within the limits of the Garber-Wellington Groundwater Basin. Currently, Tinker derives most of its water supply from this aquifer and supplements the supply by purchasing from the Oklahoma City Water Department. The nearby communities of Midwest City and Del City derive water supplies from both surface sources and wells tapping the

aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by a municipal distribution system also depend on the Garber-Wellington aquifer. Communities presently depending upon surface supplies (such as Oklahoma City) also maintain a well system drilled into the Garber-Wellington as a standby source of water in the event of drought.

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 AFB is located in an aquifer outcrop area, the Base is considered to be situated in a recharge zone.

According to Wood and Burton (1968) and Wickersham (1979), the quality of groundwater 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.

Tinker AFB presently obtains its water supplies from a distribution system comprised of 29 water wells constructed along the east and west Base boundaries and by purchase from the Oklahoma City Water Department. All Base wells are finished into the Garber-Wellington aquifer. Base wells range from 700 to 900 feet in finished depth, with yields ranging from 205 to 250 gallons per minute. The wells incorporate multiple screens, deriving water supplies from sand zones with a combined thickness from 103 to 184 feet (Wickersham, 1979).

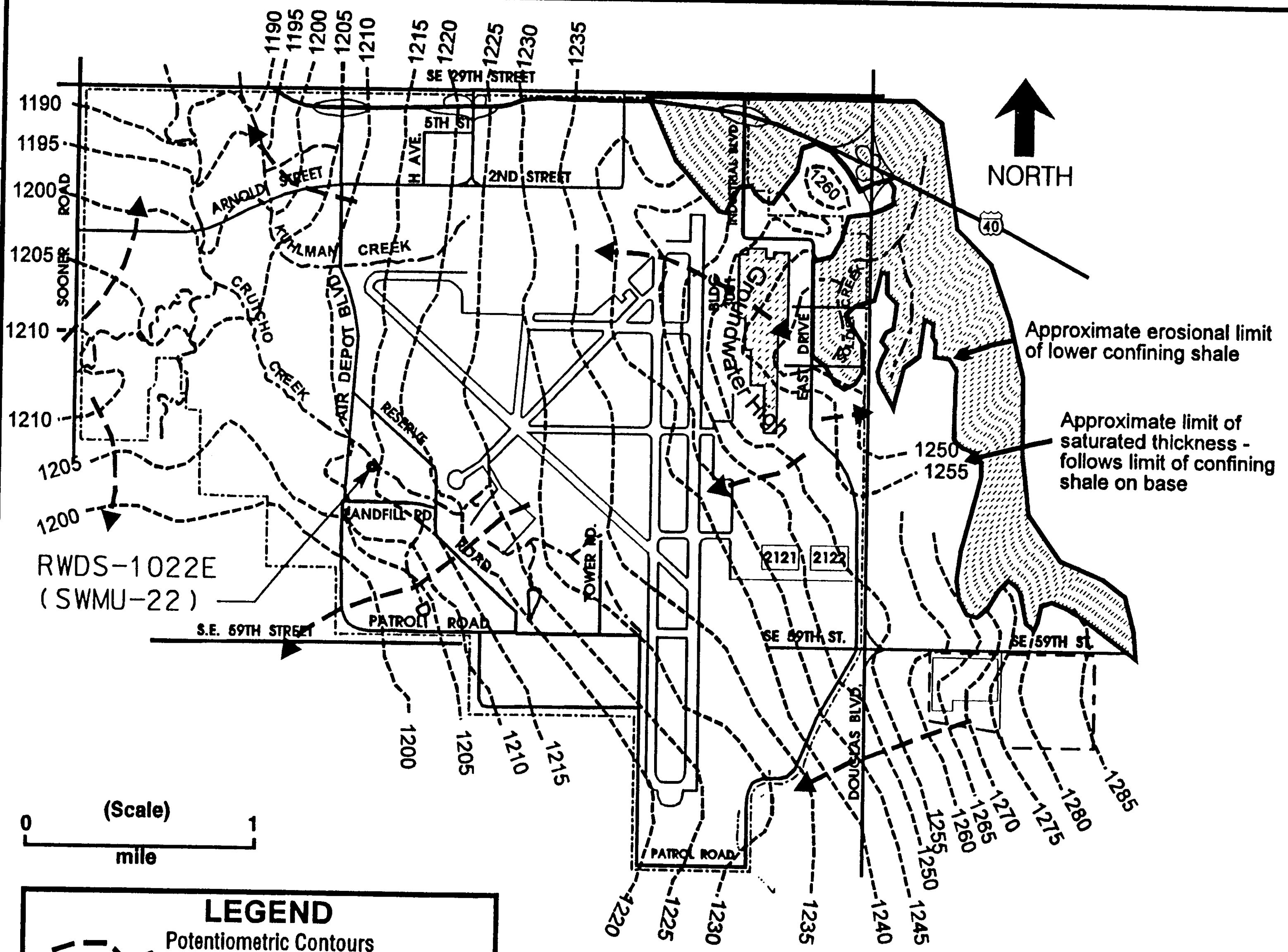
Although the variability in the geology and the recharge system at Tinker AFB makes it difficult to predict local flow paths, Central Oklahoma aquifer water table data show that regional groundwater flow under Tinker varies from west-northwest to southwest, depending on location. This theory is supported by contoured potentiometric data from base monitoring wells which show groundwater movement in the upper and lower aquifer zones to generally follow regional dip. Measured normal to potentiometric contours, groundwater flow gradients range from 0.0019 to 0.0057 ft/ft. However, because flow in the near-surface portions of the aquifer at Tinker AFB is strongly influenced by topography, local stream base-levels, complex subsurface geology, and location in a recharge area, both direction and magnitude of groundwater movement is highly variable. The interaction of these factors not only influences

regional flow but gives rise to complicated local, often transient, flow patterns at individual sites.

As a result of ongoing environmental investigations and the approximately 450 groundwater monitoring wells installed on the Base during various investigations, a better understanding of the specific hydrological framework has emerged. The current conceptual model developed by Tinker AFB (Tinker, 1993), based on the increased understanding of the hydrological framework, has been revised from an earlier model adopted by the USACE. Previous studies reported that groundwater was divided into four water-bearing zones: the perched aquifer, the top of regional aquifer, the regional aquifer, and the producing zone. In the current model, two principal water table aquifer zones and a third less extensive zone have been identified. The third is limited to the southwest quadrant. The third aquifer zone consisted of saturated siltstone and thin sandstone beds in the Hennessey Shale and equates to the upper water bearing zone (UWBZ) described by the USACE at Landfills 1 through 4 (SWMUs 3 through 6) (USACE, 1993). In addition, numerous shallow, thin saturated beds of siltstone and sandstone exist throughout the Base. These are of limited areal extent and are often perched.

In the current conceptual hydrologic model, an upper saturated zone (USZ) and a lower saturated zone (LSZ) are recognized in the interval from ground surface to approximately 200 feet. Below this is found the producing zone from which the Base draws much of its water supply. Figure 3-4 shows the potentiometric surface for the USZ and Figure 3-5 shows the potentiometric surface for the LSZ. The USZ exists mainly under water table (unconfined) conditions, but may be partially confined locally. Conditions in the LSZ are difficult to determine due to screen placement and overly long sandpacks below the screen interval.

The USZ is found at a depth of 5 to 70 feet below ground surface and has a saturated thickness ranging from less than 1 foot at its eastern boundary to over 20 feet in places west of Building 3001. The USZ is erosionally truncated by Soldier Creek along the northeastern margin of Tinker AFB. This aquifer zone is considered to be a perched aquifer over the eastern one-third of Tinker AFB, where it is separated from the LSZ by an underlying confining shale layer and a vadose zone. The confining interval extends across the entire Base, but the vadose zone exists over the eastern one-third of this area. The available hydrogeologic data indicate that the vadose zone does not exist west of a north-south line located approximately 500 to 1,000 feet west of the main runway; consequently, the USZ is not perched west of this line. However, based on potentiometric head data from wells screened above and below the confining shale layer, the USZ remains a discrete aquifer zone



(Scale)

0 — 1 mile

LEGEND

- Potentiometric Contours Elevation above MSL
- Approximate Direction of Groundwater Flow

Contours are extrapolated across center of base due to lack of data

FIGURE 3-4
TINKER AIR FORCE BASE
UPPER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 23MAR94	DATE LAST REV.:	DRAFT. CHCK. BY:	INITIATOR: C.WALLACE	DWG. NO.: 409832O9C.
DRAWN BY: C.E.TUMLIN	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.: J.TAYLOR	PROJ. NO.: 409832

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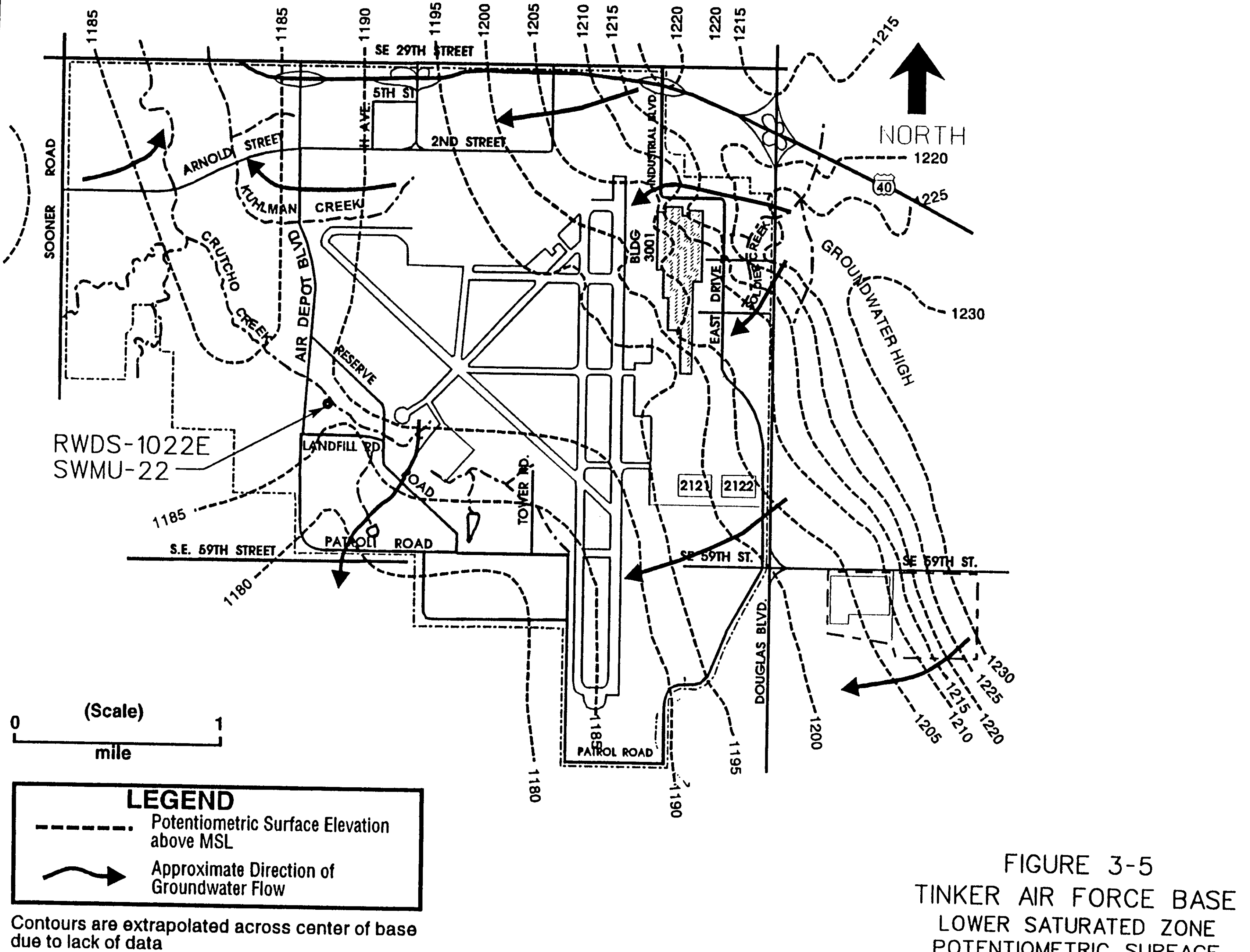

FIGURE 3-5
TINKER AIR FORCE BASE
LOWER SATURATED ZONE
POTENTIOMETRIC SURFACE

STARTING DATE: 23MAR94	DATE LAST REV.:	DRAFT. CHCK. BY:	INITIATOR: C. WALLACE	DWG. NO.: 40983209C.
DRAWN BY: C.E. TUMLIN	DRAWN BY:	ENGR. CHCK. BY:	PROJ. MGR.: J. TAYLOR	PROJ. NO.: 409832

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distinct from the LSZ even over the western part of the Base. In areas where several shales interfinger to form the lower confining interval rather than a single shale bed, "gaps" may occur. In general, these "gaps" are not holes in the shale, but are places where multiple shales exist that are separated by slightly more permeable strata. Hydrologic data from monitoring wells indicate that these zones allow increased downward flow of groundwater above what normally leaks through the confining layer.

The LSZ is hydraulically interconnected and can be considered one aquifer zone down to approximately 200 feet. This area includes what was referred to by the USACE as the top of regional and regional zones. Hydrogeologic data from wells screened at different depths at the same location within this zone, however, provide evidence that locally a significant vertical (downward) component of groundwater flow exists in conjunction with lateral flow. The magnitude of the vertical component is highly variable over the Base. Preliminary evidence suggests that the LSZ is hydraulically discrete from the producing zone. Due to variations in topography, the top of the lower zone is found at depths ranging from 50 to 100 feet below ground surface under the eastern parts of the Base and as shallow as 30 feet to the west. Differences in potentiometric head values found at successive depths are due to a vertical (downward) component of groundwater flow in addition to lateral flow and the presence or absence of shale layers which locally confine the aquifer system. The LSZ extends east of the Base (east of Soldier Creek) beyond the limits of the USZ where it becomes the first groundwater zone encountered in off-Base wells. Because of the regional dip of bedding, groundwater gradient, and topography, the LSZ just east of the Base is generally encountered at depths less than 20 feet.

3.3.2 Site Hydrology

Groundwater in the area around RWDS 1022E exists in both the Hennessey Group and the Garber-Wellington. Groundwater in the Garber-Wellington near the site is divided into two aquifer zones, the USZ and the LSZ. These two zones are separated by a low permeability shale layer which extends across the entire area and which correlates to the second mappable layer discussed earlier under the section on stratigraphic correlation.

In the Hennessey Group groundwater is found in siltstones and sandstone beds at depths as shallow as 5 feet below ground surface. Trenches dug into this strata at the landfills intersect this aquifer zone. In general, the water appears to flow semiradially from the topographic high at Landfills 2 and 4 towards Crutcho Creek, passing under RWDS 1022E before discharging into the creek. Flow is generally south to north. As this groundwater nears

stream base-level, and where hydraulic conditions allow, some water also appears to leak or flow vertically downward to recharge the underlying USZ, as demonstrated by the "mounding" at Landfill 3. At the site, it is difficult to differentiate water levels in the Hennessey from those in the USZ with available data since the potentiometric surface of the USZ is at or near stream level in this area and, therefore, closely matches that found in the Hennessey near the creek.

The USZ equates with the first sandstone layer of the Garber Sandstone beneath the Hennessey. The sandstone is generally 15 to 20 feet thick. On a regional basis, groundwater in the USZ flows to the southwest, intersecting Crutcho Creek in this area. However, local anomalous flow patterns exist near and along Crutcho Creek as described above. Away from the influences created by the creek, the USZ is easily distinguished from the overlying Hennessey aquifer zone by properly screened monitoring wells.

The LSZ is differentiated from the USZ on the basis of potentiometric head data from wells screened above and below the low permeability shale layer mentioned previously. Groundwater flow in the LSZ appears to be more southerly than in the USZ, and may actually be to the southeast.

3.4 Soils

Three major soil types have been mapped in the Tinker AFB area and are described in Table 3-2 (U.S. Department of Agriculture [USDA], 1969). The three soil types, the Darrell-Stephenville, Renfrow-Vernon-Bethany, and Dale-Canadian-Port, consist of sandy to fine sandy loam, silt loam, and clay loam, respectively. The Darrell-Stephenville and the Renfrow-Vernon-Bethany are primarily residual soils derived from the underlying shales of the Hennessey Group. The Dale-Canadian-Port association is predominantly a stream-deposited alluvial soil restricted to stream floodplains. The thickness of the soils ranges from 12 to 60 inches.

Table 3-2

Tinker AFB Soil Associations
(Source: USDA, 1969)

Association	Description	Thickness (in.)	Unified Classification[a]	Permeability (in./hr)
Darrell-Stephenville: loamy soils of wooded uplands	Sandy loam Sandy clay loam Soft sandstone (Garber Sandstone)	12-54	SM,ML,SC	2.0-6.30
Renfrow-Vernon-Bethany: loamy and clayey soils on prairie uplands	Silt loam - clay Clay loam Shale (Fairmont Shale)	12-60	ML,CL,MH,CH	<0.60-0.20
Dale-Canadian-Port: loamy soil on low benches near large streams	Fine sandy loam Silty clay loam Loam Clay loam	12-60	SM,ML,CL	0.05-6.30

[a]Unified classifications defined in U.S. Bureau of Reclamation, 5005-86.

4.0 Source Characterization

4.1 Records Search

The IRP Phase I records search report (ES, 1982) stated that eight to ten containers of radioactive material from Building 230 were buried 30 feet deep at RWDS 1022E. Other reports have indicated that this material probably consisted of boxes of blocking tubes (vacuum tubes) each containing 1 mCi of radium-226.

RWDS 1022E is reported to be located northwest of Landfill 3. The only marker was an unlabeled piece of angle iron. At one time, a red reflector on a metal rod with two pieces of angle iron stuck in the ground at either side of the reflector was reported to have been in place at the approximate site location. The contaminant of concern for RWDS 1022E is radium-226.

Radium is a metabolic analog of calcium and as such if ingested is deposited in the bone skeleton. Any radium-226 that is deposited in the skeleton serves a source of alpha radiation to the bone and contiguous tissues.

Radium-226 also decays to form radon-222. Since radon is a gas, it has the potential for diffusing out of the ground and becoming airborne. Radon-222 has a half-life of 3.82 days. If radon is inhaled into the lungs and undergoes decay, the alpha radiation from the radon progeny will provide a radiation dose to the lungs and contiguous tissues.

4.2 Nonintrusive Investigation

The Chem-Nuclear (1990) survey, conducted in March 1990, used the unlabeled piece of angle iron as the center of the survey.

Background gamma radiation exposure level (by hand-held survey instruments) in the site vicinity at the time of the survey ranged from 6.5 to 7.0 μR/hr. The site radiation levels were at or below background, with the exception of one isolated spot. This spot was an area approximately 6 inches in diameter located approximately 30 feet east of the center marker. Gamma radiation exposure level at this spot at ground elevation was 10.6 μR/hr. During the geophysical survey, a verification radiological survey identified another isolated area 8 inches to the south of the original spot. This new area had a reading of 14.2 μR/hr. According to Chem-Nuclear, it appeared that the elevated levels at the second location were related to the first, which still read approximately 10.6 μR/hr.

A GPR survey was conducted over RWDS 1022E. Numerous anomalies were detected, indicative of small buried objects at depths ranging from 1 to 7 feet. Due to the characteristics of the soil, GPR penetration was limited to a maximum of 7 feet. No direct correlation could be made with the detected anomalies and the area of elevated radiation levels.

An induced electromagnetic (EM) survey was conducted at RWDS 1022E, collecting data over four east-west parallel lines across the 100 by 100 feet area of interest. An anomaly covering a 13 by 39 feet area was detected. The anomaly may be a large metallic object or a group of small metallic objects, at a depth of 6 to 8 feet. A separate EM-34 survey corroborated the existence of this anomaly, and indicated it may extend to a depth of 25 feet. This large anomaly lies about 10 feet to the west of the elevated radiation levels.

A total magnetic field gradiometer survey was conducted at RWDS 1022E and revealed four separate gravity anomalies. Three of these anomalies were in the area coinciding with the large EM anomaly. The estimated depths of these anomalies were 15 to 20 feet. The fourth anomaly was located approximately 32 feet to the east of the site's center mark, close to the area with the elevated radiation levels, at a depth of approximately 5 feet.

4.3 Intrusive Surveys

Groundwater samples taken from MW-2B in the vicinity of RWDS 1022E had radium-226/228 levels that were undetectable. The gross alpha was 4.38 $\pm$ 2.65 pCi/L (the MCL for gross alpha activity is 15 pCi/L). The gross beta activity from MW-2B was 4.06 $\pm$ 1.48 pCi/L, which is consistent with background for the Base.

Tables 4-1 through 4-3 show the concentration of volatile organics, semivolatile organics, and metals detected in groundwater samples from MW-2A and MW-2B. Table 4-4 summarizes the pH, conductivity, and temperature data for the groundwater samples. Because RWDS 1022E is located adjacent to the landfills, any detected constituents cannot necessarily be attributed to RWDS 1022E without further investigations.

4.4 Removal Action

The removal action work consisted of excavating RWDS 1022E to resolve the anomalies which were identified by a previous geophysical survey of the site. The work was performed from July 8 to July 12, 1991.

Table 4-1

Summary of VOCs Analytical Data for Monitoring Wells 2A and 2B and Drinking Water Standards December 1993 Groundwater Sampling Program RWDS 1022E, SWMU-22, Tinker AFB

Sample ID	Parameters																	
	Benzene	sec-Butyl-benzene	Carbon tetrachloride	Chloro-benzene	Chloroform	cis-1,2-Dichloro-ethene	Trans-1,2-Dichloro-ethene	1,3-Dichloro-benzene	1,4-Dichloro-benzene	1,1-Dichloro-ethane	1,2-Dichloro-ethane	Methylene Chloride	Tetrachloro-ethene	Trichloro-ethene	Vinyl chloride	1,2,4-Trichloro-benzene	1,2,3-Trichloro-benzene	Toluene
2A/12	--	--	--	8	--	8	--	--	--	--	0.7	--	--	--	--	--	--	--
2B/12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 4-2

Summary of Semivolatiles, Pesticides, and PCBs Analytical Data for Monitoring Wells 2A and 2B and Driking Water Standards December 1993 Groundwater Sampling Program RWDS 1022E, SWMU-22, Tinker AFB

Sample ID	Parameters (µg/L)[a]									
	Semivolatiles								Pesticides and PCBs	
	Phenol	bis(2-ethyl-hexyl)phthalate	Diethyl-phthalate	di-n-Octyl-phthalate	1,4-Dichloro-benzene	Dimethyl-phthalate	Benzyl Alcohol	2,4-Di-methyl-phenol	Dieldrin	Chlorodane
2A/12	--	--	--	--	--	49	--	6	--	--
2B/12	--	22	--	--	--	710	--	--	--	--

[a]µg/L - micrograms per liter or parts per billion.

Table 4-3

Summary of Metals and General Chemistry Analytical Data for Monitoring Wells 2A and 2B and Drinking Water Standards December 1993 Groudnwater Sampling Program RWDS 1022E, SWMU-22, Tinker AFB

Sample ID	Parameters (mg/L)[a]										
	Barium	Cadmium	Lead	Nickel	Arsenic	Selenium	Chromium	Mercury	Nitrate	TDS	TOC
2A/12	18.400	0.0070	0.0734	0.223	0.147	--	0.237	--	--	2510	22.3
2B/12	0.592	--	0.0070	--	0.0031	--	--	--	0.175	339	5.97

[a]mg/L - milligrams per liter or parts per million.

Table 4-4

Summary of pH, Conductivity, and Temperature Data for Monitoring Wells 2A and 2B December 1993 Groundwater Sampling Program RWDS 1022E, SWMU-22, Tinker AFB

Sample ID	pH (unit)	Conductivity (µmhos/cm)	Temperature (°F)
2A/12	7.39-7.46	782	69.4
2B/12+	6.92	528	40.1

RWDS 1022E was excavated with a tracked backhoe. Following clearing of the site and setting up the controlled area, soil was removed in lifts and stockpiled on the site. Screening of each lift was performed with a metal detector, radiation survey instruments, and a photoionization detector (PID). Samples of each lift were collected from the stockpiles and were analyzed by Armstrong Laboratory's on-site laboratory for gross alpha, gross beta, and gamma spectroscopy. The total activity of the soils and any objects encountered was compared to the total effective dose equivalent (TEDE) for the site. This had been calculated by CDM for the 10 millirems per year (mrem/yr) TEDE based on the groundwater pathway model of the draft NUREG 5512 (Battelle Pacific Northwest Laboratories, 1990). The 10 mrem/yr TEDE for this site was calculated to be equivalent to 36 picocuries per gram (pCi/g) radium-226. For the calculations, the dimensions of the excavated material were the planned dimensions according to the work plan and the density parameter was a conservative, assumed value. Following completion of the excavation, the TEDE was recalculated using the actual dimensions of the excavation (CDM, 1992).

Samples of the stockpiles were analyzed by the Tinker AFB Chemical Laboratory for organics by gas chromatograph (GC) headspace analysis. If a stock also had a considerable amount of trash in it, the stockpiles were also sampled for Toxicity Characteristic Leaching Procedure (TCLP) metals analysis. During the initial phase of the excavation, the shallow (5-foot deep) metallic anomaly, which corresponded to the elevated gamma radiation exposure readings (twice background), was encountered approximately 1 to 2 feet beneath the surface. Analysis by Armstrong Laboratory led to the determination that the small chunk of metal found here was magnesium-thorium, weighing 291 grams with an activity of 2.1 nanocuries per gram (nCi/g), apparently from an old airplane part. The soils surrounding the metal were analyzed and were determined to be sufficiently low in radioactivity to allow soils to remain in situ. Excavation continued, and CDM decided to keep stockpiles of each lift separate until test results came back from both Armstrong Laboratory and Tinker AFB Chemistry Laboratory. Although the field screening with hand-held instruments was not showing any contamination, it was determined that it would be easier to keep the stockpiles separated until test results were available. Based on those test results, stockpiles could then be combined, using a dozer. Samples were collected from each stockpile for analysis by Armstrong Laboratory and Tinker AFB Chemical Laboratory.

Large sheets of "foil" were encountered in the excavation at 1 to 3 feet in depth and again at 5 to 7 feet in depth. The foil trash covered the entire area of the IEM anomaly and probably accounts for that conductive anomaly. At the work plan workshop for the project, it was

indicated that the RWDS 1022E was likely located just outside the limits of Landfill 3. However, it appears that Landfill 3 may encompass one-half of RWDS 1022E. The limit of the western edge of Landfill 3 is apparently located along the north-south axis of the center of RWDS 1022E. Analysis by the Armstrong Laboratory detected no radioactivity associated with the foil.

Trash was encountered in layers in the eastern half of the excavation from approximately 3 to 8 feet deep. A second small magnesium-thorium object, weighing 119 grams with an activity of 1.7 nCi/g, was encountered in a trash layer removed from the south end of the excavation in the fourth lift. Because of this finding, each stockpile was screened with radiation survey instruments to ensure no small objects were missed. Existing stockpiles were either moved and new ones built in 1-foot lifts, or were knocked down to a 1-foot lift so more detailed surveys could be performed.

New stockpiles resulting from further excavation in the trash layers were built in 1-foot lifts so screening with the radiation survey instruments could be more thorough. This screening was in addition to that conducted prior to removing each lift.

Armstrong Laboratory allowed CDM to use Armstrong's more sensitive hand-held survey instruments for the more detailed screening of the stockpiles. Once cleared by CDM personnel and laboratory test results, a confirmatory survey of each stockpile was conducted by Armstrong Laboratory personnel.

Utilizing these procedures, the excavation was continued to a depth of approximately 8 feet where the layers of trash terminated. The three metallic anomalies in and adjacent to the IEM anomaly apparently were caused by the foil trash, which was thicker in areas of the metallic anomalies.

A third potential radioactive object, a compass with radium paint on the dial, weighing 70 grams with an activity of 544 pCi/g, was encountered. This was also turned over to Armstrong Laboratory.

A crushed 55-gallon drum was encountered at the north end of the excavation; the drum contained some liquid and had contaminated the surrounding soils with that liquid. The waste gave off a solvent-like odor. A sample of the soils was taken to the Tinker Chemistry Laboratory for analysis. The chemical analytical results from the Tinker Chemistry Laborato-

ry showed the soils to be contaminated with organics (no specifics on constituents or concentration were detailed in the Closure Report), and the radiochemical results showed no activity. Following upgrading of levels of protection to include respirators, the contaminated soils were containerized in two B-25 boxes, and set aside for later transport to interim storage.

Organically-contaminated soils (180 cubic feet [6.67 cubic yards]) removed from the excavation were containerized and placed in interim storage. Disposal of these soils has been completed by Tinker AFB through their Defense Reutilization Marketing organization (DRMO). The weight of soils disposed of off-site was 9,820 pounds.

At the 8-foot-depth level, there were no strong disturbances on the metal detectors at the locations of the three metallic anomalies, but there was some instrument noise at the locations of the anomalies at the north and south ends of the IEM anomaly. This noise appeared to be caused by the trash in the walls of the excavation close to the anomalies. Therefore, it was decided to lengthen the excavation to the north and south to move the trash further away from the locations of the anomalies and, at the same time, deepen the excavation in the area of all three metallic anomalies.

In deepening the excavation in those three areas, a gravel layer was encountered at 11 feet and a sandstone lens was encountered at 12 feet. These layers were obviously undisturbed. At the conclusion of this final phase of the excavation there were no disturbances on the metal detectors in the bottom of the excavation, and undisturbed soils had been encountered in the areas of the metallic anomalies. Excavation was terminated per the approved work plan.

Following a final survey of the excavation by CDM personnel which found no radiation contamination, a confirmatory survey was conducted by Armstrong Laboratory. After surveying the sides and bottom of the excavation, the excavation was declared clear. Following completion of radiological analysis and detailed screening of the stockpiles by Armstrong Laboratory, RWDS 1022E was declared clear of radioactive waste. This confirmatory survey was conducted by hand-held instruments.

Groundwater filled the deeper part of the middle of the excavation overnight. Approximately 420 gallons of groundwater infiltered into the excavation. A sample of the groundwater was analyzed and was found to test positive for organics. However, since the excavation was

complete, no groundwater had to be discharged out of the excavation. Therefore, in accordance with the work plan, no attempt was made to remediate the contamination.

The excavation was backfilled in lifts using a dozer to compact the material. A layer of clean clay soils was placed in the bottom of the excavation to ensure any trash would be above the groundwater table. The soils with the trash in them were placed next, and finally a cap of clean clay soils, a minimum of 1-foot thick, was placed over the top of the soils with trash.

An interim storage area was constructed to the northwest of the site and the two B-25 boxes were placed in the storage area.

Because two magnesium-thorium objects were found on the site, Tinker AFB requested a permit from the U.S. Air Force Radioisotope Committee (RIC) to take possession of this radioactive material. This involved the RIC activating their master license with the Nuclear Regulatory Commission (NRC) and granting Tinker AFB a permit. The three radioactive items encountered at RWDS 1022E were placed in interim storage in the Building 1005 Conex on Tinker AFB. This facility is in a fenced, secured area and receives periodic inspections to ensure no contamination has spread. On September 27, 1991, possession of this material was turned over to Kelly AFB for disposal.

5.0 Contaminant Characterization

As a result of the removal action, RWDS 1022E was cleared by Armstrong Laboratory. Personnel from Armstrong Laboratory conducted a confirmatory survey of the excavation's and the stockpile, finding no readings above background. Based on their findings, it was concluded that no radioactive waste or contamination currently exists at RWDS 1022E. However, none of the studies conducted at this site have addressed hazardous waste constituents.

6.0 Potential Receptors

A specific potential human and ecological receptor search has not been performed for RWDs 1022E. Data are available in the form of chemical analysis of groundwater, and can be used to initiate a potential receptors search. The following sections describe the data available to begin identification of potential receptors.

6.1 Human Receptors

Tinker AFB is situated on a relatively flat expanse of grassland. Prior to the development of the Base, the area was characterized by large tracts of agricultural land. The Base currently occupies approximately 5,000 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.

The Garber-Wellington aquifer, which underlies Tinker AFB, is the single most important source of potable groundwater in the Oklahoma City area. The recharge area for the Garber-Wellington aquifer covers the eastern half of Oklahoma County, including Tinker AFB. Approximately 75 percent of the Base's water supply is obtained from production wells pumping from this aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by municipal distribution systems also depend on the Garber-Wellington aquifer. Communities, such as Oklahoma City, presently depending upon surface water supplies also maintain a well system drilled into this aquifer as a standby source of water in the event of drought. Lake Stanley Draper, a local surface water supply reservoir with a small portion of its drainage basin within the boundaries of Tinker AFB, serves a significant recreational function as well.

In 1989, approximately 26,000 military and civilian personnel worked at Tinker AFB. Of these, approximately 2,722 personnel occupied on-Base housing, which consisted of 530 family housing units and seven dormitories. At that time, 1,262 of these residents were children. Military personnel and their families who reside on Base represent the nearest receptors to releases from Tinker AFB.

The current land use at and near the Base is not expected to change because the facilities have decades of useful life remaining and the Base has an important and continuing mission. However, other future land use scenarios and any human receptors associated with those scenarios may need to be considered.

6.2 Ecological Receptors

Tinker AFB lies within a grassland ecosystem, which is typically composed of grasses, forbes, and riparian (i.e., trees, shrubs, and vines associated with water courses) vegetation. This ecosystem has generally experienced fragmentation and disturbances as result of urbanization and industrialization at and near the Base. While no threatened or endangered plant species occur on the Base, the Oklahoma penstemon (*Penstemon oklahomensis*), identified as a rare plant under the Oklahoma Natural Heritage Inventory Program, thrives in several locations on Base. Tinker AFB policy considers rare species as if they were threatened or endangered and provides the same level of protection for these species.

In general, wildlife on the Base is typically tolerant of human activities and urban environments. No federal threatened or endangered species have been reported at the Base. However, one specie found on the Base, the Texas horned lizard (*Phrynosoma cornutum*), is a Federal Category 2 candidate specie and under review for consideration to be listed as threatened or endangered. Air Force policy (AFR 126-1) considers candidate species as threatened or endangered and provides the same level of protection.

The Oklahoma Department of Wildlife Conservation also lists several species within the state as Species of Special Concern. Information on these species suggests declining populations but information is inadequate to support listing, and additional monitoring of populations is needed to determine the species status. These species also receive protection by Tinker AFB as threatened or endangered species. Of these species, the Swainson's hawk (*Buteo swainsoni*) and the burrowing owl (*Athene cunicularia*) have been sighted on Tinker AFB. The Swainson hawk, a summer visitor and prairie/meadow inhabitant, has been encountered Basewide. The burrowing owl has been known to inhabit the Air Field at the Base.

7.0 Action Levels

An "action level" is defined by EPA in proposed rule 40 CFR 264.521 (55 FR 30798; 7/27/90), "Corrective Action for Solid Waste Management Units (SWMU) at Hazardous Waste Management Facilities," as a health- and environment-based level, determined by EPA to be an indicator for protection of human health and the environment. In the preamble to this proposed rule, the focus of the RFI phase is defined as "characterizing the actual environmental problems at the facilities." As part of this characterization, a comparison of the contaminant concentrations to certain action levels should be made to determine if a significant release of hazardous constituents has occurred. This comparison is then used to determine if further action or corrective measures are required for a SWMU or an AOC. The preamble to the proposed rule states that the concept of action levels was introduced because of the need for "a trigger that will indicate the need for a Corrective Measures Study (CMS) and below which a CMS would not ordinarily be required" (55 FR 30798; 7/27/90). If constituent concentrations exceed certain action levels at a SWMU or an AOC, further action or a CMS may be warranted; if constituent concentrations are below action levels, a finding of no further action may be warranted. This chapter of the report presents the initial analytical data as compared to certain potential action levels.

Action levels are concentrations of contaminants at or below which exposure to humans or the environment should not produce acute or chronic effects.

The action level information is presented in this chapter so that a constituent concentration at a sample location can be compared with its potential action level. Only constituents identified in the analysis are listed in the SWMU-22, RWDS 1022E table. Table 7-1 shows the action levels for soil, water, and air as published in federal or state regulations, policies, guidance documents, or proposed rules.

The action levels listed in Table 7-1 are:

- ***SWMU Corrective Action Levels (CAL)*** - The first set of action levels provided in the table are those taken from the proposed rule (40 CFR 264.521) and provided as Appendix A to the rule as "Examples of Concentrations Meeting Criteria for Action Levels." These levels are health-risk based and are provided

Table 7-1

Action Levels
SWMU 22, RWDS 1022E, Tinker AFB

	SWMU CAL[a]			MCL[b]
Parameters	Soil (mg/kg)	Water (mg/L)	Air ($\mu g/m^3$)	Water (mg/L)
Organics				
Acetone	8000	4.0		
Carbon Tetrachloride	5.0	0.0003	0.03	0.005
Methy Ethyl Ketone	4000	2.0	300	
Methylene Chloride	90	0.005	0.3	0.005
Radiometrics				
Radium 226/228				20 pCi/L
Gross Alpha				15 pCi/L
Radon				300 pCi/L

[a]CAL - Corrective Action Levels
[b]MCL - Maximum Contaminant Levels

as specific examples of levels below which corrective action would not be required.

- ***Maximum Contaminant Levels (MCL)*** - These values are provided from 40 CFR Subpart G, Sections 141.60 through 0.63 as promulgated under the Safe Drinking Water Act. These levels are designated for water media only.

- ***USGS Background*** - These values are provided from the USGS report titled "Elemental Composition of Surficial Materials from Central Oklahoma" (USGS, 1991). These values represent the levels of metals which naturally occur in Central Oklahoma soils.

- ***Background*** - These levels are provided where background could be determined. Where available, background concentrations are listed for metals in soil samples taken on site, which were thought to be unaffected by releases from a unit.

- ***National Ambient Air Quality Standards (NAAQS)*** - These standards are published in 40 CFR Part 50 under the Clean Air Act and apply to point sources that emit a limited number of constituents to the air. The constituents regulated are nitrogen dioxide, sulphur dioxide, carbon monoxide, lead, ozone, and particulate matter. Currently, it is assumed that none of the SWMUs or AOCs emit these compounds in regulated quantities and no air samples have been taken which would allow for a valid comparison.

- ***Water Quality Standards (WQS)*** - The WQS are the standards for surface water quality as established by the State of Oklahoma. These standards apply to point source discharges to surface waters and have been listed for those units adjacent to surface water.

8.0 Summary and Conclusions

RWDS 1022E is located northwest of Landfill 3. It was suspected that 8 to 10 containers of radioactive material from Building 230 were buried 30 feet deep at this site, and that the material probably consisted of boxes of vacuum tubes each containing 1 mCi of radium-226.

The objective of RWDS 1022E removal action was to close the site by resolving the anomalies which were identified by a previous geophysical survey of the sites. This was accomplished by excavating the site. The thrust of the removal action was to either locate and exhume the radioactive objects reported to be buried at the site or to show that those objects did not currently exist at the site by resolving the anomalies. The plan was to resolve the anomalies by locating objects that accounted for the anomalies or by excavating down to native (undisturbed) soils.

The excavation was performed the week of July 8, 1991. RWDS 1022E was excavated to the depth required to both resolve the anomalies and to reach native (undisturbed) soils. The anomalies were accounted for by locating foil blankets at various depths of the excavation.

Following completion of the excavations, the site was cleared by Armstrong Laboratory, who conducted a confirmatory survey of the excavations and the stockpiles, finding no readings above background.

At RWDS 1022E, three small, radioactive objects were discovered in the trash layers encountered at the site. These objects were removed from the site and turned over to Tinker AFB under a permit issued by the U.S. Air Force RIC. The objects were placed in secure storage and have been properly disposed of by the Air Force.

Chemically-contaminated soils removed from the excavation were containerized and placed in interim storage. Disposal of these soils has been completed by Tinker AFB through their DRMO. The weight of soils disposed of off site was 9,820 pounds.

During the course of the excavation, trash was encountered at RWDS 1022E. At the Work Plan workshop for the project it was indicated that the RWDS 1022E was probably located just outside the limits of Landfill 3. However, it appears that Landfill 3 may encompass one-

half of RWDS 1022E. The limit of the western edge of Landfill 3 is apparently located along the north-south axis of the center of RWDS 1022E.

Based on the foregoing findings, it was concluded that no radioactive waste or contamination currently exists at RWDS 1022E. A closure report was issued in January 1992 (CDM, 1992). The cap for Landfill 3 now extends out over the entire RWDS 1022E site.

9.0 Recommendations

This RFI Summary Report has been prepared to determine and document whether sufficient investigations at RWDS 1022E have been performed to meet the permit requirements. Based on the documents reviewed, it was concluded that radioactive contamination did exist at the site and that the removal action was successful in removing the source of this contamination. The site is now covered by the RCRA cap for Landfill 3. However, all the investigations at this site have involved mainly the analysis of radioactive constituents. Hazardous waste constituents have not been addressed. Also, based on the documents reviewed, data collected at this site are limited. Additional investigations are necessary to confirm the presence or absence of hazardous waste constituents at the site. In addition, the nature and extent of contamination, if any, should be determined.

In view of these deficiencies, several additional investigations are recommended during the Phase II RFI. Based on the location of RWDS 1022E, it will be more appropriate to investigate this site as part of a group comprising several waste units in close proximity: RWDS 1030W, RWDS 62598, Landfills 1 through 4, the SP, and FTA1. Specific sampling needs to meet the objectives of the additional investigations will be presented in the work plan and sampling plan for the Phase II RFI. The following recommendations should be implemented under the Phase II RFI:

- Obtain soil samples for VOC and SVOC analyses.
- Obtain water samples for VOC and SVOC analyses.

In addition, to fully evaluate the extent of soil contamination at this site it is recommended that site-specific soil background samples be collected during the Phase II RFI. This additional information along with the USGS background values should be used in the Phase II report to distinguish site-related from background concentrations in a statistically significant manner. During the development of the Phase II RFI work plan, the number of background samples to be collected, the location of the soil borings, and the soil analysis to be performed on the samples should be determined for EPA approval.

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