INSTALLATION RESTORATION PROGRAM
PHASE II-CONFIRMATION/QUANTIFICATION
STAGE 2

FINAL REPORT

FOR

TINKER AFB, OKLAHOMA

AIR FORCE LOGISTICS COMMAND
WRIGHT-PATTERSON AFB, OHIO

PREPARED FOR

UNITED STATES AIR FORCE
OCCUPATIONAL AND ENVIRONMENTAL HEALTH LABORATORY (OEHL)
BROOKS AIR FORCE BASE, TEXAS 78235

OCTOBER 1985

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DCN 85-212-027-21-03
Volume I

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PREPARED BY

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CONTRACT NO. F33615-83-D-4001

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PREFACE

Radian Corporation is the contractor for the Installation Restoration Program (IRP) Phase II, Stage 2 investigation at Tinker AFB, Oklahoma. The work was performed under USAF Contract No. F33615-83-D-4001, Delivery Order 21.

Ground-water monitor wells were installed in the vicinity of Building 3001 and Landfill 6 to determine if environmental contamination has resulted from solvent storage and waste disposal practices at Tinker AFB. Water samples collected were analyzed by EPA Methods 601, 624, and 625. In addition, sediment samples were collected from Base streams for analysis for a broad range of parameters, a survey for buried pits and tanks was conducted in the vicinity of Building 3001, geophysical surveys were conducted to locate two radiological waste storage sites, and depths to water were measured in Base production wells.

Key Radian project personnel were:

Marshall F. Conover - Contract Administrator
Thomas W. Grimshaw - Program Manager
William M. Little - Project Director
Lawrence N. French - Supervising Geologist and Principal Author.

Radian would like to acknowledge the cooperation of the Tinker AFB Bioenvironmental Engineering Staff and especially the assistance of Capt. Darrel R. Cornell.

The work reported herein was accomplished between June and October 1984. Capt. Robart W. Bauer, and Dr. Dee Ann Sanders, Technical Services Division, USAF Occupational Environmental Health Laboratory, were Technical Monitors.

SUMMARY

Background and Purpose

The Department of Defense (DOD) is conducting a nation-wide program to evaluate past waste disposal practices on DOD property, control the migration of hazardous contaminants, and control hazards that may have resulted from these waste disposal practices. This program, the Installation Restoration Program (IRP), consists of four phases: Phase I, Initial Assessment/ Record Search; Phase II, Problem Confirmation; Phase III, Technology Base Development; and Phase IV, Remedial Action. The United States Air Force (USAF) has initiated an IRP investigation at Tinker Air Force Base near Oklahoma City, Oklahoma.

Phase I studies for the Tinker AFB Installation Restoration Program were completed in April 1982. The purpose of the Phase I study was to conduct a records search for the identification of past waste management activities which may have caused ground-water contamination and the migration of contaminants off-Base. Of the fourteen individual sites identified during Phase I, eight sites (six landfills and two industrial waste pits), comprising four zones, were selected for Phase II (Stage 1) studies. Two additional problem areas, not addressed in Phase I, were added to the list of sites for Phase II (Stage 1) studies. These are the Base water supply wells and the wells in Building 3001 (Oklahoma City Air Logistics Center).

The Phase II (Stage 2) investigation was a continuation of the Phase II (Stage 1) program. The purpose of Phase II (Stage 2) was to determine if environmental contamination has resulted from solvent storage and waste disposal practices at Tinker AFB. In addition, the investigation included an estimate of the magnitude and extent of contamination, the identification of environmental consequences of migrating pollutants, and the recommendation of additional investigations to identify the magnitude, extent and direction of movement of discovered contaminants.

Authorization to proceed on the Tinker AFB Phase II (Stage 2) program was given on 23 May 1984. Field activities were conducted from June through August and October, 1984. The field work consisted of the installation and sampling of ground-water monitoring wells, geophysical surveys of two radiological waste disposal sites, sampling and analysis of sediments from base streams and drainage channels, a survey of buried pits and tanks in the vicinity of Building 3001, and measurement of depth-to-water in the Base production wells.

Waste Disposal Practices

Management of wastes at Tinker AFB was reviewed as part of the Phase I investigation conducted in 1982. Results of the investigation show that waste generated during most of the history of Tinker AFB has generally been handled on-site; recent operations (since about 1980) have directed wastewater streams to treatment units on base prior to discharge and have contracted with private waste disposal firms to handle solid wastes (including liquid wastes from industrial operations). In the past, on-site disposal operations included the use of landfills for solid waste, industrial waste pits for the disposal of liquids and sludges, and other disposal sites for low-level radioactive materials.

Disposal of solid waste occurred from 1942 to 1979 at six locations across the southern part of the Base. Most waste deposited in the landfills consisted of general refuse (paper, trash, construction debris, and garbage). The landfills, numbered 1 through 6, were constructed by excavating a series of parallel trenches, depositing waste, and covering with soil. The depth of the trenches has not been accurately recorded; it is probable that the depth is largely related to the ease of excavation of the shallow soil above shale bedrock, generally 10 to 15 feet below land surface. The landfills are visible today as features slightly elevated above the surrounding topography, with a hummocky surface corresponding to the former trenches that have undergone differential settling.

Liquid wastes and sludges generated during the period 1947-1965 were directed to industrial waste pits located in the southeast portion of the Base. These sites, Industrial Waste Pits 1 and 2, were used for the disposal of waste streams originating from the various aircraft maintenance shops at Tinker AFB. The waste streams may have contained contain high levels of heavy metals, and a variety of organic contaminants (solvents and cleaners). The pits were probably unlined since there was no requirement to do so, with the materials in the pits periodically burned.

Site Descriptions

For IRP Stage 2, Radian continued the investigations of the Building 3001 area and Landfill 6. Additional areas investigated included the four streams located on the base, two radiological waste storage sites (RWDS-1022E and 62598) and depth to water measurements in the base water supply wells. These areas are shown on Figure 1. Each investigation site is described below.

Building 3001

Building 3001 houses numerous maintenance and repair activities and shops which support the mission of the Oklahoma City Air Logistic Center. This command operates an overhaul and modification complex engaged in repairing and upgrading aircraft including a quantity of engines and many thousands of accessory items. Industrial operations within the Building 3001 area encompass a variety of repair and maintenance facilities which include:

- o Disassembly, cleaning, and inspection of aircraft systems and components;
- o Plating, painting, heat treating, testing of metal parts and components;

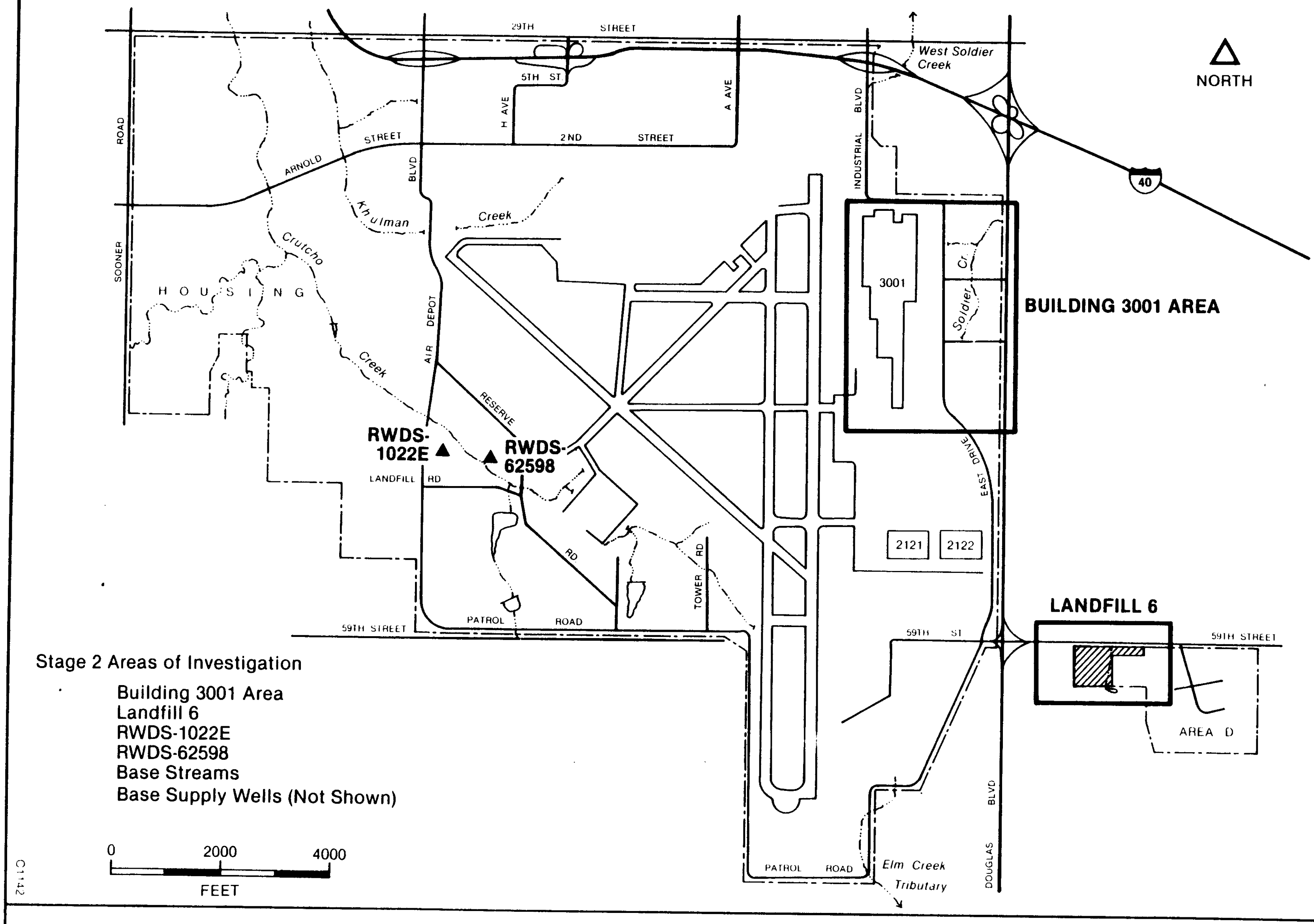


Figure 1. Areas of Investigation, Tinker AFB IRP Phase II Stage 2.

- Accessory shops including electrical, valve and governor, gear box, tubing and cable, fuel controls, nozzles, pumps, bearings, and other specialized repair shops; and

- Assembly and testing and packaging of aircraft and aircraft components.

In addition, other functions housed within this or other nearby buildings include utility (water, power and steam production), administrative and engineering offices, parts and material storage, and others.

Landfill 6

Landfill No. 6 was used for the disposal of refuse from 1970 to 1979. This landfill is located in Area "D" approximately 1/2 mile east of Tinker AFB along S.E. 59th Street on land leased from Oklahoma City. Although 40 acres are available at the site, only about 20 were used prior to the closing of the site during 1979. The western half of the landfill was filled, as were two trenches adjacent to S.E. 59th St. in the eastern half. Base refuse since that time has been disposed of off-site by private contractor. This facility is the subject of a current Phase IV effort, under control of the Base Civil Engineers.

Base Streams

The principal drainages for Tinker AFB are Crutcho and Soldier Creeks. Most of the Base is drained by Crutcho Creek and its tributary, Khulman Creek. The eastern part of the Base, near Douglas Boulevard and the Air Logistics Center, is drained by Soldier Creek. The extreme southern part of the Base is drained by Elm Creek, which is normally dry. Sediment sampling sites were established for each of the drainages on the Base, including sites along the length of each stream and a site at the Base boundary. Sites were established in accordance with the recommendations in the Phase I report (Engineering-Science, 1982).

Radiological Waste Disposal Sites

Radioactive waste disposal site RWDS 62598 is located south of Facility 1025 and north of Crutcho Creek. A concrete post with attached radiation warning sign marks the general disposal area. The site contains a "lead still" made of sheet lead used to evaporate methyl ethyl ketone (MEK) or acetone for reuse. The MEK and acetone were contaminated with radium paint from cleaning radium dials. In the early 1950's, the lead still was reportedly buried in the general area marked by the concrete post. The depth of burial is not known. The level of radium, an alpha and gamma emitter, is not known. One Air Force document states the waste may later have been removed; however, no conclusive evidence exists for either the presence or absence of the waste (Engineering-Science, 1982).

Another radioactive waste disposal site, RWDS 1022E, is located adjacent to the northwest corner of Landfill No. 3 south of West Crutcho Creek. During the mid-1950's approximately 8 to 10 containers of radioactive material were disposed of at the site. The nature of the radioactive material is not known. The material was placed in a hole approximately 30 feet deep located next to landfill No. 3, which was operative during the period 1952-1961 (Engineering-Science, 1982).

Base Water Supply Wells

Tinker AFB presently obtains water supplies from a system of 22 on-base water wells constructed along the east and west Base boundaries. All Base wells are completed in the Garber-Wellington Aquifer. Base wells range from 650 to 1100 feet in depth, with yields ranging from 71 to 210 gallons per minute. The wells incorporate multiple screens, deriving water supplies from sand zones that vary in thickness from 103 to 184 feet.

Sampling and Analytical Program

The sampling program at Tinker consisted of the collection of stream sediments and ground water. Stream sediment samples were collected using a tube sampler driven into the substrate (wet sites) or with a small auger or hand trowel (dry sites). The sediment samples were placed individually in glass jars and chilled. Samples of water were collected from monitoring wells installed as part of this Phase II (Stage 2) IRP investigation and from one monitoring well installed as part of the Stage 1 investigation. Water samples were collected with a Teflon bailer. The schedule of chemical analyses is summarized on Table 1.

Field Program

Various field activities were performed at Tinker AFB support of the IRP Phase II (Stage 2) investigation. The activities consisted of performance of a survey of buried pits and tanks in the vicinity of Building 3001, completion and sampling of 14 deep and two shallow ground-water monitor wells, sediment sampling in Base streams and drainage channels, performance of two geophysical surveys, and measurement of depth-to-water in Base water supply wells. The locations of the field investigations are shown on Figure 1. The periods of performance of the field activities were June-August and October 1984.

The following paragraphs contain descriptions of the various field techniques used in the Tinker AFB Phase II Stage 2 investigation. These techniques included geophysical surveying, air rotary drilling, monitor well installation, stream sediment and ground-water sampling.

Geophysical Surveying

Geophysical surveying was performed in order to accurately define the most probable location of two Radiological Waste Disposal Sites (RWDS-1022E and 62598). The two sites are currently vacant land; no surface remnants of the facilities are visible. The geophysical techniques selected for the investigation consisted of an electromagnetic survey using two devices (the Geonics EM31 and the EM34-3 ground conductivity sensors) and a magnetometer survey using the EDA PPM-500 Vertical Gradiometer.

TABLE 1. ANALYTICAL SCHEDULE FOR SOIL AND WATER SAMPLES, TINKER AFB IRP, PHASE II, STAGE 2

Parameter

Monitor Wells

Volatile Organic Halogens (EPA Method 601)
Volatile Organic Compounds (VOC) (EPA Method 624)
Base/Neutrals and Acid Extractable Compounds (BNE) (EPA Method 625)

Stream Sediment

Arsenic	Fluoride
Barium	Nitrate
Cadmium	Cyanide
Chromium	Phenol
Lead	PCB's
Mercury	Total Organic Carbon (TOC)
Selenium	Endrin
Silver	Lindane
Copper	Methoxychlor
Zinc	Toxaphene
Manganese	2,4-D
Nickel	2,4,5-Silvex

Drilling Technique

Drilling at Tinker AFB was accomplished by the air-rotary method with a Failing 1250 truck-mounted rig. A 6-7/8 inch tricone bit was used to drill the bore hole to a depth of 10 feet below the first ground water encountered. No drilling fluids or additives were used in the drilling program. The air rotary method is considered the most suitable method of drilling for monitor well installation, since the borehole is open and clean at the end of the drilling program. Any small effects of utilizing air as the circulating fluid are removed in the process of well development and well purging prior to sampling. As the bore hole was advanced, the cuttings discharged at the surface were examined for lithology, moisture, and other features to describe the geologic section. Drilling conditions, such as relative rate and ease of penetration, were noted by the driller. Water encountered during drilling was noted with respect to depth of occurrence and rate of production; if needed, drilling was suspended temporarily to allow for recovery of water in the borehole. The decision to complete the borehole and install the screen and casing for the monitor well was made on the basis of relative water level (with respect to the approximate predicted regional water level), the likelihood of perched water above a regional water table, and the representativeness of the water table in terms of evaluating the impact of the waste disposal site on the quality of ground water.

Initially, the hollow-stem auger method with split-spoon sampling was contemplated for installation of the shallow monitor wells at Landfill 6. However, an initial reconnaissance revealed that the substrate was too indurated for this method to be successful. Therefore, all boreholes were advanced with the air rotary rig. Since this method provides continuous cuttings returns, no split-spoon samples need be taken.

Monitor Well Installation

Ground-water monitor wells were installed immediately upon completion of the drilling operations. Usually, the borehole was observed for a period of time, as necessary, to determine the approximate static water level. Monitor well construction specifications are summarized in Table 2. For the parameters and concentrations expected, PVC casing with threaded (not glued) joints is not expected to interfere with sampling and analysis. Appropriate changes in the specifications were made on a site-by-site basis. Decisions regarding the setting of screen and casing, length of screen, and amount of gravel pack for each well were made on the basis of the observed static water level.

Ground-Water Sampling

Ground-water samples were collected for analysis from eleven of the ground-water monitor wells installed during this program, and from one previously existing ground-water monitor well. Depth to water, pH and conductivity measurements were made at the time of sampling.

Stream Sediment Sampling

Twenty-four sediment sampling stations were identified along Crutcho Creek (including significant tributaries), Khulman Creek, West Soldier Creek, Soldier Creek, a tributary to Elm Creek and two drainage ditches within the installation. A total of 27 sediment samples were collected for analysis, including three duplicates for field quality control. At each sampling location, measurements were taken for determining the cross-section of the stream at the sampling point. General observations on stream conditions and aquatic life present (if any) at each sampling point were also noted. Observations, measurement and features of each stream sampling station were recorded in a field notebook.

Results of the Investigation

The results of the IRP Phase II Stage 2 are presented below for each of the areas investigated.

TABLE 2. MONITOR WELL CONSTRUCTION SPECIFICATIONS

- Casing: 2-inch or 4-inch diameter, flush (not glued) joint, Schedule 40 or 80 PVC.
- Screen: 2-inch or 4-inch diameter, flush joint, Schedule 80 PVC, 0.010-inch mill slot. Normal screen length was 10 feet, reduced to 5 feet at the discretion of the supervising geologist.
- Gravel pack: 8-12 mesh silica, emplaced from bottom of hole to 2 feet above top of screen.
- Bentonite seal: 2 feet above top of sand pack.
- Grout: neat cement (Type I Portland cement) grout, emplaced by tremie pipe, from the top of the bentonite seal to the land surface.
- Surface completion: the PVC casing was cut off to provide a 2 to 3 foot stickup and solid cap placed on the casing. A 6-inch diameter guard pipe, 4 feet in length, was placed over the exposed casing, and seated in the cement. A locking cap lid was installed on the guard pipe.
- Guard pipes or posts: 3-inch diameter steel posts, 6 feet in length, with a minimum of 2 feet below ground, 3 each installed radially 4 feet from the wellhead.
- After each well was installed, it was developed by air lifting or bailing until a clear stream was produced, or until the supervising geologist determined that development was complete.

Building 3001

Samples from the monitor wells in the Building 3001 area reveal the presence of synthetic organic chemicals in the shallow ground-water system. Results are summarized in Table 3.

Observations in the Building 3001 area support the following conclusions:

- o The origin of the trichloroethylene and other synthetic organic compounds is not a single, defined source, but rather the cumulative results of 30 or more years of industrial operations;

- o The pattern of occurrence of contaminants in the IRP Phase II Stage 2 monitor wells does not clearly suggest a plume from a single, definable source;

- o The occurrence of contaminants is confined to relatively shallow levels of the aquifer, since, as reported in Stage 1, base production wells in the vicinity are relatively clean, with the exception of Wells 18 and 19; and

- o Wells 18 and 19, which are perforated in multiple zones and may not be adequately sealed in the upper portion, can provide vertical conducts for contaminant migration, as well. Such inactive, unrehabilitated wells would provide for rapid movement of contaminants into the deeper portion of the aquifer.

The synthetic organic chemicals occurring in the shallow subsurface in the vicinity of Building 3001 pose two threats to human health and the environment. The first is that, due to the existing vertical head gradient and the influence of the nearby base production wells along East Drive, these contaminants can move downward and enter the strata from which these wells

TABLE 3. SUMMARY OF SAMPLING RESULTS, BUILDING 3001

Parameter	Range of Levels Detected (μg/L)*
EPA 601 (Volatile Organics)	
Chloroethane	n.d.-1.1
Methylene Chloride	n.d.-2.0
Trichlorofluoromethane	n.d.-22.0
1,1-Dichloroethene	n.d.-2.0
1,1-Dichloroethane	n.d.-1.8
trans-1,2-Dichloroethene	n.d.-3.2
Chloroform	n.d.-19.6
1,2-Dichloroethane	n.d.-4.9
1,1,1-Trichloroethane	n.d.-4.2
1,2-Dichloropropane	n.d.-0.3
Trichloroethylene	n.d.-642.0
1,1,2,2-Tetrachloroethane	n.d.-2.7
Tetrachloroethylene	n.d.-4.7
Chlorobenzene	n.d.-34.5
1,2-Dichlorobenzene	n.d.-11.0
EPA 625 (Acid Extractables)	
none detected	
EPA 625 (Base/Neutrals)	
bis(2-ethylhexyl)phthalate	n.d.-13
di-n-octyl phthalate	n.d.-44
EPA 624 (Volatiles)	
Benzene	n.d.-47
Toluene	n.d.-670

*Levels ranged from "not detected" at the limit specified in the method to the maximum level shown.

produce water. This constitutes a future threat to the base water supply. The second is that the contaminants can move laterally to the southwest, in the direction of both the local and regional gradients. As these contaminants move, they will become more widely dispersed in the aquifer. The nearest potential receptors in the direction of the regional flow are the base wells along the western boundary of the Base.

Landfill 6

Monitor well drilling and sampling at Landfill 6 have revealed a complex hydrogeologic setting. Ground-water bodies are perched on thin shale beds within the section overlying the regional aquifer system.

The ground-water flow paths in the overlying perched zones may be locally the reverse of that of the regional aquifer due to the effect of low permeability shale lenses on vertical ground-water flow. Figure 2 schematically illustrates a model of possible ground-water flow relationships in the vicinity of Landfill 6. Water percolating in and through the landfill would likely encounter one or more series of shale lenses. Water from the perched zones may continue to flow down toward the regional water table or it may be locally diverted by a shale lens and flow horizontally along the shale surface until it encounters a breach in the shale and again percolates downward. The quality of water near Landfill 6 has been observed to improve with depth, which is consistent with the model outlined in Figure 2. Analytical results are summarized on Table 4.

The available hydrogeologic and chemical data suggest that Landfill 6 is releasing synthetic organic chemicals to the environment. These released chemicals are following a circuitous path downward to the regional ground-water body, as illustrated in the conceptual diagram of Figure 2. Thus, it is likely that contaminants from Landfill 6 have moved north along these shale lenses and entered the Ainsworth well. As the contaminants move through the perched ground-water bodies, they are becoming more dilute. The data suggest a southward flow in the regional system. Because no wells have been installed south of the area there are no data on the occurrence of contaminants downgradient in the regional body.

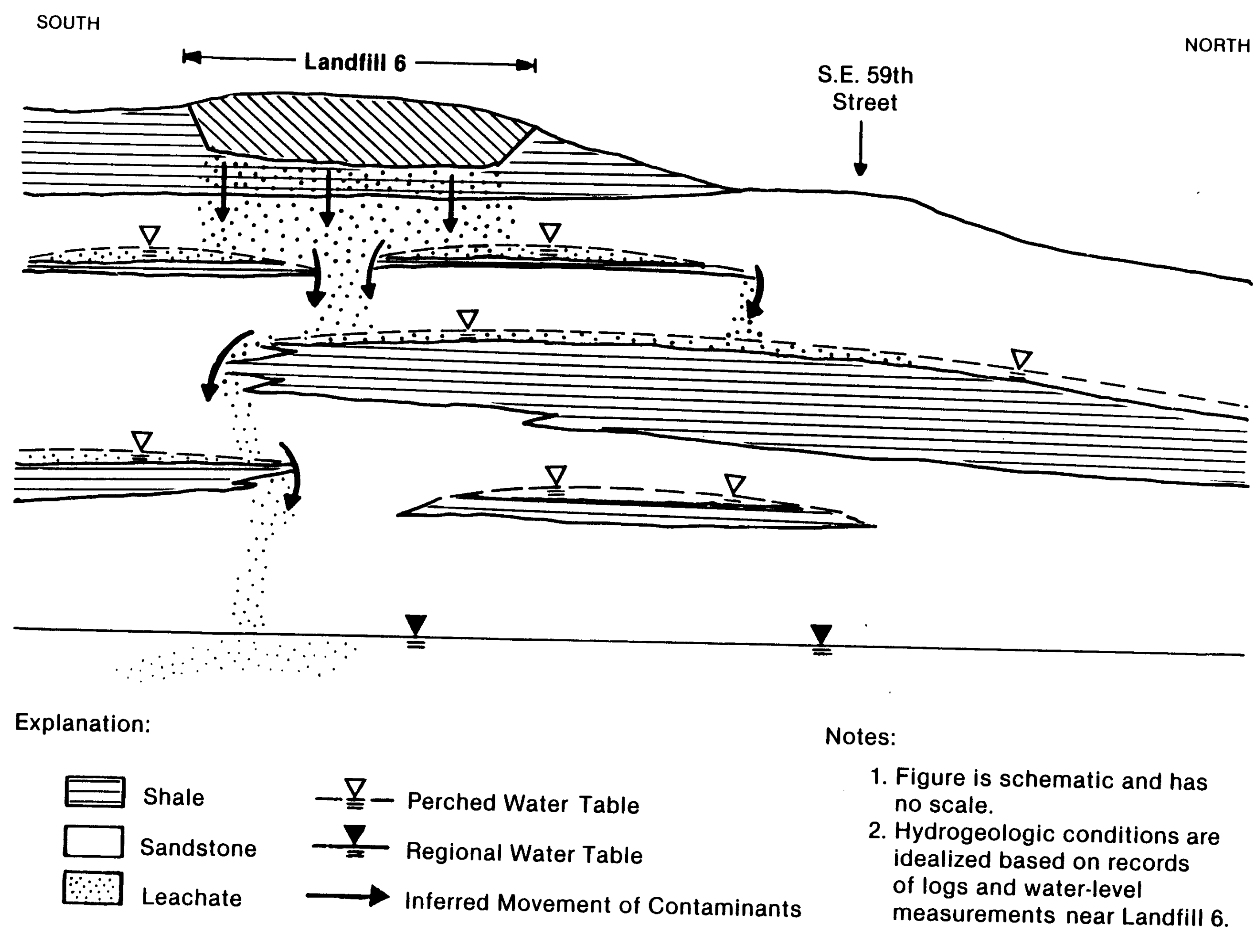


Figure 2. Conceptual Model of Hydrogeologic Conditions, Landfill 6.

TABLE 4. SUMMARY OF SAMPLING RESULTS, LANDFILL 6

Parameter	Range of Levels Detected (μg/L)*
EPA 601 (Volatile Organics)	
Chloromethane	n.d.-63.8
Vinyl Chloride	n.d.-10.8
Chloroethane	n.d.-15.3
Methylene Chloride	n.d.-11.5
Trichlorofluoromethane	n.d.-12.2
1,1-Dichloroethane	n.d.-29.9
Chloroform	n.d.-19.2
1,2-Dichloroethane	n.d.-0.2
1,1,1-Trichloroethane	n.d.-4.2
1,2-Dichloropropane	n.d.-0.6
Trichloroethylene	n.d.-61.0
Tetrachloroethylene	n.d.-22.5
Chlorobenzene	n.d.-5.7
1,2-Dichlorobenzene	n.d.-6.5
EPA 625 (Acid Extractables)	
none detected	
EPA 625 (Base/Neutrals)	
1,4-Dichlorobenzene	n.d.-12
bis(2-ethylhexyl)phthalate	n.d.-8
Diethyl phthalate	n.d.-32
EPA 624 (Volatiles)	
Benzene	n.d.-8
trans-1,2-dichloroethene	n.d.-21
Ethylbenzene	n.d.-18
Toluene	n.d.-6

*Levels ranged from "not detected" at the limit specified in the method to the maximum level shown.

Buried Pit and Tank Survey

The survey identified pits and tanks which could be considered candidates for possible sources of contamination. However, the survey results suggest that the trichloroethylene contamination is most likely the result of past industrial operations which occurred in degreasing pits throughout Building 3001 over a period of up to 30 years.

Stream Sediment Sampling

In general, analyses of sediment show no evidence of widespread or elevated levels of industrial contaminants. No other follow-up action is deemed appropriate.

Radiological Waste Disposal Site (RWDS)

The most probable location of RWDS-1022E was identified and marked in the field. The Base Civil Engineer is to construct a permanent concrete marker at the site. No indication of the location of RWDS-62598 was found. It is probable that, as previously reported, the materials have been removed. No further actions are recommended at either of these sites.

Base Water Supply Wells

Observations in the Base water supply wells suggest ground-water flow is generally from east to west. The data are not sufficient to resolve any southerly component of the flow. They also document strong downward gradients within the ground-water system. That is, shallow wells display a higher head than deeper wells, showing a tendency for water to move downward in the aquifer.

Recommendations

Based on the findings of this study, Radian recommends the following actions at each of the Stage 2 study areas. The recommendations are organized by category, as follows:

Category I	Sites where no further action is required.
Category II	Sites requiring additional Phase II investigations to fully describe or quantify conditions.
Category III	Sites which require remedial action and are sufficiently well known for Phase III/IV actions to begin.

All Stage 2 study areas are discussed below. Recommendations concerning Category II and III sites are presented in Table 5.

Category I Sites

No further actions will be required at three Tinker AFB study areas. These are:

- o Radiological Waste Disposal Sites;
- o Base Water Supply Wells; and
- o Stream Sediment Sampling.

Category II Sites

The buried pits and tanks in the Building 3001 area are classed as Category II. Additional work will be required to assess the potential environmental impacts of these facilities. The recommended actions are as follows:

- o Inspect, and obtain samples from the contents and subsurface soils from selected pits buried beneath Bldg. 3001. Analyze samples for the presence of chlorinated solvents by EPA Method 601.

- o Obtain samples of any liquids from abandoned tanks buried in the vicinity of Bldg. 3001 where access is possible through vent pipes or surface connections. Analyze these samples for the presence of chlorinated solvents and hydrocarbon content.

TABLE 5. RECOMMENDATIONS CONCERNING CATEGORY II AND III SITES, TINKER AFB

Area	Recommended Action	Rationale
Landfill 6	Install additional monitor wells south and west of the Landfill	Existing monitor well network does not adequately document impacts to regional aquifer.
Building 3001 Area	Initiate remedial action to remove industrial organic chemicals from upper part of aquifer.	Presence of contaminants poses potential threat to regional Garber-Wellington aquifer.
Buried Pits and Tanks, Bldg. 3001	Conduct limited sampling of identified pits and tanks within Bldg. 3001.	Document environmental impact of pits and tanks.

Category III Sites

Both Landfill 6 and the Building 3001 area constitute Category III sites where remedial actions may begin.

Building 3001: While the complete area of occurrence of contamination is not known, Radian considers that the current system is sufficiently well defined to allow activities to proceed to remediation. The most obvious method of remedial action is a pump-out-and-treat system of relatively shallow (∿200 foot depth) production wells, followed by appropriate treatment or consumptive use in industrial processes. The following guidance is offered concerning the execution of this remedial action:

- Well drilling should be initiated adjacent to the building (east and west sides), substantially along its full north-south length. Gaps in the data concerning the occurrence of contaminants may be filled in during drilling for remediation.

- Pumping for remediation can begin as soon as a substantial number of the wells are in place, with continued testing for the occurence of halogenated organics as the program progresses. If a complete system of wells on the west side of Building 3001 shows extensive contamination, consideration will have to be given to production well installation within the airfields, active runways, and taxiways.

- The renovation of Well 18 should also be accomplished at the same time.

Landfill 6: Radian recommends that two to three additional monitor wells be installed to test the impact of the landfill on the regional aquifer to the south and southwest. These wells should be of sufficient depth to monitor the top of the regional system, a depth equivalent to approximate elevation 1200 feet. In order to accommodate the effect of the contaminants moving laterally along shale zones above the water table, these wells should be located away from the landfill by 100-200 feet.

1.0 INTRODUCTION

The Department of Defense (DOD) is conducting a nation-wide program to evaluate past waste disposal practices on DOD property, control the migration of hazardous contaminants, and to control hazards that may result from these waste disposal practices. This program, the Installation Restoration Program (IRP), consists of four phases: Phase I, Initial Assessment/Record Search; Phase II, Problem Confirmation; Phase III, Technology Base Development; and Phase IV, Remedial Actions. The United States Air Force (USAF) has initiated an IRP investigation at Tinker Air Force Base near Oklahoma City, Oklahoma. Phase I was conducted in 1982; Phase II (Stage 1) was conducted in 1983-1984. Radian Corporation has performed the Phase II (Stage 2) Field Evaluation under USAF Contract No. F33615-83-D-4001, Delivery Order 0021.

1.1 Purpose of the Investigation

The purpose of the Phase II (Stage 2) investigation was to determine if environmental contamination has resulted from solvent storage and waste disposal practices at Tinker AFB. In addition, the investigation included an estimate of the magnitude and extent of contamination, the identification of environmental consequences of migrating pollutants, and the recommendation of additional investigations to identify the magnitude, extent and direction of movement of discovered contaminants.

1.2 Duration of the Program

Authorization to proceed on the Tinker AFB Phase II (Stage 2) program was given on 23 May 1984. Following the initial site visit conducted on 13 June 1984, field activities were conducted from June through August 1984. A second field season was completed during October, 1984. The field work consisted of the installation and sampling of ground-water monitoring wells, geophysical surveys of two radiological waste disposal sites, sampling and analysis of sediments from base streams and drainage channels, a survey of buried pits and tanks in the vicinity of Building 3001 and measurement of depth to water in the base production wells.

1.3 Waste Disposal Practices

Management of wastes at Tinker AFB was reviewed as part of the Phase I investigation conducted in 1982. Results of the investigation show that waste generated during most of the history of Tinker AFB has generally been handled on-site; recent operations (since about 1980) have directed wastewater streams to treatment units on base prior to discharge and have contracted with private waste disposal firms to handle solid wastes. On-site disposal operations included the use of landfills for solid waste, industrial waste pits for the disposal of liquids and sludges, and other disposal sites for low-level radioactive materials.

Disposal of solid waste occurred from 1942 to 1979 at six locations across the southern part of the Base. The landfills, numbered 1 through 6, were constructed by excavating a series of parallel trenches, depositing waste, and covering with soil. The depth of the trenches has not been accurately recorded; it is probable that the depth is largely related to the ease of excavation of the shallow soil above shale bedrock, generally 10 to 15 feet below land surface. The landfills are visible today as features slightly elevated above the surrounding topography, with a hummocky surface corresponding to the former trenches that have undergone differential compaction. Most waste deposited in the landfill consisted of general refuse (paper, trash, construction debris, and garbage). Table 1-1 identifies the features of each landfill and lists the probable contents at each site.

Liquid wastes and sludges generated during the period 1947-1965 were directed to industrial waste pits located in the southeast portion of the Base. These sites, Industrial Waste Pits 1 and 2, were used for the disposal of waste streams originating from the various aircraft maintenance shops at Tinker AFB. The streams were thought to contain high levels of heavy metals, and a variety of organic contaminants (solvents and cleaners). The pits were probably unlined, with the materials in the pits periodically burned.

The six landfills and two industrial waste pits, along with the base water supply wells, were investigated during Phase II (Stage 1) (Radian, 1984). The Stage 1 zones of investigation are shown on Figure 1-1.

TABLE 1-1. SUMMARY OF LANDFILLS AT TINKER AIR FORCE BASE (Engineering-Science, 1982)

Landfill	Period of Operation	Approximate Area (Acres)	Types of Wastes	Estimate Quantity (yd^3)	Method of Operation	Closure Status	Geological Setting	Surface Drainage	Comments
1	1942-1945	1.2	General refuse	30,000	Burning, Trench	Closed, covered with earth, vegetation	Fine-grained sandstone; shale and mudstone	To Crutcho Creek	Some water ponding due to differential settling in trenches
2	1945-1952	20	General refuse, probably some industrial waste	500,000	Trench	Closed, covered with earth, vegetation	Fine-grained sandstone; shale and mudstone	To Crutcho Creek	A large pond is present above parts of the landfill
3	1952-1961	8	General refuse, probably some industrial waste	200,000	Trench	Closed, covered with earth	Fine-grained sandstone; shale and mudstone	To Crutcho Creek	Now used as storage area for hardfill and dirt
4	1961-1968	16	General refuse, probably some industrial waste, and POL sludges	400,000	Trench	Closed, covered with earth, partial vegetation	Fine-grained sandstone; shale and mudstone	To Crutcho Creek	Leachate occasionally visible along west side of landfill. Past leachate samples show high mercury and phenols.
5	1968-1970	3	General refuse, probably some industrial waste	75,000	Trench	Closed, covered with earth, vegetation	Fine-grained sandstone; shale and mudstone	To Crutcho Creek	Some leachate reported along side of landfill near creek.
6	1970-1979	11	General refuse, probably some industrial waste, and industrial waste treatment sludge	500,000	Trench	Closed, covered with earth, partial vegetation	Terrace; sand, silt, clays	To Soldier Creek	Covered and graded. No waste visible.

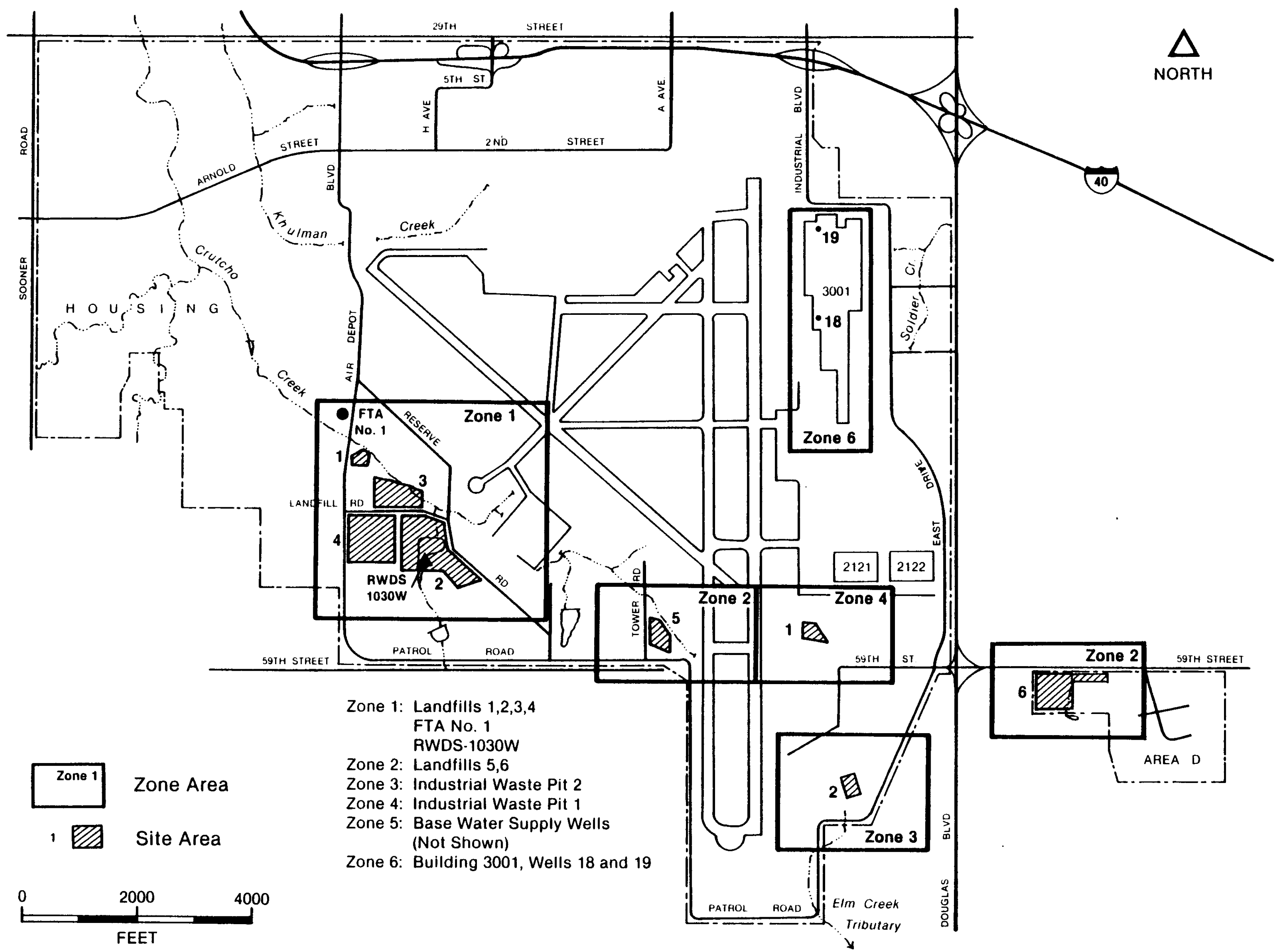


Figure 1-1. Zones of Investigation, Tinker AFB IRP Phase II, Stage 1.

1.4 Site Description

For Stage 2, Radian continued the investigations of the Building 3001 area and Landfill 6. Additional areas investigated included the Base streams, two radiological waste storage sites (RWDS) and depth to water measurements in the Base water supply wells. These areas are shown on Figure 1-2. Each investigation site is described below.

1.4.1 Building 3001

Building 3001 houses numerous maintenance and repair activities and shops which support the mission of the Oklahoma City Air Logistic Center. This command operates an overhaul and modification complex engaged in repairing and upgrading aircraft including a vast quantity of engines and many thousands of accessory items. Industrial operations within the Building 3001 area encompass a variety of repair and maintenance facilities which include:

- Disassembly, cleaning, and inspection of aircraft systems and components;
- Plating, painting, heat treating, testing of metal parts and components;
- Accessory shops including electrical, valve and governor, gear box, tubing and cable, fuel controls, nozzles, pumps, bearings, and other specialized repair shops; and
- Assembly and testing and packaging of aircraft and aircraft components.

In addition, other functions housed within this or other nearby buildings include utility (water, power and steam production), administrative and engineering offices, parts and material storage, and others.

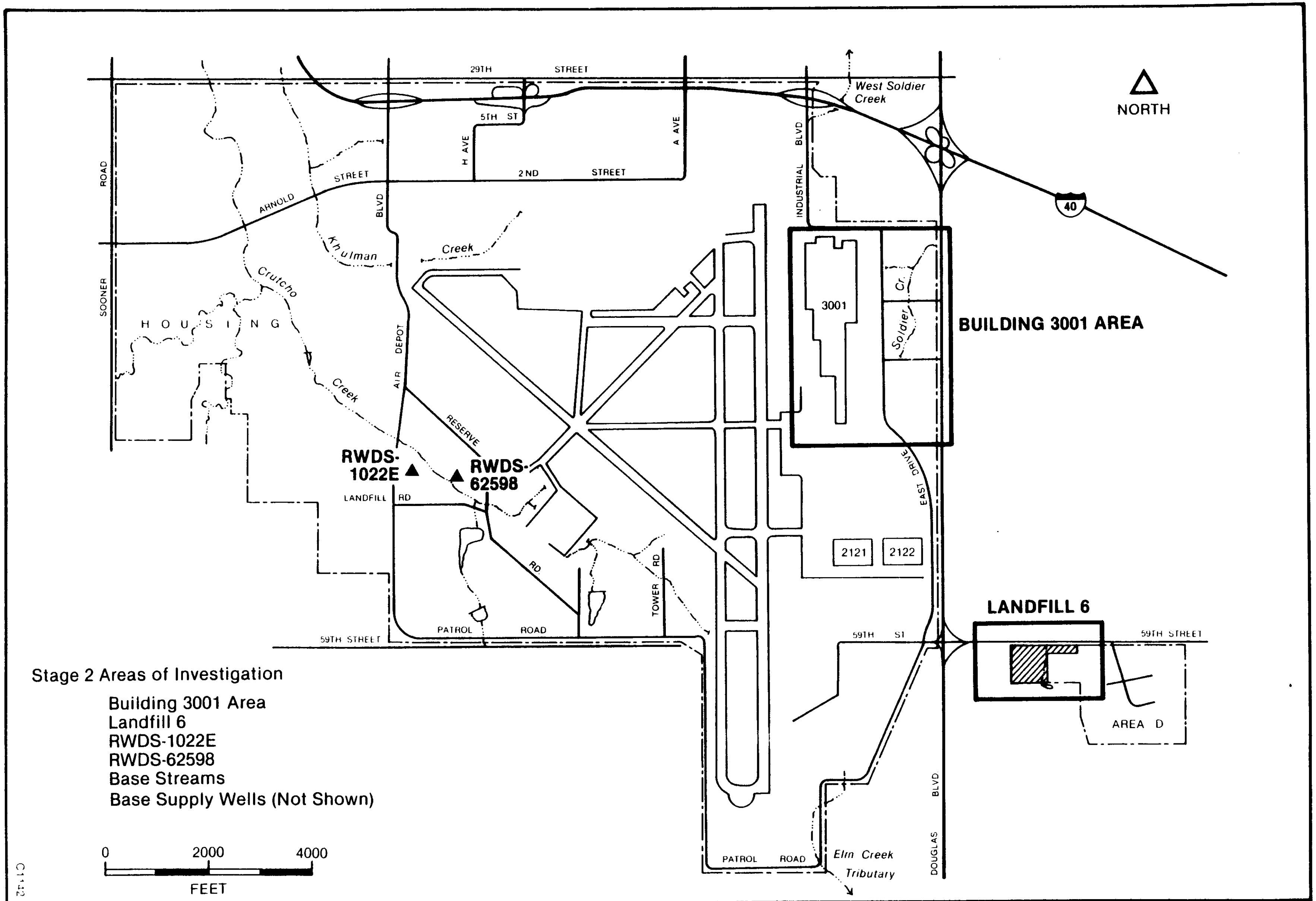


Figure 1-2. Areas of Investigation, Tinker AFB IRP Phase II Stage 2.

1.4.2 Landfill 6

Landfill No. 6 was used for the disposal of refuse from 1970 to 1979. This landfill is located in Area "D" approximately 1/2 mile east of Tinker AFB along S.E. 59th Street on land leased from Oklahoma City. Although 40 acres are available at the site, only about 20 acres were used prior to the closing of the site during 1979. The western half of the landfill was used, as were two trenches adjacent to SE 59th St. in the eastern half. Base refuse since that time has been disposed of off-site by private contractor.

1.4.3 Base Streams

The principal drainages for Tinker AFB are Crutcho and Soldier Creeks. Most of the Base is drained by Crutcho Creek and its tributary, Khulman Creek. The eastern part of the Base, near Douglas Boulevard and the Air Logistics Center, is drained by Soldier Creek. The extreme southern part of the Base is drained by Elm Creek, which is dry under normal conditions. Sediment sampling sites were established for each of the drainages on the Base, including sites along the length of each stream and a site at the Base boundary. Sites were established in accordance with the recommendations in the Phase I report.

1.4.4 Radiological Waste Disposal Sites

Radioactive waste disposal site RWDS 62598 is located south of Facility 1025 and north of Crutcho Creek. A concrete post with attached radiation warning sign marks the general disposal area. The site contains a "lead still" made of sheet lead used to evaporate methyl ethyl ketone (MEK) or acetone for reuse. The MEK and acetone were contaminated with radium paint from cleaning radium dials. After use, a residue of radium paint solids remained in the still. Following a period of usage, the lead still became radioactive due to the accumulation of solids. In the early 1950's, the lead still was reportedly buried in the general area marked by the concrete post. The depth of burial is not known. One Air Force document states the waste may later have been removed; however, no conclusive evidence exists for either the presence or absence of the waste. Recent radiological monitoring has identified no area of increased radioactivity near the site. (Engineering-Science, 1982).

Another radioactive waste disposal site, RWDS 1022E, is located adjacent to the northwest corner of Landfill No. 3 south of West Crutcho Creek. During the mid-1950's approximately 8 to 10 containers of radioactive material were disposed of at the site. The material was placed in a hole approximately 30 feet deep located next to landfill No. 3, which was operative during the period 1952-1961. The area was marked with radiation warning signs, although none are now present. The area was surveyed with beta/gamma radioactivity detector equipment during November 1981. Radiation levels of 0.03 millirem per hour (mr/hr) above a background of 0.02 mr/hr were detected; indicating radioactive materials are present, but do not result in radioactivity levels hazardous to human health (Engineering-Science, 1982).

1.4.5 Base Water Supply Wells

Tinker AFB presently obtains water supplies from a system of 22 on-base water wells constructed along the east and west Base boundaries. All Base wells are completed in the Garber-Wellington Aquifer. Base wells range from 650 to 1100 feet in depth, with yields ranging from 71 to 210 gallons per minute. The wells incorporate multiple screens, deriving water supplies from sand zones that vary in thickness from 103 to 184 feet.

1.5 Sampling and Analytical Program

The sampling program at Tinker consisted of the collection of stream sediments and ground water. Stream sediment samples were collected using a tube sampler driven into the substrate (wet sites) or with a small auger or hand trowel (dry sites). The sediment samples were placed individually in glass jars and chilled. Samples of water were collected from monitoring wells installed as part of this Phase II (Stage 2) IRP investigation and from one monitoring well installed as part of the Stage 1 investigation. Water samples were collected with a Teflon bailer.

All samples were transported to Radian Analytical Services for analysis. The schedule of analyses is summarized on Table 1-2, with complete descriptions provided in Section 3.0.

As part of the overall project Quality Assurance (QA) program, approximately 10% of samples were collected in duplicate and submitted for analysis. Results of these duplicate analyes are tabulated in Section 4. In addition, of course, the analytical laboratory conducts an internal QA/QC program, as discussed in Appendix F. Spikes, duplicates and blanks are analyzed and compared with established control limits. If quality control (QC) results exceed limits, samples are re-analyzed. Data are reported out only after the QC data pass muster. All QA/QC data are archived and available for audit.

Investigation Personnel

The Tinker AFB IRP Phase II (Stage 2) investigation was conducted by several individuals from the Austin office of Radian Corporation. Thomas W. Grimshaw, Program Manager, was responsible for the contractual administration of this program. The overall technical program was directed by William M. Little, Senior Engineer and Certified Professional Geological Scientist. Mr. Little was involved in the coordination of all activities of the program, including direct participation with USAF personnel in the areas of contract and technical matters. The geophysical surveys and monitor well installation were supervised by Mr. Little and Lawrence N. French, Certified Professional Geological Scientist. The pit and tank survey was conducted by Robert C. Wallace. Sediment sampling activities were conducted by Mr. Wallace and David H. Gancarz. Monitor well sampling activities were conducted by Nancy P. Stein and Mr. Gancarz. Mr. French was the principal author of the draft report. Cartographic and technical illustrations were prepared by Jill P. Rossi. Ann E. St.Clair provided senior technical staff review and editing. All of the above individuals were involved in the preparation of the draft and final reports. Resumes for these individuals are provided in Appendix K.

TABLE 1-2. ANALYTICAL SCHEDULE FOR SOIL AND WATER SAMPLES, TINKER AFB IRP, PHASE II, STAGE 2

Monitor Wells

Parameter

Volatile Organic Halogens (EPA Method 601)
Volatile Organic Compounds (VOC) (EPA Method 624)
Base/Neutrals and Acid Extractable Compounds (BNE) (EPA Method 625)

Stream Sediment

Arsenic	Fluoride
Barium	Nitrate
Cadmium	Cyanide
Chromium	Phenol
Lead	PCB's
Mercury	Total Organic Carbon (TOC)
Selenium	Endrin
Silver	Lindane
Copper	Methoxychlor
Zinc	Toxaphene
Manganese	2,4-D
Nickel	2,4,5-TP Silvex

2.0 ENVIRONMENTAL SETTING

This discussion of the Tinker AFB environmental setting was principally derived from the Installation Restoration Program Phase I Records Search report (Engineering-Science, 1982). Information developed from that report is supplemented by the literature and the general findings of this study. The following sections describe the environmental setting of Tinker AFB. Basic features and history of the sites investigated in this study are also discussed here.

2.1 General Geographic Setting and Land Use

Tinker AFB is located in central Oklahoma, within the corporate limits of Oklahoma City and adjacent to the suburbs of Midwest City and Del City (Figure 2-1). Tinker AFB is bordered by Interstate 40 to the north, Douglas Boulevard to the east, Sooner Road to the west, and industrial and undeveloped land near S.E. 59th Street to the south. The general features of Tinker AFB are illustrated in Figure 2-2.

The Base lies within an area representing a transition from residential and industrial/commercial land use on the west to agricultural land on the east and south. The principal industrial use of the area southwest of the Base is the General Motors installation south of S.E. 59th Street.

2.2 Physiographic and Topographic Features

Tinker AFB is located within the Central Redbed Plains section of the Central Lowland Physiographic Province, an area characterized by nearly level to gently rolling hills, broad flat plains and well-entrenched main streams. Surface elevations in the Oklahoma City area range from 1,070 to 1,400 feet MSL; at Tinker AFB the elevations range from 1,210 feet MSL (at Crutcho Creek, near the northwest portion of the Base) to about 1,320 feet MSL (at the southeast corner of the installation, south of 59th Street at Area "D"). Topographic features of the various sites investigated in this study are discussed in Section 4.0.

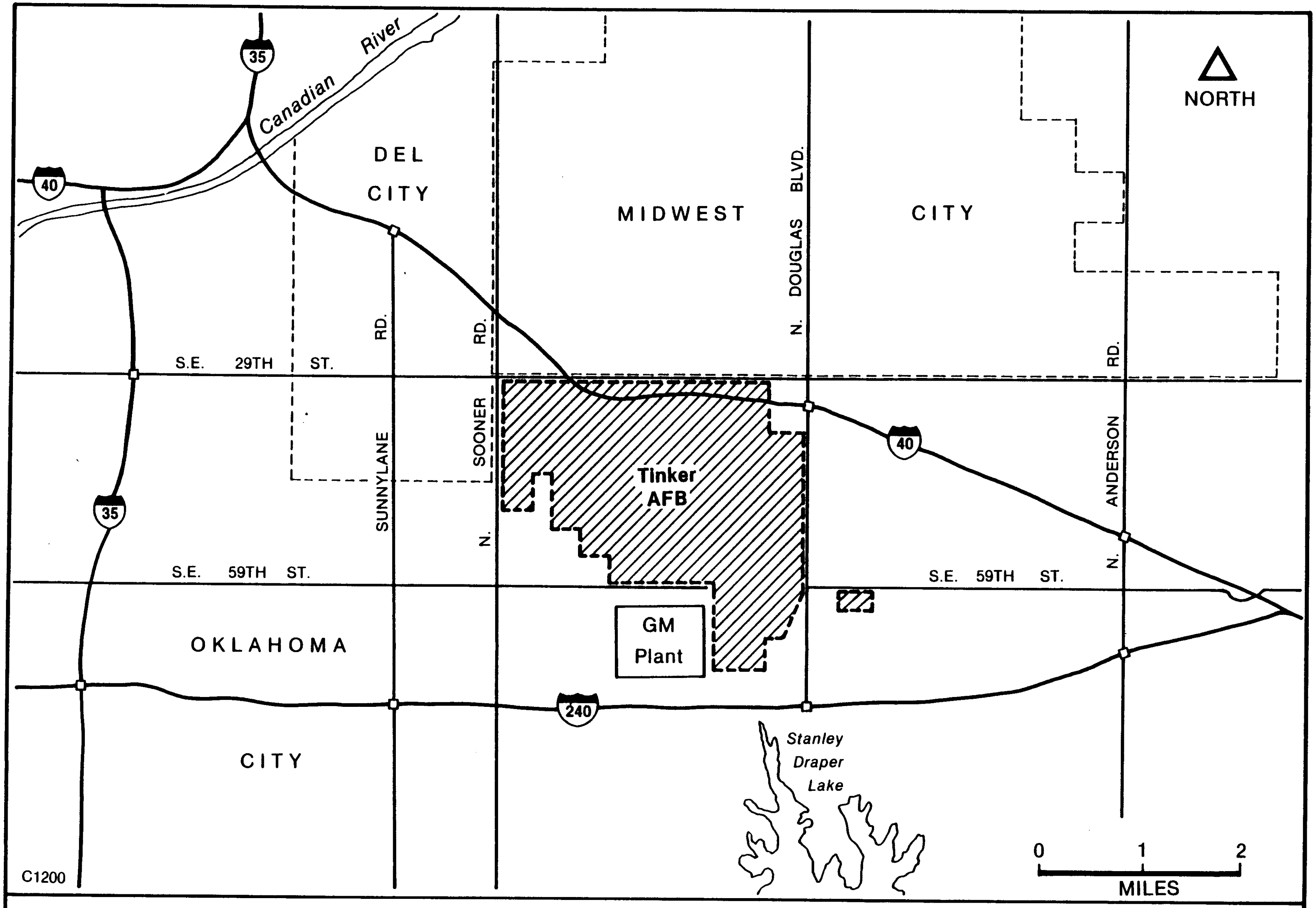


Figure 2-1. General Location Map, Tinker AFB.

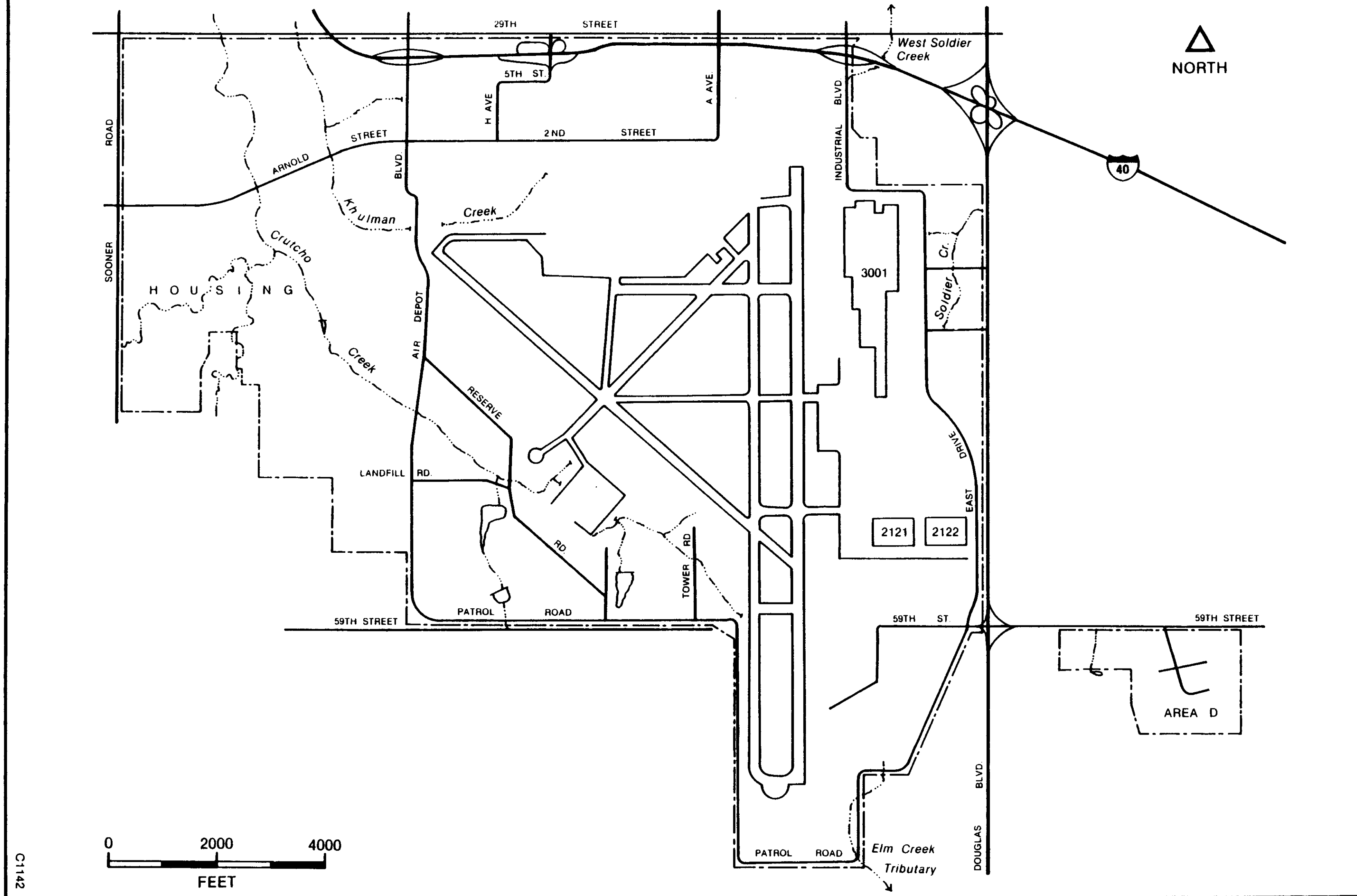


Figure 2-2. General Features of Tinker AFB.

The principal drainages for Tinker AFB are Crutcho and Soldier Creeks. Most of the base is drained by Crutcho Creek and its tributary, Khulman Creek. The eastern part of the base, near Douglas Boulevard and the Air Logistics Center, is drained by Soldier Creek. The extreme southern part of the Base is drained by Elm Creek. The drainage characteristics of the sites evaluated in this investigation are discussed in Section 4.0.

2.3 Geologic and Hydrogeologic Conditions

Surficial Soils

The surficial soils of Tinker AFB are described by the USDA, Soil Conservation Service (1969). The three major soil associations occurring on the installation are shown on Figure 2-3 and described on Table 2-1. The surface soils of the installation area are predominantly fine-grained and consist of two basic types: residual and alluvial. The residual soils associations, Darrell-Stephenville and Renfrow-Vernon-Bethany, are the product of in-place weathering of underlying bedrock. The alluvial materials (Dale-Canadian-Port Association) are stream-deposited silts and sands, whose occurrence is generally restricted to the floodplains of area streams.

Lithology

The physical distribution of significant geologic units relevant to this study is shown on Figure 2-4, which has been modified from the work of Bingham and Moore (1975). Tinker AFB geologic units are summarized on Table 2-2. Generally, the surfical geology of the north section of the installation is dominated by the Garber Sandstone, which crops out across a broad area of Oklahoma County. The surficial geology in the south portion of the Base is reportedly underlain by the Hennessey Group, consisting of the Kingman Siltstone and the Fairmont Shale, as indicated on geologic maps by Miser (1959) and Bingham & Moore (1975) and confirmed by drilling in Phase II (Stage 1). The Fairmont Shale (Hennessey Group) strata, consisting predominantly of shale, are difficult to distinguish from upper portions of the underlying

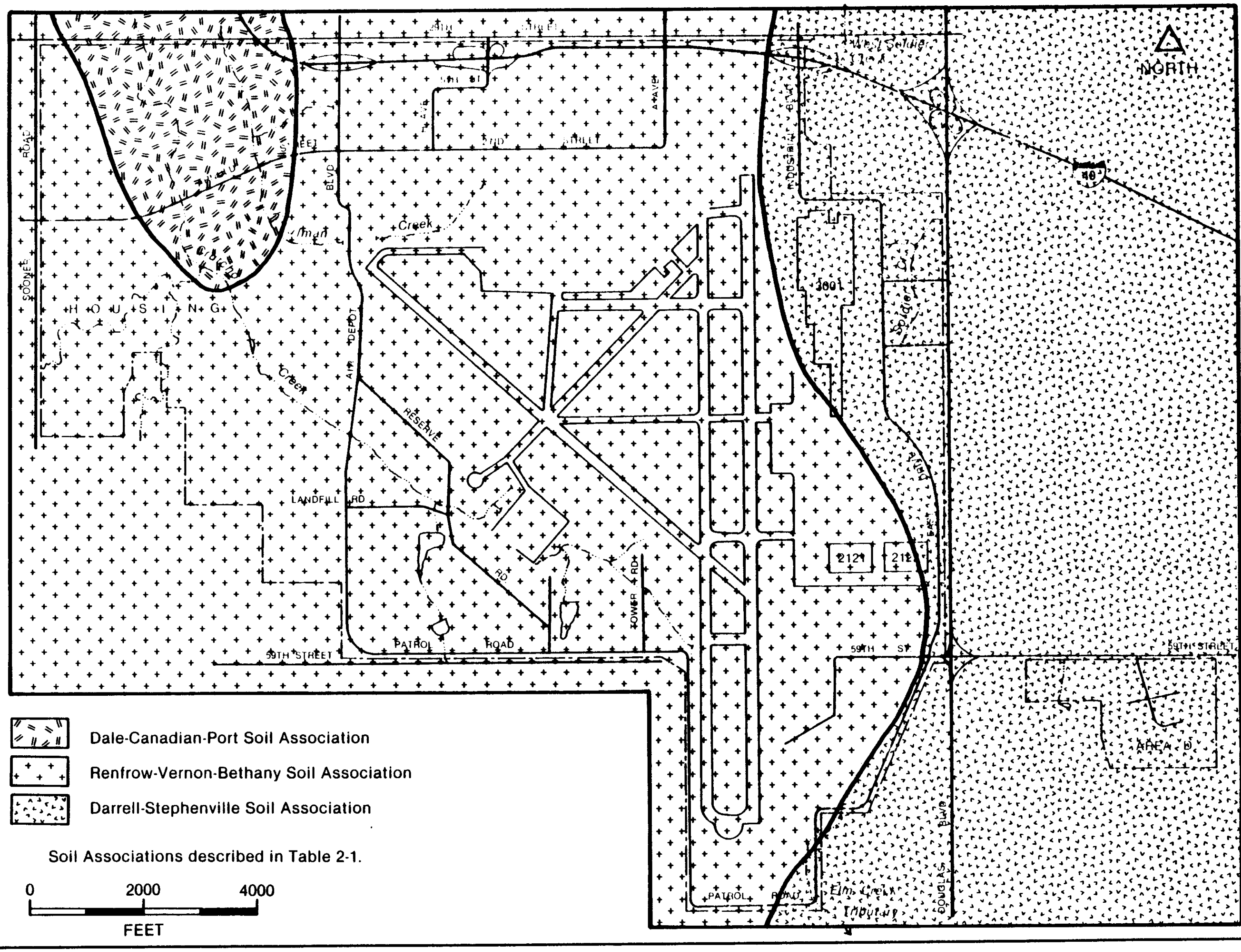


Figure 2-3. Soil Associations, Tinker AFB (USDA, Soil Conservation Service, 1969).

TABLE 2-1. TINKER AIR FORCE BASE SOIL ASSOCIATIONS

Association	Description	Thickness (in.)	Unified Class.	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	<0.06-0.20
Dale-Canadian-Port: loamy soils on low benches near large streams.	Fine sandy loam Silty clay loam Loam Clay loam	12-60	SM,ML,CL	0.05-6.30

SOURCE: USDA, Soil Conservation Service (1969).

* Although this characteristic of base soils is called "Permeability" by the Soil Conversation Service, it is actually a description of infiltration rates - the rate at which water moves through unsaturated earth materials.

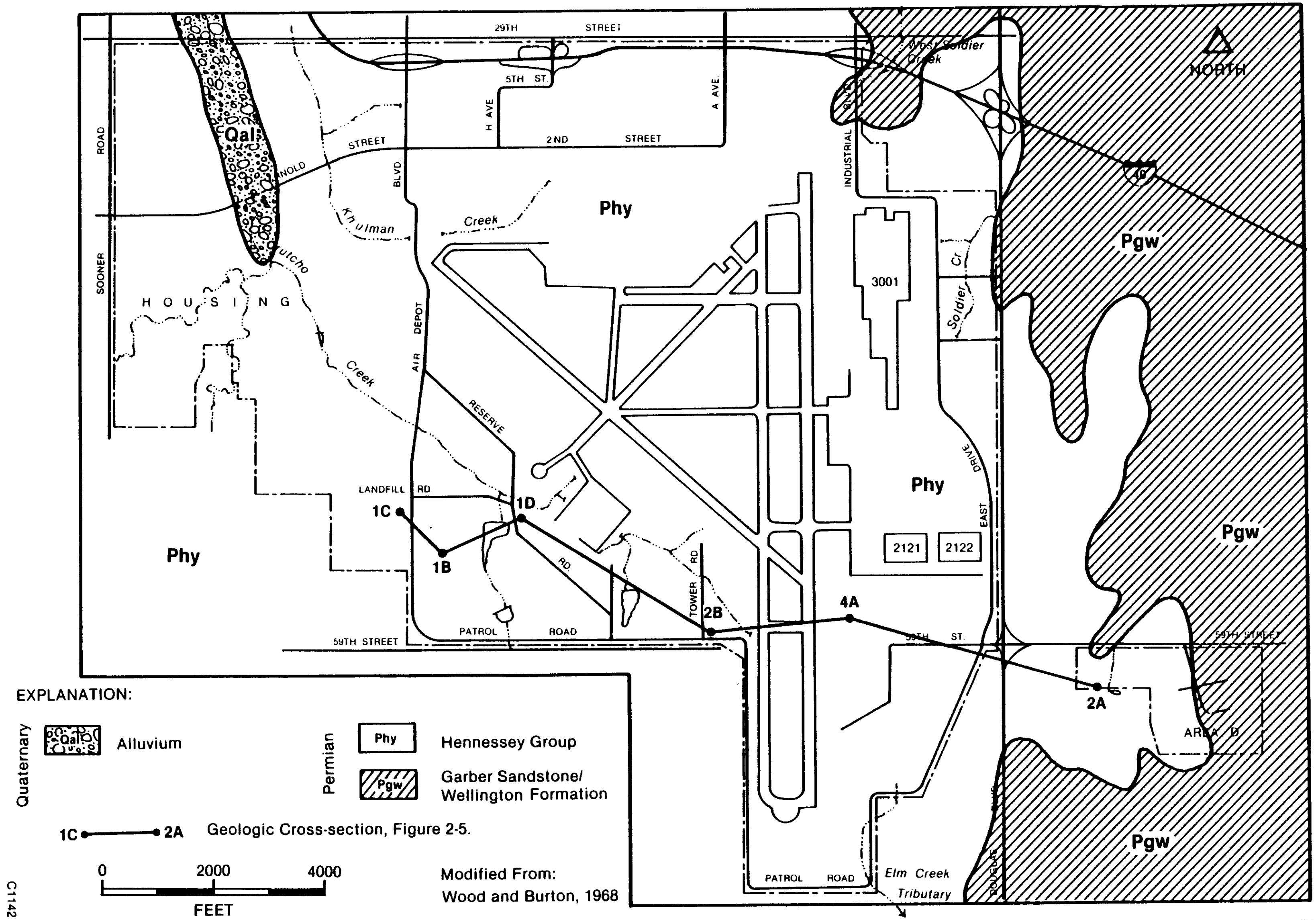


Figure 2-4. Geologic Map of Tinker AFB.

TABLE 2-2. 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 streams.	Moderately permeable. Yields small to moderate quantities of water to wells 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.
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 prairies.	Poorly permeable. Yields meager quantities of 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 to reddish-orange, massive and cross-bedded fine-grained sandstone interbedded with and interfingered with red shale and siltstone.	Poorly to moderately permeable. Important source of ground water 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.	

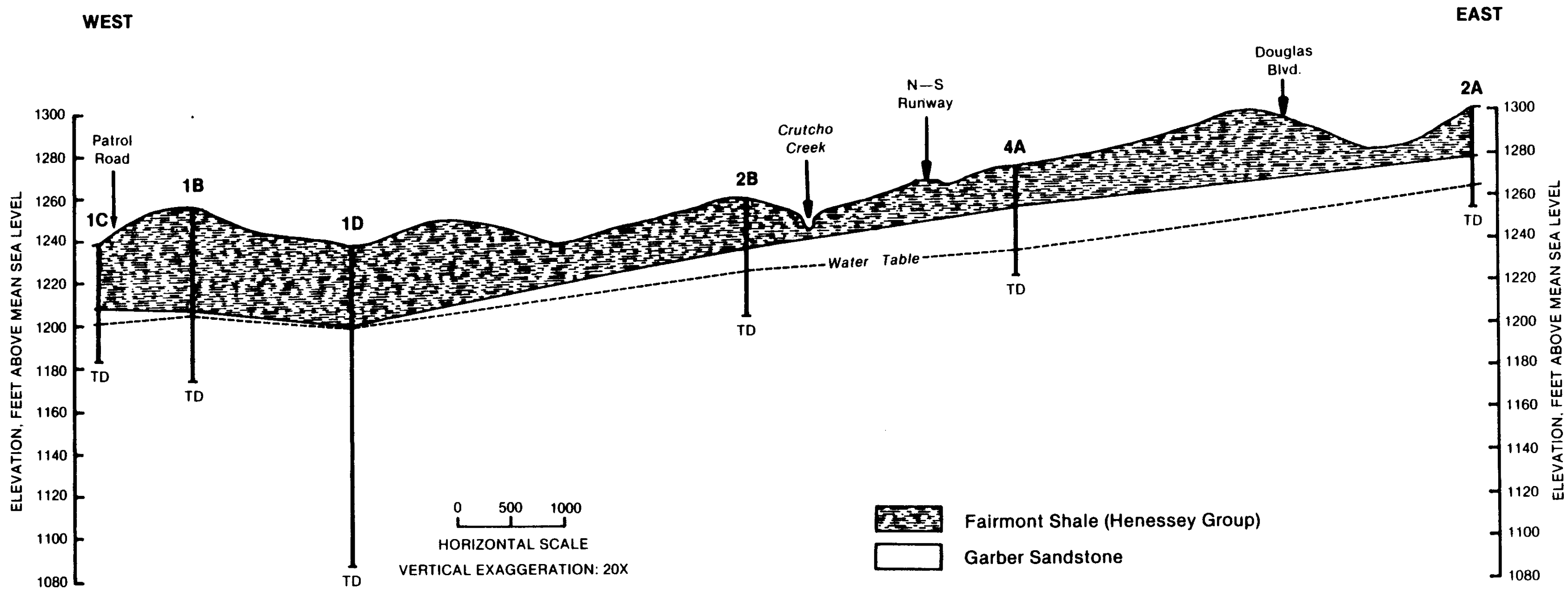
Garber Sandstone, which is reported to be shaly. The contact between the Fairmont Shale and Garber Sandstone is gradational throughout the Oklahoma City area. Published geologic maps differ in the interpretation of the surface geology at Tinker AFB; Wood and Burton (1968) extend the Fairmont Shale (Hennessey Group) over most of the Base, but Bingham and Moore (1975) map the Garber Sandstone over most of the Base and show the contact with the Fairmont Shale to lie, for the most part, south of S.E. 59th Street. Figure 2-5 is a shallow cross section across the southern portion of Tinker AFB, based on Phase II (Stage 1) drilling. This cross section is consistent with the Wood and Burton (1968) map, in that it shows the Fairmont Shale occurring north of S.E. 59th St. However, no geologic mapping, per se, was done to support or refute either interpretation. In either event, the significant observations are the occurrence of shale and sandstone beds, whether they be Fairmont or Garber. Results of drilling are discussed further in Section 4.0.

Structure

Tinker AFB lies within a tectonically stable area. No major faults or fracture zones have been mapped near the base. Most of the consolidated rock units of the Oklahoma City area are nearly flat-lying. The reported regional dip is forty feet per mile in a generally westward direction (Bingham and Moore, 1975).

Ground Water

Shallow Aquifer - Shallow, ephemeral aquifers exist temporarily within the study area where zones of alluvium border streams or where shallow sandy residual soils collect precipitation. At Tinker AFB, sandy residual soils overlying bedrock at shallow depths form such an ephemeral aquifer. Soil aquifers are typically recharged directly by precipitation. Seasonally, they gradually run dry as base flow to local streams and recharging of underlying rock aquifers deplete limited supplies. The significance of the shallow aquifer is that it may facilitate the contamination of important lower aquifers or surface waters by leachate generation and mobilization of wastes. It is not useable from a water-supply standpoint.



NOTES:
1. Location of cross-section is shown on Figure 2-4.
2. Geologic conditions are known only at the borings; contacts are interpolated between borings.
3. Only significant geologic contacts are shown, refer to logs of borings for detailed geologic descriptions.
4. Configuration of water table is based upon ground-water levels measured on February 13-17, 1984. Water level at 1D observed during drilling.
5. Geologic nomenclature is from Bingham and Moore (1975).

Figure 2-5. Shallow Geologic Cross-Section, Tinker AFB.

Garber-Wellington Aquifer - Tinker AFB lies within the limits of the Garber-Wellington Ground-Water Basin. The Garber Sandstone and the Wellington Formations together comprise the Garber-Wellington Aquifer, the most significant source of ground-water supplies in the Oklahoma City area. At the present time, Tinker AFB derives most of its water supplies 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 systems 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. The aquifer area is depicted in Figure 2-6.

The Garber Sandstone and the Wellington Formation are lithologically similar and in hydraulic contact. They were deposited under similar conditions and consist of lenticular beds of sandstone, siltstone and shale that tend to vary in thickness over relatively short horizontal distances (Wood and Burton, 1968). The sediments constituting the aquifer tend to be loosely cemented and have a maximum thickness of some 1,000 feet. In the area of outcrop, ground water occurs under water table (unconfined) conditions and may occur at relatively shallow depths below ground surface (100 to 150 feet). In areas overlain by younger geologic units, ground water occurs in the aquifer under artesian (confined) conditions and wells must be drilled deeper (200-250 feet) in order to encounter it (Wickersham, 1979). Ground water can occur under either water table or artesian conditions in the vicinity of Tinker AFB.

The Garber-Wellington aquifer is exposed at ground surface or mantled by a thin soil over the northern two-thirds of Tinker AFB. As noted above, the aquifer is probably overlain by a thin, discontinuous sequence of Hennessey Group sediments (Kingman Siltstone and Fairmont Shale) over the southern portion of the base. Water in useable quantities from productive zones in the Garber-Wellington is encountered at depths of approximately 100

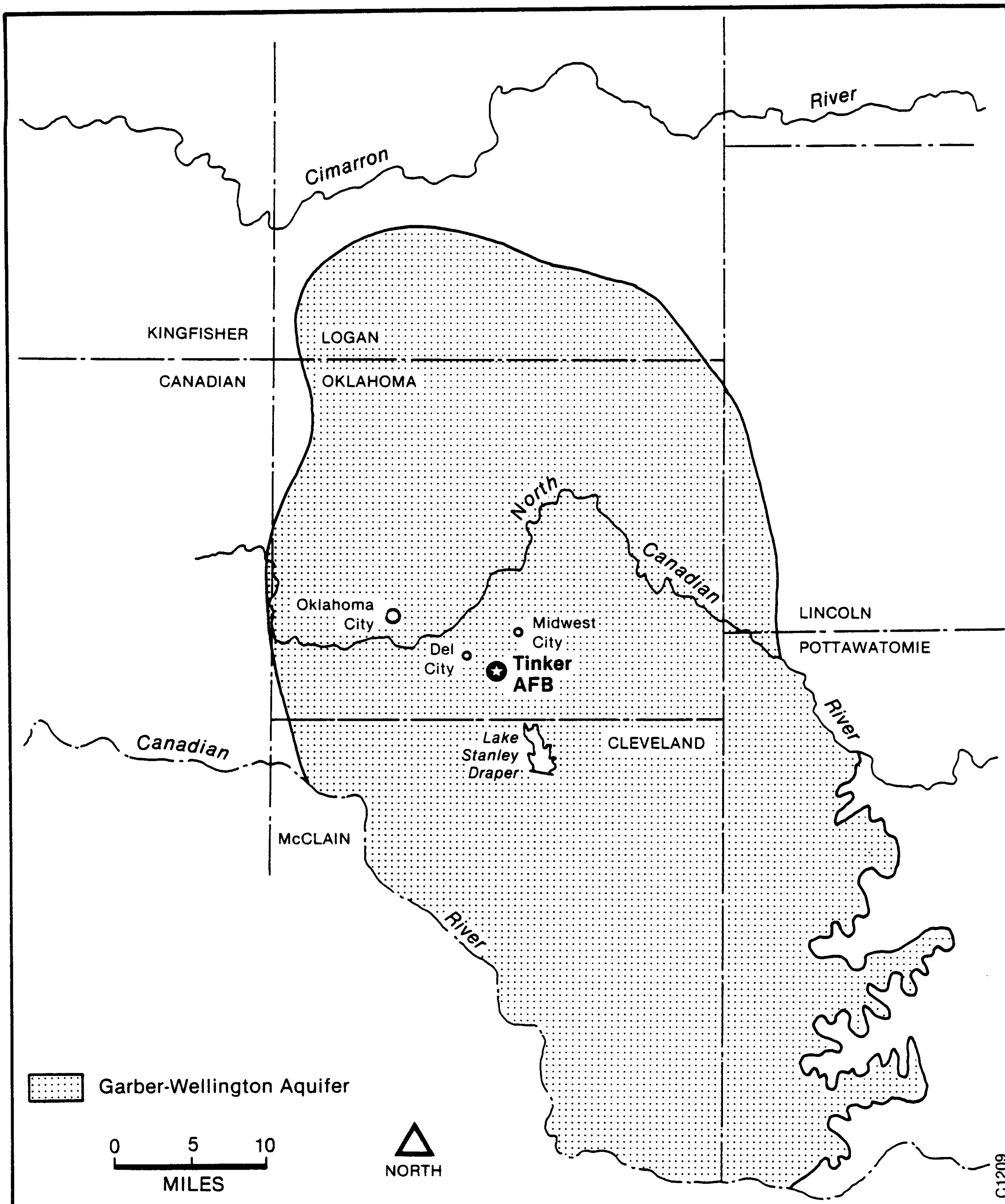


Figure 2-6. Location of Garber-Wellington Aquifer.

SOURCE: Marcher (1972); Wickersham (1979).

feet at Tinker AFB, although the top of the saturated, but poorly productive, zone delineated by Phase II (Stage 1) drilling was usually less than 50 feet. A geologic cross-section of base wells developed by Wickersham (1979) is presented as Figure 2-7. This figure graphically depicts the lenticular nature of the sandy zones. Although most of the aquifer is believed to be saturated, multiple screened wells are usually constructed in order to obtain water from the more productive zones.

Recharge of the Garber-Wellington Aquifer is accomplished principally by rainfall infiltration and by percolation of surface waters crossing the area of outcrop. Because most of Tinker AFB is located in an aquifer outcrop area, it is therefore assumed that the base is situated in a recharge zone (Havens, 1981). The aquifer is therefore susceptible to contamination in the study area. Ground-water levels and flow directions (1976 data) are presented as Figure 2-8. It is important to note that Figure 2-8, a verbatim transcript from Wickersham (1979), is based on generalized data from throughout the area shown. It is "true" in only a regional sense. Results of detailed investigations in any one small portion of the area are likely to be at variance with the regional data. The maps show Tinker AFB to be within a roughly 10-mile long zone, trending northeast-southwest which makes up a regional ground-water "high" - i.e., a recharge zone. Within this high area there is a local "low" or "saddle surface" area encompassing Tinker AFB, perhaps reflective of the ground-water withdrawals by the Base wells. The low is not sufficiently pronounced to prevent ground-water outflow from the base. According to the indicated hydraulic gradients, ground-water flow at Tinker AFB is presently directed to the west and northwest over most of the Base and to the south in the southeast part of the base. Local (i.e., on-base) ground-water data developed for this study are discussed in Section 4.0.

According to Wood and Burton (1968) and Wickersham (1979), the quality of ground water derived from the Garber-Wellington aquifer is generally good, although wide variations in the concentrations of some constituents such as hardness, sulfate, chloride, fluoride, nitrate, or dissolved solids, are known to occur. Wells drilled to excessive depths may encounter a saline zone, generally greater than 900 feet below ground surface.

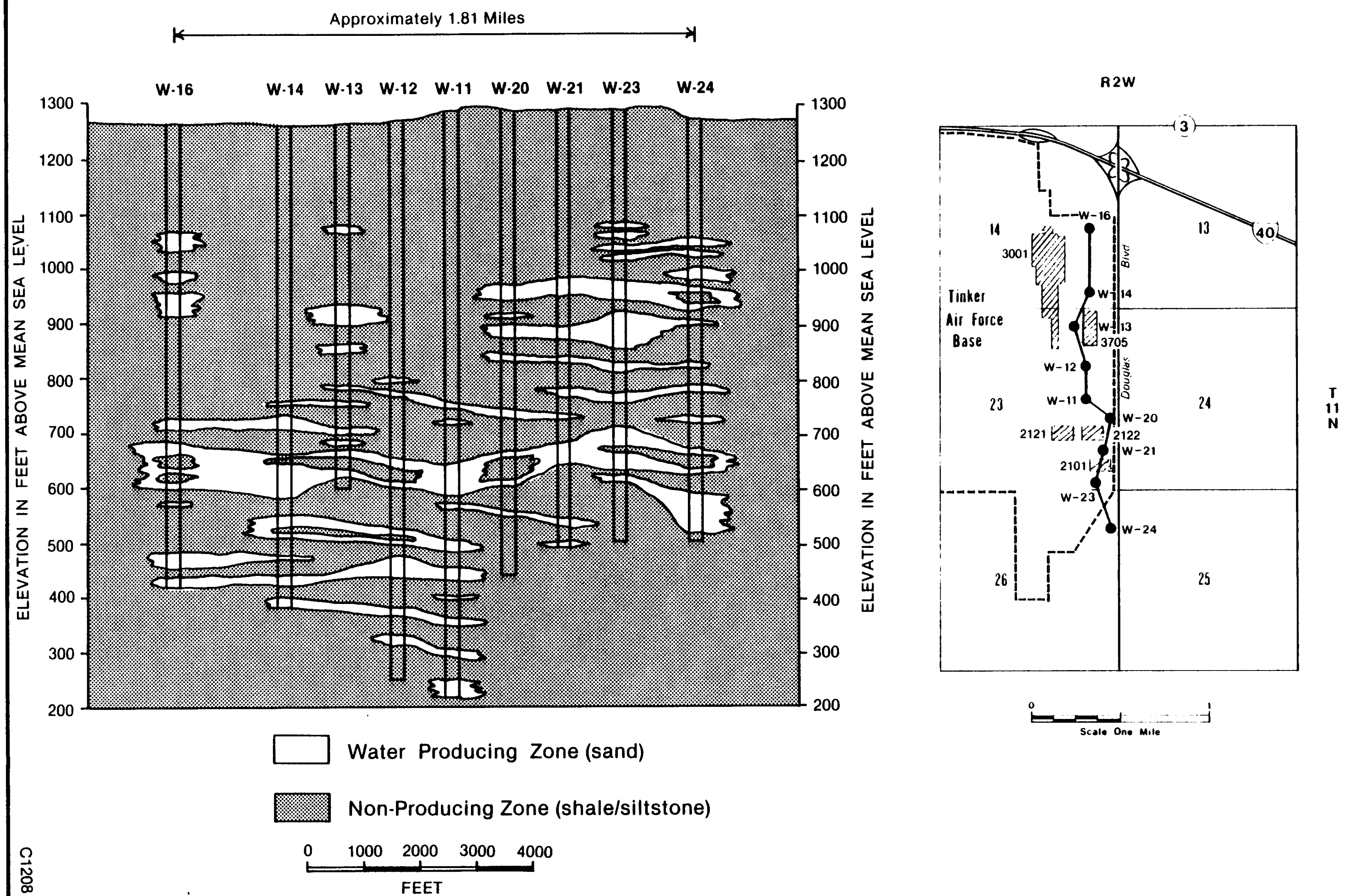


Figure 2-7. Geologic Section of the Garber-Wellington Aquifer at Tinker AFB (from Wickersham, 1979).

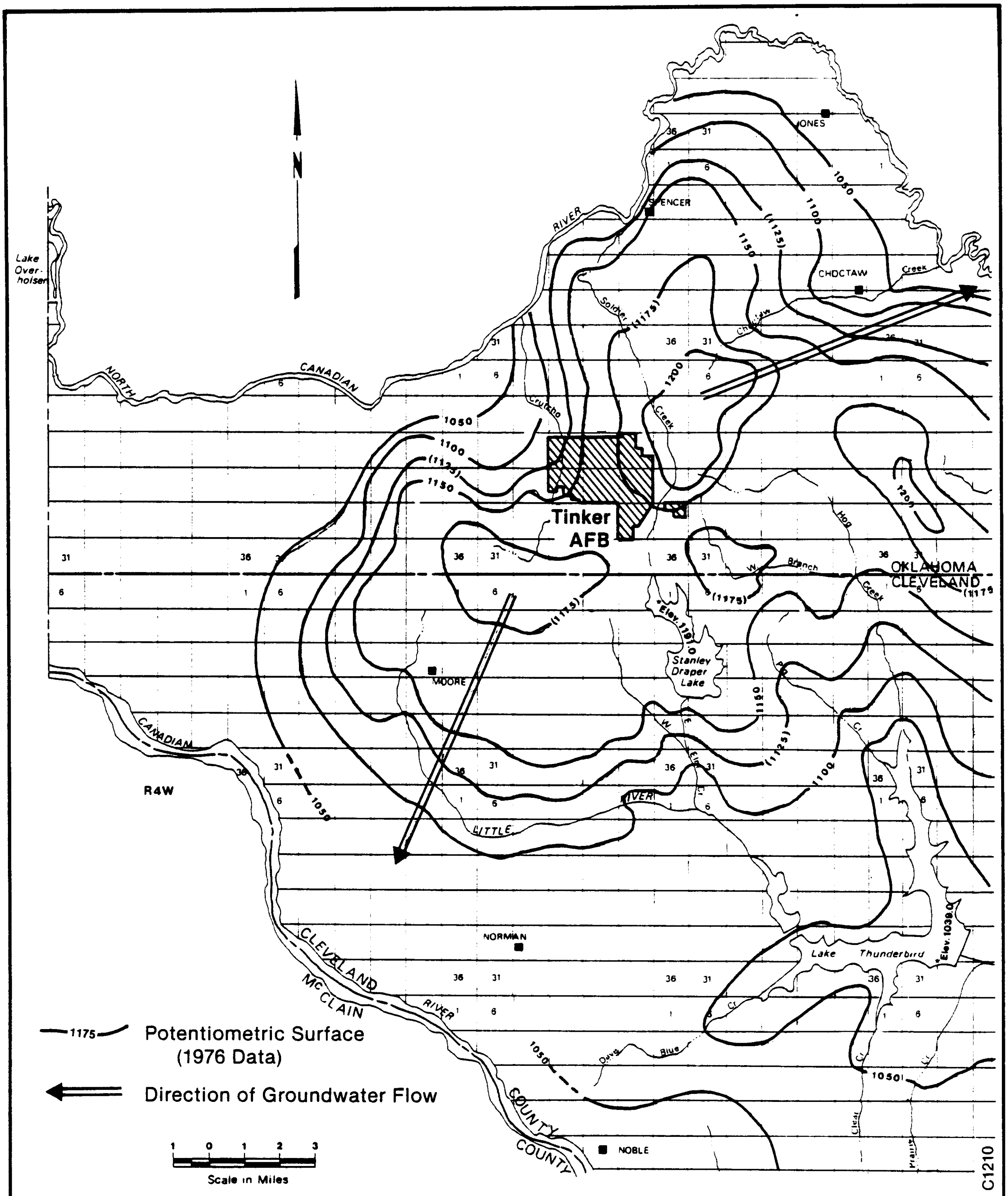


Figure 2-8. Ground-Water Levels and Flow Directions in the Garber-Wellington Aquifer (from Wickersham, 1979).

2.4 Site Descriptions

Phase I studies for the Tinker AFB Installation Restoration Program were completed by Engineering Science in April 1982. The purpose of the Phase I study was to conduct a records search for the identification of past waste management activities which may have caused ground-water contamination and the migration of contaminants off-base.

Fourteen individual sites at Tinker AFB were identified as containing hazardous waste. The potential environmental consequence of each site was evaluated using the Air Force's HARM (Hazard Assessment Rating Methodology) system. This system took into account such factors as the site environmental setting, the nature of the wastes present, past waste management practices and the potential for contaminant migration.

Of the 14 individual sites identified, eight sites, comprising four zones, were selected for Phase II (Stage 1) studies. Two additional problem areas, not addressed in Phase I, were added to the list of sites for Phase II (Stage 1) studies. These are the Base water supply wells and the wells in Building 3001. The Phase II (Stage 1) study sites are shown on Figure 2-9.

The Phase II (Stage 2) study is a continuation and expansion of the Stage 1 work. The general features of the sites evaluated in this study are discussed below. Detailed features of each site are discussed in Sections 3.0 and 4.0. The location of each of the sites is illustrated in Figure 2-10.

2.4.1 Building 3001

Building 3001 houses numerous maintenance and repair activities and shops which support the mission of the Oklahoma City Air Logistic Center. This command operates an overhaul and modification complex engaged in repairing and upgrading aircraft including a vast quantity of engines and many thousands of accessory items. Industrial operations within the Building 3001 area encompass a variety of repair and maintenance facilities which include:

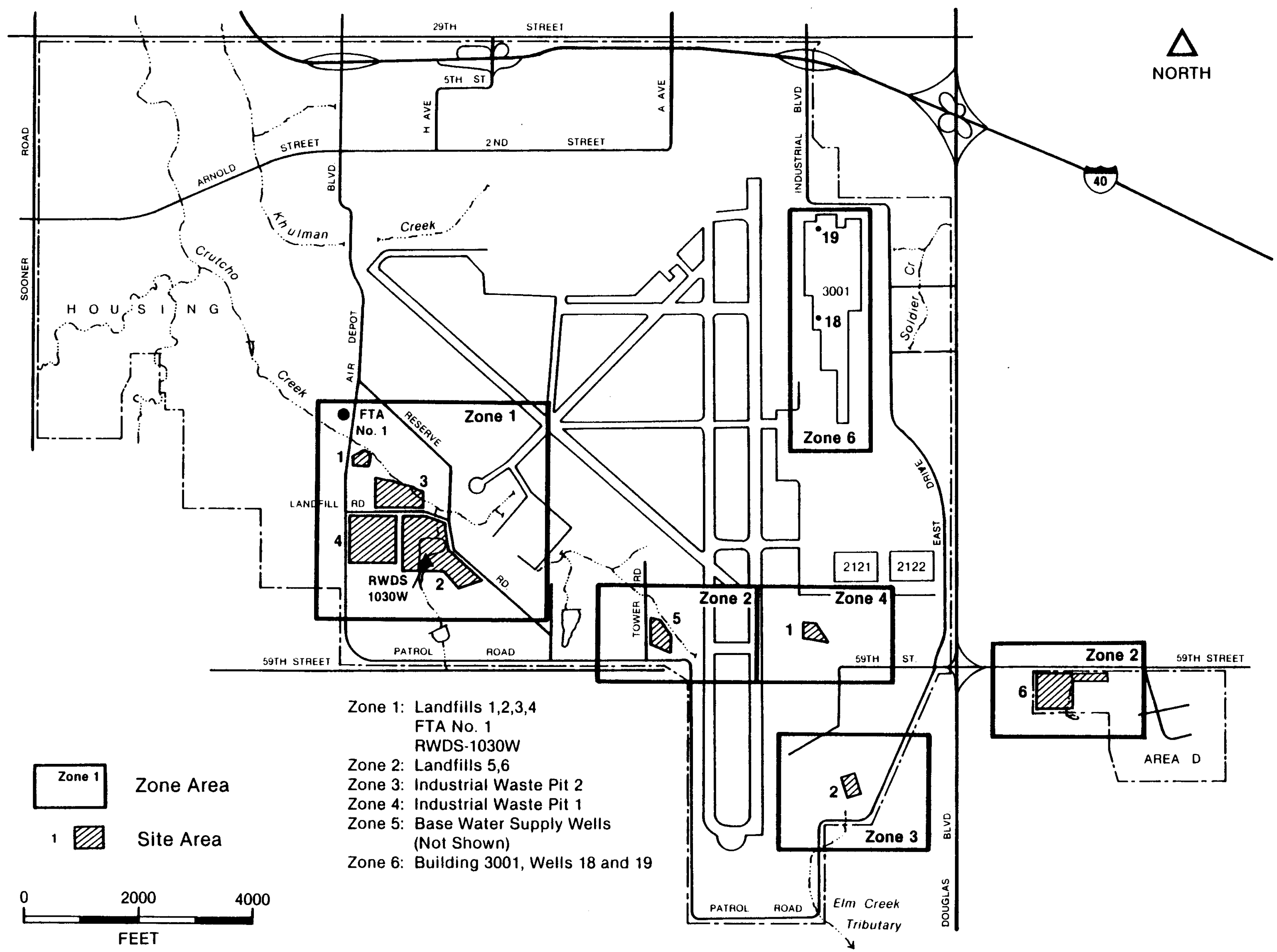


Figure 2-9. Zones of Investigation, Tinker AFB, IRP Phase II Stage 1.

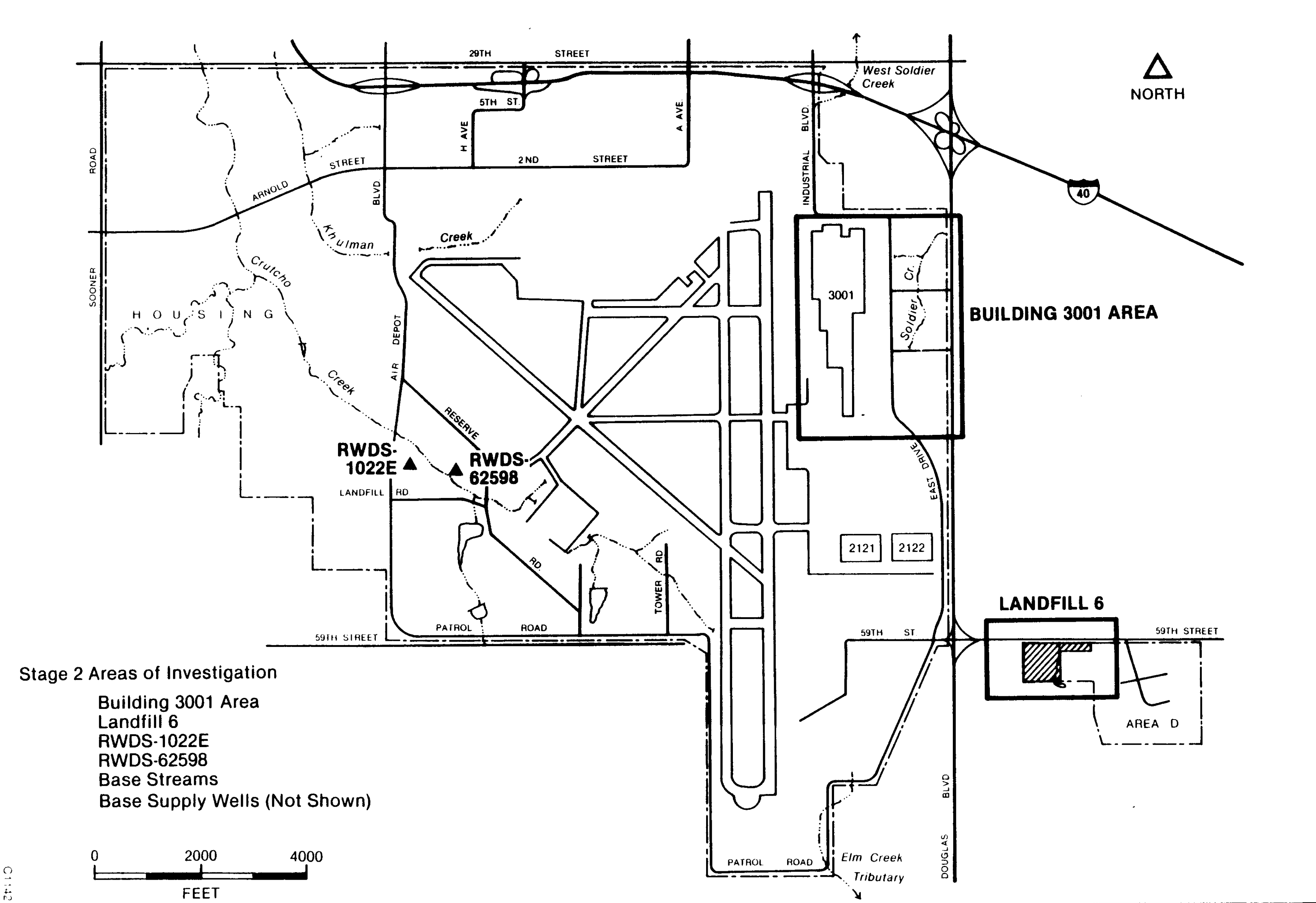


Figure 2-10. Areas of Investigation, Tinker AFB IRP Phase II Stage 2.

- Disassembly, cleaning, and inspection of aircraft systems and components;
- Plating, painting, heat treating, testing of metal parts and components;
- Accessory shops including electrical, valve and governor, gear box, tubing and cable, fuel controls, nozzles, pumps, bearings, and other specialized repair shops; and
- Assembly and testing and packaging of aircraft and aircraft components.

In addition, other functions housed within this or other nearby buildings include utility (water, power and steam production), administrative and engineering offices, parts and material storage, and others.

Construction of the Oklahoma Aircraft Assembly Plant (as the Building 3001 complex was known originally) began in 1942. Since then it has been operated as an aircraft overhaul and repair facility, as it is today. Although the specific aircraft and associated engines have changed, in most cases the nature of the industrial repair functions pertinent to this investigation have remained basically the same.

Halogenated hydrocarbon solvents have been and continue to be used primarily for cleaning and degreasing of metal engine parts undergoing overhaul or repair. Trichloroethylene was the solvent of choice for most degreasing operations from the early 1940's until the early 1970's, when tetrachloroethylene began to be substituted because of its lower vapor pressure. As originally designed, degreasing operations took place in metal tanks set below the floor level in concrete pits. These pits ranged in depth from three to eight feet and in size from approximately 8x10 up to 30x90 feet. Coincident with the shift from trichloroethylene to tetrachloroethylene, these below-floor pits were closed (typically filled with sand and topped with a concrete cap) and replaced with specially designed degreasing machines (complete system including all piping, tanks and pumps) which are above ground or floor level.

Changes in the layout and purpose of the repair shops in this complex have coincided with shift from reciprocating to jet engine repair and overhaul. These changes affected the nature and number of underground storage tanks in the Building 3001 area. Most of the storage tanks were and are for use during testing of aircraft engines or components, or for fuel storage for the utility boilers and electrical generators. Also there are solvent (not halogenated) storage tanks for a variety of uses but mostly connected with aircraft surface painting and cleaning. As the function or location of various shops changed, tanks were added and old tanks were either relocated or abondoned. Storage tanks for aviation (high octane) gasoline were converted over to either kerosene type fuels used in jet engines or to solvent storage. Records and interviews at Tinker indicate a practice of "abandoning in place" old tanks which were either no longer needed or not functioning (leaking). This was accomplished by removing surface connections and filling with sand where possible.

2.4.2 Landfill 6

Six landfills used for the disposal of refuse were identified at Tinker AFB. Landfill No. 6 was used for the disposal of refuse from 1970 to 1979. This landfill is located in Area "D" approximately 1/2 mile east of Tinker AFB along S.E. 59th Street on land leased from Oklahoma City. Although 40 acres are available at the site, only about 20 acres were used prior to the closing of the site during 1979. The western half of the landfill was filled, as were two trenches adjacent to S.E. 59th Street in the eastern half. Base refuse since that time has been disposed of off-site by private contractor.

Materials disposed in Landfill No. 6 consisted primarily of general refuse with small quantities of industrial waste materials such as paint buckets, insecticide cans, etc. Industrial wastewater treatment plant sludge was also intermittently disposed of in this landfill. The refuse was covered daily with 6 to 8 inches of compacted soil, and several feet of compacted cover was used as a final trench covering. Highly permeable river sand was used for daily cover for several years, although other areas had a cover of excavated clay and sand/rock. After closure, the site was revegetated with grasses. Field reconnaissance of the site indicated moderate surface erosion and no observed leachate. This facility is the subject of a current Phase III/IV effort being conducted by the Base Civil Engineers.

2.4.3 Base Streams

The principal drainages for Tinker AFB are Crutcho and Soldier Creeks. Most of the Base is drained by Crutcho Creek and its tributary, Khulman Creek. The eastern part of the Base, near Douglas Boulevard and the Air Logistics Center, is drained by Soldier Creek. The extreme southern part of the Base is drained by Elm Creek which is normally dry. Sediment sampling sites were established for each of the drainages on the Base, including sites along the length of each stream and a site at the Base bondary. Sites were established in accordance with the recommendations in the Phase I report.

2.4.4 Radiological Waste Disposal Sites

Radioactive waste disposal site, RWDS 62598, is located south of Facility 1025 and north of Crutcho Creek. A concrete post with attached radiation warning sign marks the general disposal area. The site contains a "lead still" made of sheet lead used to evaporate methyl ethyl ketone (MEK) or acetone for reuse. The MEK and acetone were contaminated with radium paint from cleaning radium dials. After use, a residue of radium paint solids remained in the still. Following a period of usage, the lead still became radioactive due to the accumulation of solids. In the early 1950's, the lead still was reportedly buried in the general area marked by the concrete post. The depth of burial is not known. One Air Force document states the waste may later have been removed; however, no conclusive evidence exists for either the presence or absence of the waste. Recent radiological monitoring has identified no area of increased radioactivity near the site. (Engineering-Science, 1982).

Another radioactive waste disposal site, RWDS 1022E, is located adjacent to the northwest corner of landfill No. 3 south of West Crutcho Creek. During the mid-1950's approximately 8 to 10 containers of radioactive material were disposed of at the site. The material was placed in a hole approximately 30 feet deep located next to landfill No. 3, which was operative during the period 1952-1961. The area was marked with radiation warning signs, although none are now present. The area was surveyed with beta/gamma radioactivity detector equipment during November 1981. Radiation levels of 0.03 mr/hr above a background of 0.02 mr/hr were detected; indicating radioactive materials are present, but do not result in radioactivity levels hazardous to human health. (Engineering-Science, 1982)

2.4.5 Base Water Supply Wells

Tinker AFB presently obtains water supplies from a system of 22 on-base water wells constructed along the east and west Base boundaries. All Base wells are completed in the Garber-Wellington Aquifer. Base wells range from 650 to 1100 feet in depth, with yields ranging from 71 to 210 gallons per minute. The wells incorporate multiple screens, deriving water supplies from sand zones that vary in thickness from 103 to 184 feet.

3.0 FIELD PROGRAM

Various field activities were performed at Tinker AFB in support of the IRP Phase II (Stage 2) investigation. The activities consisted of performance of a survey of buried pits and tanks in the vicinity of Building 3001, completion and sampling of 14 deep and two shallow ground-water monitor wells, sediment sampling in Base streams and drainage channels, performance of two geophysical surveys, and measurement of depth-to-water in Base water supply wells. The locations of the field investigations are shown on Figure 3-1. The periods of performance of the field activities were June-August and October 1984.

3.1 Field Techniques

The following paragraphs contain descriptions of the various field techniques used in the Tinker AFB Phase II Stage 2 investigation. These techniques included geophysical surveying, air rotary drilling, monitor well installation, stream sediment and ground-water sampling.

3.1.1 Geophysical Surveying

Geophysical surveying was performed in order to accurately define the most probable location of two Radiological Waste Disposal Sites (RWDS-1022E and 62598). The two sites are currently vacant land; no surface remnants of the facilities are visible. The geophysical techniques selected for the investigation consisted of an electromagnetic survey using two devices (the Geonics EM31 and the EM34-3 ground conductivity sensors) and a magnetometer survey using the EDA PPM-500 Vertical Gradiometer. Both sensors are designed for rapidly obtaining data over large areas. The conductivity meters employ magnetic dipoles or magnetic induction loops for transmission and reception of low-frequency electromagnetic waves. The effective depth sampled by the EM31 is 6 meters; the depth sampled by the EM34-3 depends on the coil separation and orientation, applied frequency, and to some extent on the conductivity profile of the subsurface (McNeill, 1980). The EDA PPM-500

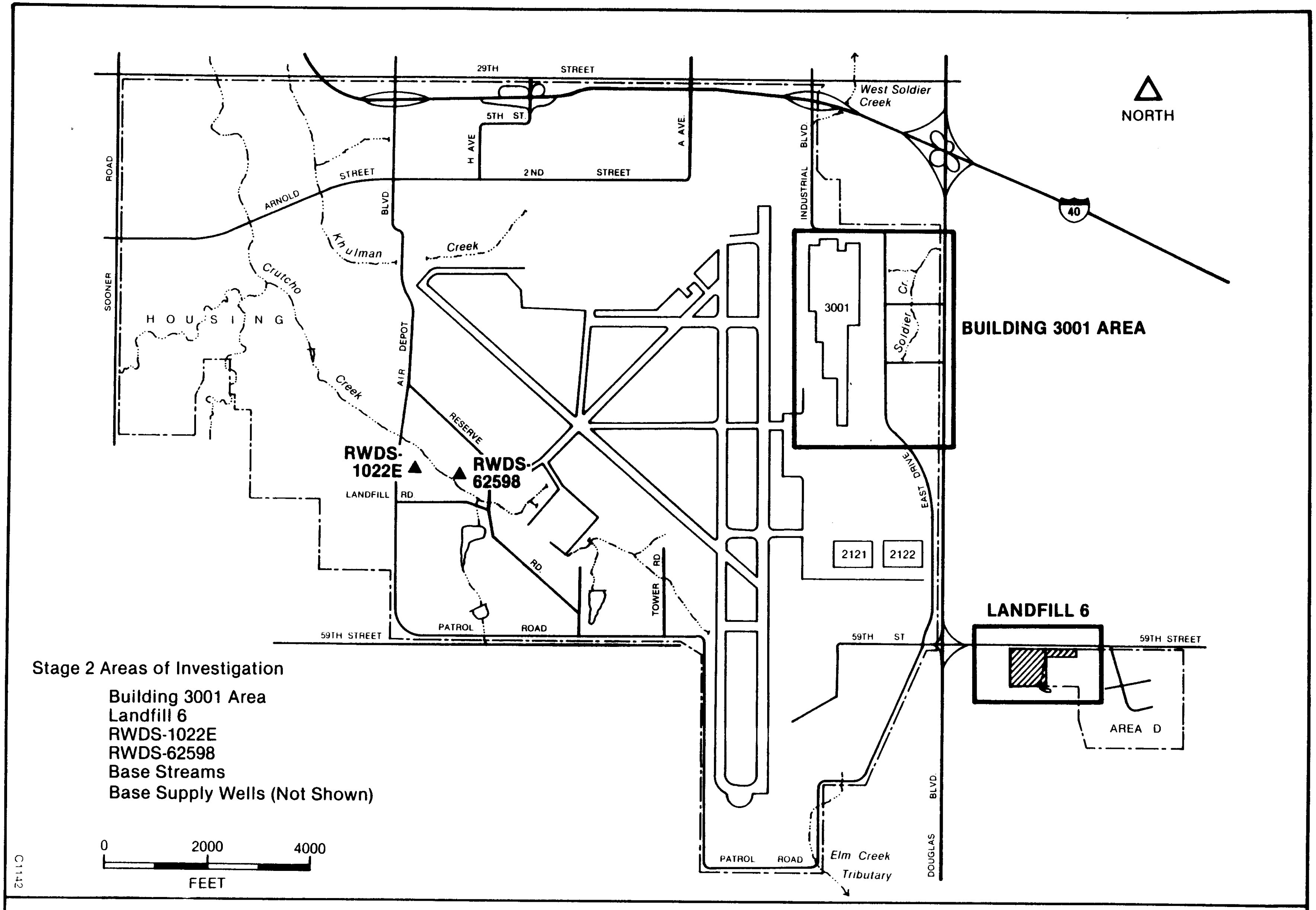


Figure 3-1. Areas of Investigation, Tinker AFB IRP Phase II Stage 2.

Vertical Gradiometer measures both the total field and the gradient of the total field. Shallow, near-surface sources (higher frequency anomalies) are emphasized by the PPM-500 relative to deeper responses (lower frequency). The Earth Technology Corporation of Golden, Colorado, performed the surveys. Operating procedures and specifications of the EM31, EM34-3 and PPM-500 are provided in Appendix L.

3.1.2 Drilling Technique

Drilling at Tinker AFB was accomplished by the air-rotary method with a Failing 1250 truck-mounted rig. A 6-7/8 inch tricone bit was used to drill the bore hole to a depth of 10 feet below the first ground water encountered. No drilling fluids or additives were used in the drilling program. The air rotary method is considered the most suitable method of drilling for monitor well installation, since the borehole is open and clean at the end of the drilling program. Any small effects of utilizing air as the circulating fluid are removed in the process of well development and well purging prior to sampling. As the bore hole was advanced, the cuttings discharged at the surface were examined for lithology, moisture, and other features to describe the geologic section. Drilling conditions, such as relative rate and ease of penetration, were noted by the driller. Water encountered during drilling was noted with respect to depth of occurrence and rate of production; if needed, drilling was suspended temporarily to allow for recovery of water in the borehole. The decision to complete the borehole and install the screen and casing for the monitor well was made on the basis of relative water level (with respect to the approximate predicted regional water level), the likelihood of perched water above a regional water table, and the representativeness of the water table in terms of evaluating the impact of the waste disposal site on the quality of ground water.

Selection of the screened interval in Tinker Stage 2 monitor wells was governed in part by assessment of the likely zones of contaminant migration. In general, the uppermost occurrences of ground water is considered most likely to show the effects of contaminant infiltration from near surface sources. The method of introduction of contaminants is by dissolved constituents moving with downward migrating infiltration. Once these contaminants reach the ground-water body they are entrained in the flow and move with it. So long as no density effects operate, there will be no tendency for contaminants to plunge or sink in the ground-water system. Common causative agents of density effects, concentrated brines or nearly pure streams of industrial chemicals denser than water (such as TCE) do not exist at Tinker AFB, so this phenomenon may safely be ignored. As was discussed in Section 2, there is a downward component of flow, so some contaminants would be expected to move down in the aquifer. However, they would also be diluted, so detection is less likely. Contaminants of interest are expected to be at their highest concentrations at the water table, so wells were completed as near the water table as practicable.

Initially, the hollow-stem auger method with split-spoon sampling was contemplated for installation of the very shallow (<30 feet) monitor wells at Landfill 6. However, an initial reconnaissance revealed that the substrate was too indurated for this method to be successful. Therefore, all boreholes were advanced with the air rotary rig. Since this method provides continuous cuttings returns, no split-spoon samples need be taken.

3.1.3 Monitor Well Installation

Ground-water monitor wells were installed immediately upon completion of the drilling operations. Usually, the borehole was observed for a period of time, as necessary, to determine the approximate static water level. Monitor well construction specifications, summarized in Table 3-1, were consistent with the specifications provided in the Statement of Work.

For the parameters and concentrations expected, the use of PVC casing with threaded (not glued) joints is not anticipated to interfere with sampling and analysis. Many investigators (Nacht, 1983; Scalf, et al., 1981) suggest that rigid PVC is acceptable, provided that the wells are suitably purged, as these were. Most concern expressed in the literature has been

TABLE 3-1. MONITOR WELL CONSTRUCTION SPECIFICATIONS

- Casing: 2-inch or 4-inch diameter, flush (not glued) joint, Schedule 40 or 80 PVC.
- Screen: 2-inch or 4-inch diameter, flush joint, Schedule 80 PVC, 0.010-inch mill slot. Normal screen length was 10 feet, reduced to 5 feet at the discretion of the supervising geologist.
- Gravel pack: 8-12 mesh silica, emplaced from bottom of hole to 2 feet above top of screen.
- Bentonite seal: 2 feet above top of sand pack.
- Grout: neat cement (Type I Portland cement) grout tremied from the top of the bentonite seal to the land surface.
- Surface completion: the PVC casing was cut off to provide a 2 to 3 foot stickup and solid cap placed on the casing. A 6-inch diameter guard pipe, 4 feet in length, was placed over the exposed casing, and seated in the cement. A locking cap lid was installed on the guard pipe.
- Guard pipes or posts: 3-inch diameter steel posts, 6 feet in length, with a minimum of 2 feet below ground, 3 each installed radially 4 feet from the wellhead.
- After each well was installed, it was developed by air lifting or bailing until a clear stream was produced, or until the supervising geologist determined that development was complete.

over solvent-welded PVC. Since the wells are to be constructed with threaded joints, only, this concern is obviated. Curran and Tomsen (1983), for example, found no more than 0 to 0.1 ppb total organics leached from rigid PVC. They also cite field data suggesting little or no leaching.

Appropriate changes in the specifications were made on a site-by-site basis. Decisions regarding the setting of screen and casing, length of screen, and amount of gravel pack for each well were made on the basis of the observed static water level. If appropriate, the borehole was allowed to remain open overnight; there were no difficulties related to the integrity of the bore hole or caving problems.

Monitor well installation followed a similar procedure at each well. Screen and casing sections were cleaned and assembled on the ground then lowered carefully into the borehole. As the string of screen and casing were lowered, additional sections of casing were added until the bottom of the screen reached the complete depth of the borehole. Normally, enough casing was attached so as to leave a 3 to 5 foot stick-up at the ground surface. Clean gravel (grain-size analysis in Appendix D) was carefully poured down the annular space until the level of the top of the gravel pack was at least 2 feet above the top of the screen, or as directed by the supervising geologist. (See individual well completion logs in Appendix D). Bentonite pellets were added to form a 2-foot thick seal, and if necessary for completion activities that occurred above the water table, water from the well was bailed and poured down the annular space to hydrate the bentonite. Neat cement grout was then prepared and tremied from the top of the bentonite seal to the land surface. The grout was allowed to cure for at least 24 hours prior to well development.

The monitor wells were developed by pumping using the air compressor on the drilling rig. The water in the casing was alternately purged and allowed to recover. Individual records of the development of each well are included in Appendix D. After completion of the well development program, protective 6-inch diameter steel casing with lockable lids was cemented into place at the surface and three steel guard posts were positioned around the well.

3.1.4 Ground-Water Sampling

Ground-water samples were collected for analysis from eleven of the ground-water monitor wells installed under this program and from one previously existing ground-water monitor well. Field sampling methodologies and equipment are detailed in the following sections.

Water Level Determination

As the first step of ground-water sampling operations at each monitor well, water level measurements were taken using a Soiltest Model 762A electrical probe. The probe and associated electrical line were washed with laboratory deionized water between each well to preclude the possibility of cross-contamination. Measurements were taken to the nearest 0.01 foot with respect to the top of the protective steel well casing. The elevation of the measuring point was surveyed as discussed in Section 3.1.8. Water level measurements taken prior to each sampling operation are listed in Appendix E.

Well Purging

Following the completion of well construction activities, each monitor well was purged using a 1.75-inch diameter submersible gas-driven pump. The pump, manufactured by ISCO, Inc. (Model 2600) delivered water to the surface by means of the rapid inflation and deflation of the pump's silicone rubber bladder. Gas (compressed air from a cylinder) did not contact the water in the well. The pump was operated in the following way: after the pump was set at the appropriate position in the well, the gas supply and pump gas lines were attached to the control box, controls were adjusted to compensate for the bladder inflation rate at varying lifts and gas supply pressure, and the gas valves were opened to begin operation of the pump. Each well was purged either immediately prior to sample collection or within 1 day of sample collection (for low-yield wells) to ensure that fresh formation water was collected as the sample. Volumes of purge water removed, along with other observations during sampling, are reported in Appendix E.

All down-hole equipment used during the purging of the monitor wells was carefully washed with laboratory deionized water to prevent cross-contamination. In cases where overt contamination, as evidenced by color, odor, viscosity or visible oil, was noted in a well, the sampling apparatus was washed with technical-grade acetone and thoroughly rinsed with deionized water.

Specific conductivity and temperature were determined in the field using a conductivity and temperature meter. Temperature readings were checked using a mercury-in-glass thermometer. The pH of the discharged water was measured with the use of a pH meter. Prior to each pH measurement, the instrument was calibrated against standard solutions for pH values of 7.0 and 4.0 or 10.0. Prior to exposure to discharge water, the probe was thoroughly washed with deionized water.

Sample Capture

After each well was purged of standing water to ensure representative ground-water characteristics, a sample was collected with a Teflon bailer and split into the analytical aliquots required by the Statement of Work. Samples from wells were collected for analysis by EPA Methods 601 (2 samples), 624 and 615. The analytical schedule for ground-water samples is summarized on Table 3-2. Analytical results are discussed in Section 4.

The samples for Methods 601 and 624 were collected in 40 mL glass vials with Teflon septa. The Method 625 sample was collected in a 1-liter glass bottle with a Teflon-lined cap. Samples were cooled to 4°C on ice and shipped via overnight express to the analytical laboratory. All aspects of the sampling protocol were conducted in accordance with EPA-approved methodologies. Field QA/QC measures were employed to ensure that once collected, sample integrity was maintained during shipping and handling prior to analyses. These QA/QC procedures are discussed in Appendix F.

TABLE 3-2. ANALYTICAL SCHEDULE FOR GROUND-WATER SAMPLES

Parameter	Round 1 (mid July)	Round 2 (early August)
Volatile Organic Halogens (EPA 601)	6A-6G, 7A-7G,2A	6A-6G, 7A-7G
Volatile Organic Compounds (EPA 624)	6A-6G, 7A-7G	--
Base/Neutral and Acid Extractible Compounds (EPA 625)	6A-6G, 7A-7G	--

3.1.5 Stream Sediment

Twenty-four sediment sampling stations were identified along Crutcho Creek (including significant tributaries), Khulman Creek, West Soldier Creek, Soldier Creek, a tributary to Elm Creek and two drainage ditches within the installation.

At each sampling location, measurements were taken for determining the cross-section of the stream at the sampling point. General observations on stream conditions and aquatic life present (if any) at each sampling point were also noted. Observations, measurement and features of each stream sampling station were recorded in a field notebook. Field notes for the sediment sampling operations have been included in Appendix E.

Sediment samples were collected using either a hand trowel or a section of 2-inch outside diameter polycarbonate tube. The tube was employed as a "plug" or coring device. Generally, the depth of sampling extended from 6 to 12 inches below the channel bottom as conditions would allow. At several sampling locations, samples were collected as composites obtained from two or more discrete points in the area of the sampling station. Multiple point samples were collected for compositing as the station sample where stream conditions varied significantly with the station reach. Point samples were composited as the station sample to be representative of local stream conditions.

3.1.6 Sampling Schedule

A total of 12 wells were sampled for ground water during Phase II (Stage 2) field activities (July-August 1984). Generally, sufficient sample was obtained during a single sampling round to satisfy the volume requirements for all analytical tests to be performed. However, in a few cases, well recovery production was very slow and sample sets from the same sampling point were collected on more than one occasion. Details of the sampling schedule, including well identification, sample type, date collected, date delivered to the laboratory, and sampler are provided in Appendices E and G.

3.1.7 Field Safety

Before the field work was initiated for Stage 1, a field Safety Plan was prepared. This plan, developed from available data, anticipated likely field hazards and prescribed appropriate personal protective equipment for the field team. Drilling, core sampling and well installation within or in close proximity to the waste sites were expected to pose the most significant potential hazards. EPA Level C protection (impervious clothing, gloves, boots and full-face cartridge respirators) was required for drilling and well installation activities. For the ground-water sampling activities, EPA Level D protection (same as Level C, except that respirators were carried, but not worn) was deemed appropriate. The Safety Plan was followed for the complete field effort, and provided adequate protection. Therefore, the same Safety Plan was utilized for Stage 2 activities. The complete text of the Safety Plan utilized for this project is contained in Appendix M.

3.1.8 Surveying

After all wells were installed, wellhead elevations were determined to the nearest 0.01 foot, by surveying from the nearest benchmark. The Base Civil Engineering Squadron surveying section accomplished this work. The report of the Base surveyors is contained in Appendix E.

3.2 Area Activities

The field program at Tinker AFB consisted primarily of the installation and sampling of ground-water monitor wells. Other activities, such as geophysical surveying, sediment sampling, and measurement of water levels in Base water supply wells were also conducted. The conduct of the field program is presented in narrative form in the following subsections. Each area of investigation (Figure 3-1) is discussed separately, below.

3.2.1 Building 3001

This section contains a description of the field activities that occurred at Building 3001. Building 3001 is located at the northeast corner of Tinker AFB. Field activities consisted of the installation of 7 monitor wells and the collection and analysis of ground-water samples. The survey of buried pits and tanks in the area is discussed separately in Section 3.2.3.

Monitor Well Installation

The well locations east of Building 3001 (Figure 3-2) were selected in order to provide coverage of the area between industrial operations at Building 3001 and the residential area east of the Base. The precise locations of the wells were selected in the field on the basis of drilling rig access. The relatively closely spaced wells along East Drive reflect the nearness of the industrial operations; the widely-spaced well locations along Douglas Boulevard are due to the increased distance from possible sources of contamination. The location of Well 6G, southwest of Building 3001, was selected because of the expected direction of regional ground-water flow to the west and south. The depths of the wells ranged from 59 feet (6D) to 115 feet (6E). Well completion details are summarized in Table 3-3; complete details of the well construction features are provided in Appendix D. A summary of the geologic conditions is provided in Section 4.2.2.

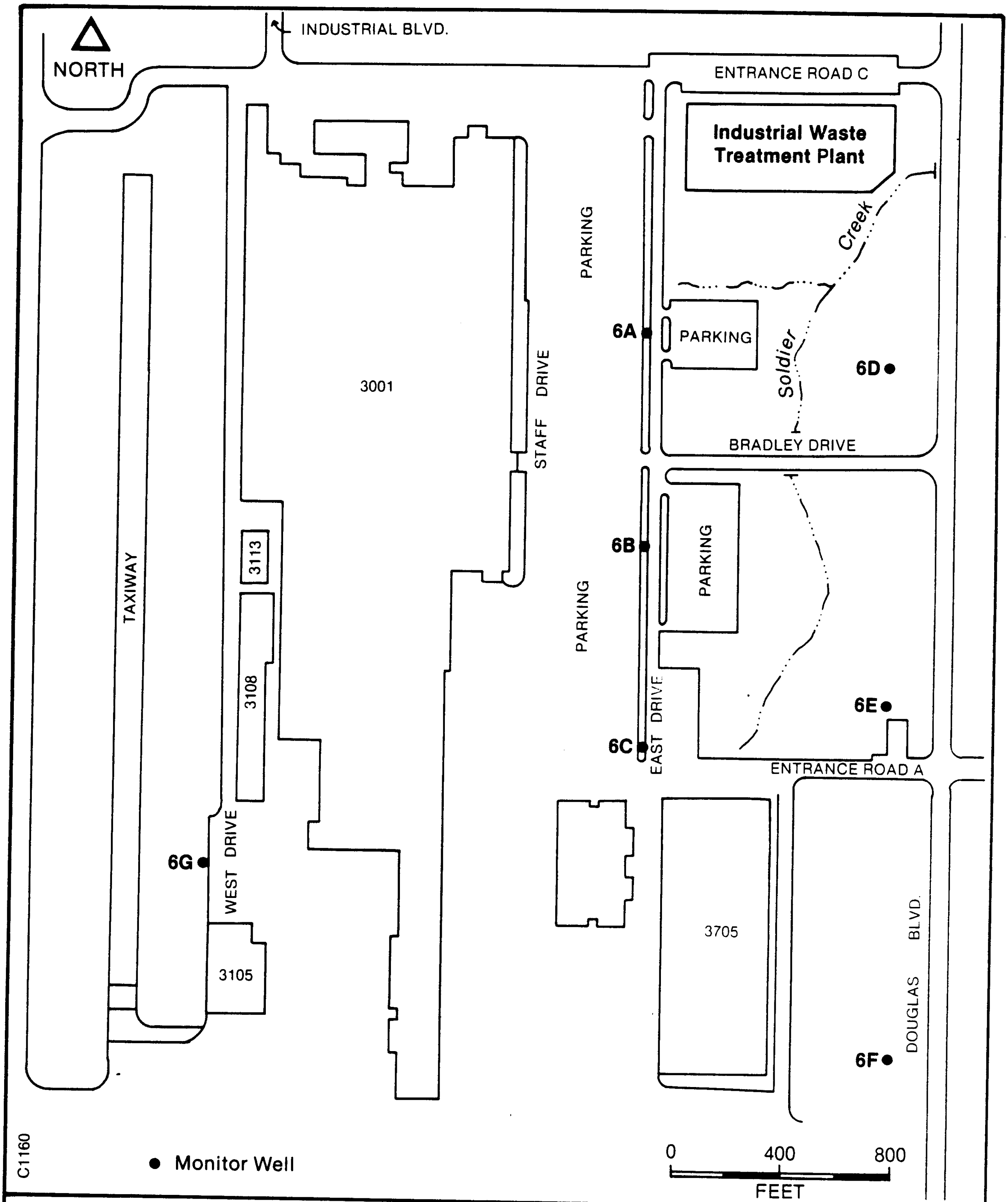


Figure 3-2. Location of Ground-Water Monitor Wells, Building 3001.

TABLE 3-3. GENERAL SPECIFICATIONS FOR BUILDING 3001 MONITOR WELLS

Monitor Well	Measuring Point Elevation[1]	Measuring Point Height	Ground Level Elevation[2]	Screened Interval[3]	Screen Elevations[4]	Total Depth[3]
6A	1271.91	3.53	1268.4	72-82	1196.4-1186.4	82
6B	1271.58	3.01	1268.6	80-90	1188.6-1178.6	90
6C	1271.03	2.2	1268.8	80-90	1188.8-1178.8	90
6D	1256.15	2.94	1253.2	47-57	1206.2-1196.2	57
6E	1270.22	3.0 (est)	1267.2	105-115	1162.2-1152.2	115
6F	1287.29	2.61	1284.7	92-102	1192.7-1182.7	102
6G	1279.1	3.13	1276	80-90	1196-1186	90

[1] Top of PVC casing. Elevation of Wells 6A-6F determined by Base Surveyors; elevation at Well 6G estimated from Base topographic map.
[2] Feet, msl taken from Base topographic map or difference between measuring point elevation and height rounded to 0.1 ft. in recognition of uneven ground surface.
[3] Feet below ground level.
[4] Feet, msl.

Monitor Well Sampling

After the completion and initial development of the monitor wells, each one was purged and sampled. Field sampling was conducted by Radian personnel during two periods: mid-July and early-August 1984. Details of the field sampling procedures are presented in Section 3.1.4. The ground-water samples were analyzed for the parameters as shown on Table 3-2. Results of analyses are discussed in Section 4.2.2 and are presented in tabular form in Appendix H.

3.2.2 Landfill 6

This section contains a description of the field activities that occurred in the area of Landfill 6. Landfill 6 is located south of S.E. 59th Street and east of Douglas Boulevard and most of Tinker AFB. Field activities consisted of the installation of six monitor wells, completion of one borehole, and collection and analysis of ground-water samples from the six new monitor wells and one existing monitor well.

Monitor Well Installation

Wells installed in the vicinity of Landfill 6 (Figure 3-3) were located in order to provide ground-water data around the landfill. Two wells, 7F and 7G, are two-inch diameter wells and were installed using the air-rotary rig described in Section 3.1.2. Drilling for a third well (7E) was performed but the well was not completed because no water was encountered in the thick unsaturated zone at the location. The borehole was grouted to the land surface upon completion. The remaining wells are four-inch diameter wells. Wells placed north of S.E. 59th Street were located in order to investigate the presence of contamination, if any, north of Landfill 6. In particular, well 7A was installed to serve as an intermediate data point between the landfill and the Ainsworth well. The depths of the wells ranged from 25 feet (7F) to 107 feet (7A). Well completion details are summarized in Table 3-4; complete details of the well construction features are provided in Appendix D. A summary of the geologic conditions is provided in Section 4.2.3.

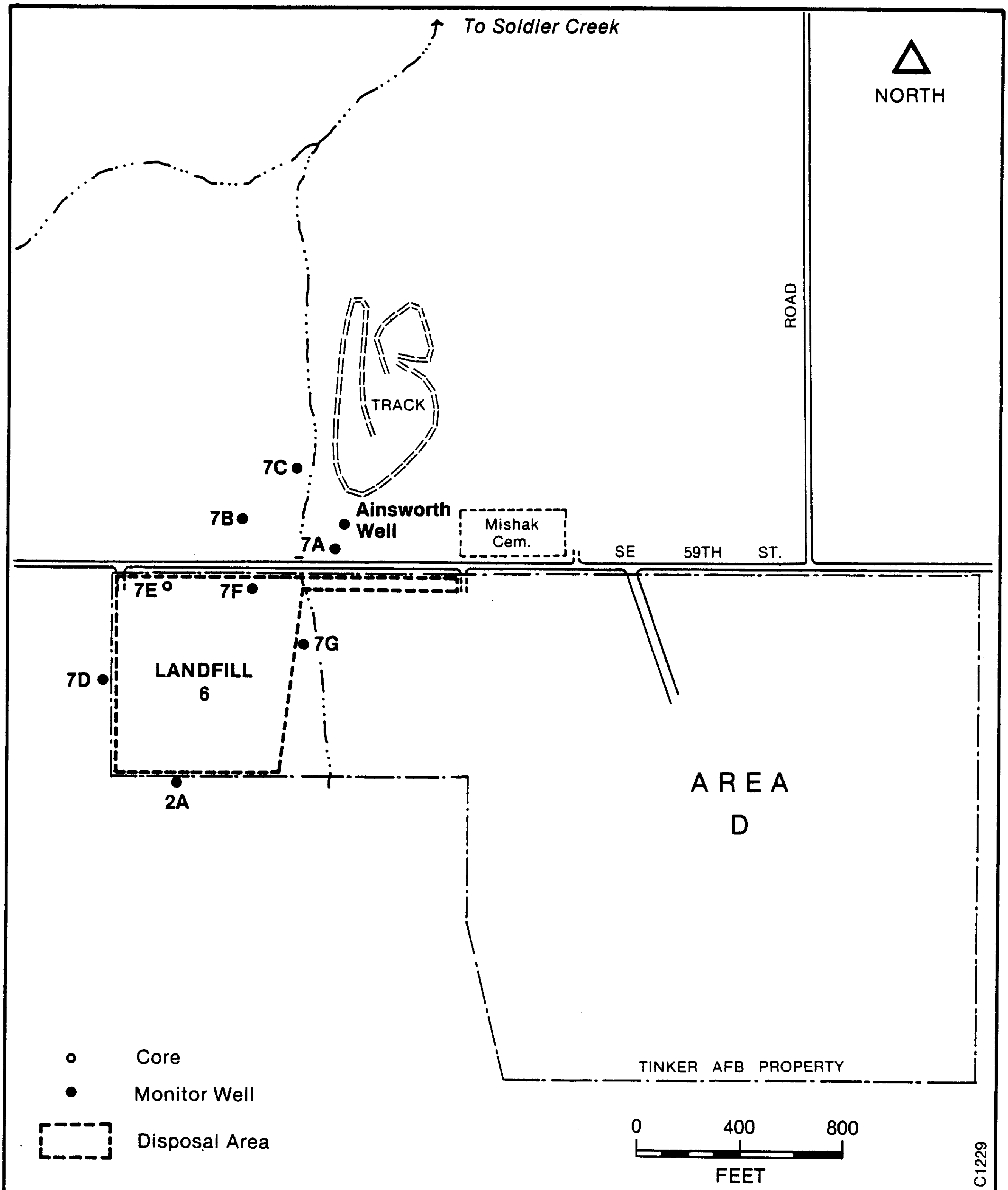


Figure 3-3. Location of Ground-Water Monitor Wells, Landfill 6.

TABLE 3-4. GENERAL SPECIFICATIONS FOR LANDFILL 6 MONITOR WELLS

Monitor Well[1]	Measuring Point Elevation[2]	Measuring Point Height	Ground Level Elevation[3]	Screened Interval[4]	Screen Elevations[5]	Total Depth[4]
7A	1277.73	3.6	1274.1	97-107	1177.1-1167.1	107
7B	1281.68	3.2	1278.5	35-45	1243.5-1233.5	45
7C	1272.30	2.93	1269.4	88-98	1181.4-1171.4	98
7D	1300.0	3.0	1297	65-75	1232-1222	75
7F	1282.55	3.25	1279.3	15-25	1264.3-1254.3	25
7G	1280.48	2.54	1277.9	13-28	1264.9-1249.9	28
2A	1306	3.0	1303	35.5-45.5	1276.5-1257.5	45.5

[1] Well 7E not constructed; borehole was abandoned and grouted. Well 2A constructed during Stage 1 activities.
[2] Top of PVC casing. Elevations at Wells 7A-7G determined by Base surveyors; elevation of Well 2A estimated from USGS topographic map.
[3] Feet, msl taken from USGS topographic map or difference between measuring point elevation and height rounded to 0.1 ft. in recognition of uneven ground.
[4] Feet below ground level.
[5] Feet, msl.

Monitor Well Sampling

After the completion and initial development of the monitor wells, each one was purged and sampled. Existing monitor well 2A was also purged prior to sampling. Field sampling was conducted by Radian personnel during two periods: mid-July and early August 1984. Details of the field sampling procedures are presented in Section 3.1.4. The ground-water samples were analyzed for the parameters as shown on Table 3-2. Results of these analyses are discussed in Section 4.2.3 and are presented in tabular form in Appendix H.

3.2.3 Buried Pit and Tank Survey

The efforts on this task included interviews with present and past Tinker AFB personnel. Those interviewed included the present Base BioEnvironmental Engineer, the present Base Civil Engineer, the present environmental engineer for the maintenance command within the Bldg. 3001 area, the present and former base fuel storage official, a former Base BioEnvironmental Engineer (1950-1956, 1968-1971), and a former aircraft production branch chief who had served in the Bldg. 3001 (1942-1980).

Records that were reviewed for this task include the Tinker AFB OPLAN 19-2 (Oil, Hazardous Substance, and Hazardous Waste Spill Prevention, Control and Countermeasures), the Real Property Inventory Detail reports, Tinker AFB civil engineering drawings, and fuel oil storage records. OPLAN 19-2 provided a list of underground storage tanks in the Bldg. 3001 area which had been prepared from input from each activity which owned or used the underground storage tanks. The real property inventory detail report was useful because it also identified underground storage tanks both currently active and historically used and provided a means of tracking the disposition of older tanks. The civil engineering drawings provided specific locations and details on each existing or historical underground storage tank. Also the original construction drawings of the Assembly Building (3001) indicated the location of degreasing pits beneath the floor. Fuel oil storage records going back to 1964 were available which indicated the type of liquid hydrocarbons which were stored on base in bulk quantities.

A detailed surface inspection of the Bldg. 3001 area was made in conjunction with the environmental engineer from the repair or maintenance activity within the building. All currently active underground storage tanks were visually inspected. In addition, any surface evidence of inactive underground storage facilities or buried pits at locations indicated on the civil engineering drawings was noted during the inspection tour. Results of the inspection are tabulated in Tables 4-10 and 4-12.

3.2.4 Stream Sediment Sampling

Recommendations for Phase II stream sediment sampling and analysis at Tinker AFB were presented in the Phase I report for the Installation Restoration Program. Twenty-four sediment sampling stations were identified along Crutcho Creek (including significant tributaries), Khulman Creek, West Soldier Creek, Soldier Creek, a tributary to Elm Creek and two drainage ditches within the installation.

Stream sediment sampling operations were conducted for Phase II (Stage 2) over a three-day period from 19 June to 21 June 1984. Follow-up sampling efforts were performed 19 July 1984 for three stations after samples collected during the initial sampling effort were destroyed during shipment. Samples were collected for analysis from stream stations within the installation as shown in Figure 3-4. A total of 27 sediment samples were collected for analysis, including three duplicates for field quality control. Table 3-5 lists general sample location and numbers.

At each sampling location, measurements were taken for determining the cross-section of the stream at the sampling point. General observations on stream conditions and aquatic life present (if any) at each sampling point were also noted. Observations, measurement and features of each stream sampling station were recorded in a field notebook. Field notes for the sediment sampling operations have been included in Appendix E.

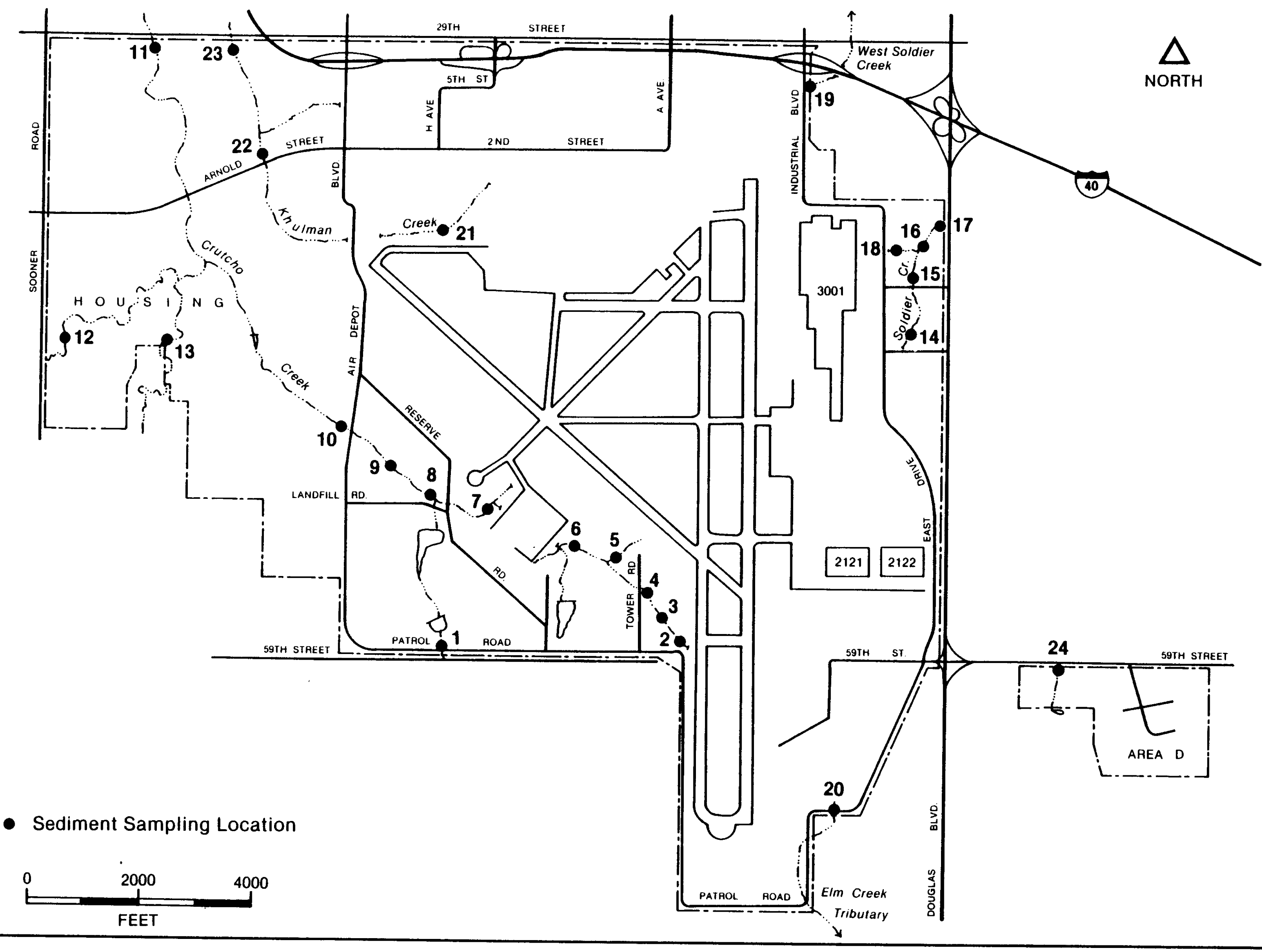


Figure 3-4. Stream Sediment Sampling Locations.

TABLE 3-5. LOCATIONS AND SAMPLE NUMBERS FOR TINKER AFB SEDIMENT SAMPLES

Sampling Station	Creek	Sample Number	Comments
1	Crutcho Creek	TSED-01	
2	" "	TSED-02	
3	" "	TSED-03	
4	" "	TSED-04	
4	" "	TSED-05	Duplicate of TSED-04
5	" "	TSED-25	
6	" "	TSED-24	
7	" "	TSED-23	Sample broken during shipment. Replaced during the follow-up sampling effort.
8	" "	TSED-20	" "
9	" "	TSED-21	
9	" "	TSED-22	Duplicate of TSED-21.
10	" "	TSED-19	
11	" "	TSED-26	
12	" "	TSED-07	
13	" "	TSED-08	
14	Soldier Creek	TSED-15	
15	" "	TSED-13	
15	" "	TSED-18	Duplicate of TSED-13
16	" "	TSED-14	
17	" "	TSED-11	
18	" "	TSED-12	
19	West Soldier Creek	TSED-16	
20	Elm Creek	TSED-06	Taken inside AFB
21	Khulman Creek	TSED-10	
22	" "	TSED-09	
23	" "	TSED-27	
24	Area "D" Stream	TSED-28	Sample broken during shipment. Replaced during the follow-up sampling effort.

Sediment samples were collected using either a hand trowel or a section of 2-inch outside diameter polycarbonate tube. The tube was employed as a "plug" or coring device. Generally, the depth of sampling extended from 6 to 12 inches below the channel bottom as conditions would allow. At several sampling locations, samples were collected as composites obtained from two or more discrete points in the area of the sampling station. Multiple point samples were collected for compositing as the station sample where stream conditions varied significantly with the station reach. Point samples were composited as the station sample to be representative of local stream conditions.

Immediately following the collection/compositing of each sediment sample, each was placed in a quart glass jar with a Teflon™ cap liner. Each sample was labeled and packed with ice in an insulated shipping container. Samples were shipped nightly to Radian Analytical Services using an overnight parcel service. All shipments were made under chain-of-custody control. Once in the laboratory, samples were frozen until analyses were begun.

3.2.5 Radiological Waste Disposal Sites

Geophysical surveys were performed at RWDS-1022E and RWDS-62598 in mid-October 1984. The locations of the surveys are shown in Figure 3-5.

Two grids were surveyed, each over the "best guess" location of the buried object. Each grid was surveyed by a compass and measuring chain. Each point was then marked with a labeled pin flag. The dimensions of the grid at RWDS-1022E were 220 feet x 200 feet. The dimensions of the grid at RWDS-62598 were 140 feet x 140 feet. Pin flags were placed at 20 foot intervals on each grid.

The measurements made at each station were:

- Measurement with the EM 31 with vertical and horizontal magnetic dipoles at 20 foot intervals, and occasionally at 10 foot intervals.

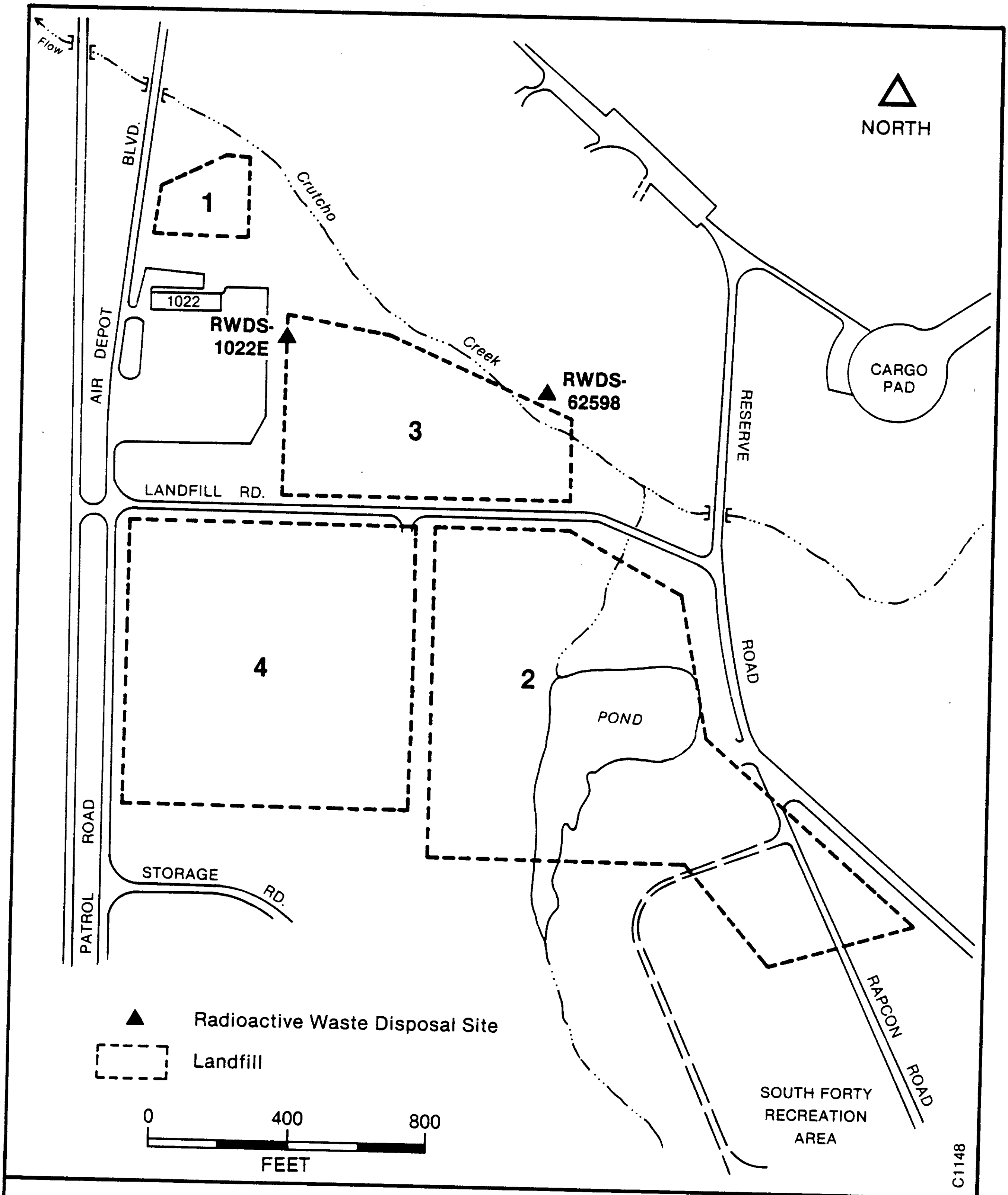


Figure 3-5. Location of Geophysical Surveys at Radiological Waste Disposal Sites.

- Measurements with the EM 34 (20 m) with horizontal magnetic dipoles at 20 foot intervals.

- Total magnetic field and gradient measurements with the EDA PPM500 Proton Magnetometer at 10 foot intervals.

Results of the geophysical investigation are discussed in Section 4.2.5.

3.2.6 Base Water Supply Wells

Tinker AFB currently obtains most of its water supply from a series of on-base production wells. There are two well fields, oriented roughly north-south, along the east and west Base boundaries. All wells are completed in the regional Garber-Wellington aquifer. The depth to water in these wells was measured in an attempt to define local flow conditions in the regional aquifer.

Before measurement, the wells were temporarily taken out of service to remove the immediate effects of pumpage on the aquifer system. When a well withdraws water, that withdrawal causes a local depression in the pressure surface of the aquifer. Further, energy losses as the water enters the well casing itself cause the water surface inside the well to be substantially lower than that in the aquifer immediately outside the wellbore. Since the desired measurement was of the aquifer system without the immediate influence of pumpage, wells were shut down to allow the system to recover. Adjacent wells were shut down together so that between-well interferences would also be removed. Normally, such recovery is substantially complete within two to four days.

It should be noted that the long-term operation of the wells causes a general depression of the pressure surface throughout the well field. The magnitude of this depression is dependent upn the relationship between long-term withdrawals and recharge. That these observations were made after a heavy summer demand period (with little or no rain) may have increased this depression. Assessment of the long-term changes of this kind would require long-term observation of water wells, rather than the one-time effort executed here.

Since the Base is dependent upon the production wells, only limited disruption to the water supply operation could be tolerated. The execution of this task was delayed until after the high water demand summer period and a shutdown strategy devised to minimize adverse impacts on the water supply. The field procedures consisted of the following sequence of events:

- A block of five wells was shut down on Friday afternoon to allow recovery within a small portion of the zone;
- Depths to water were measured in these wells on the following Monday morning, after a 2-1/2 day recovery period;
- The wells were placed back in service and the process repeated the following Friday with the next set of five wells.

In some cases, the wells had been constructed without an access port for the water level probe, so no measurements could be made. However, in all cases, at least one well in each block could be measured. The first set of measurements was made on 1 October 1984. The last measurements were made on 13 December 1984. Radian personnel conducted the first part of the task; Base Bioenvironmental Engineering staff conducted the latter portion.

After the measurements were made, known elevations of the pump house floors were used to convert the measurements to water surface elevation. The results and significance of findings are discussed in Section 4.

4.0 DISCUSSION OF RESULTS AND SIGNIFICANCE OF FINDINGS

In this section, the hydrogeologic observations and chemical analytical data are discussed on a site-by-site basis. Hydrogeologic interpretations are made on the basis of the available data. Analytical chemistry data are discussed within the context of available regulatory standards and criteria. After an introduction section dealing with available standards and criteria, the discussion of results and significance of findings for each site are discussed in separate sections.

4.1 Regulatory and Human Health Criteria and Standards

In order to determine possible water quality impacts on the local ground-water systems, the organic compounds detected in the ground-water samples were compared to various criteria. These criteria were drawn from federal drinking water regulations, standards and guidelines. Table 4-1 shows parameters detected, along with the corresponding EPA toxicity values for chemicals detected. These human health criteria are also available for most of the other organic chemicals detected. Although these criteria do not have the force of standards, they do provide a valid means of assessing properties of chemicals of concern. Many of the compounds are proven or suspected animal carcinogens where zero consumption is recommended for the protection of human health. Many are also regulated as hazardous waste under RCRA (40 CFR Parts 262 and 263). For each site, parameters detected are evaluated in comparison with these standards and criteria.

The use of human health criteria and standards for comparison of ground-water contamination at Tinker AFB provides stringent evaluations of observed concentrations. Since the shallowest aquifer zones (both the perched ground water and the uppermost portions of the Garber-Wellington) are not used as water supply sources, as long as the contaminants remain in the shallow aquifer, the contaminants have neither human health nor environmental consequences. As these contaminants exit from the shallow ground-water system, they encounter any potential receptors that may exist (surface waters fed by

TABLE 4-1. GUIDELINES FOR ORGANIC COMPOUNDS DETECTED IN GROUND WATER

Compound	EPA Toxicity[1,2] ppb Unless Noted
Chloromethane	(1.9)[3]
Vinyl Chloride (Chloroethene)	0 (20)
Chloroethane	0 (7.4)
Methylene Chloride	0 (1.9)[3]
Trichlorofluoromethane	n.c.[4]
1,1-Dichloroethene	0 (0.33)
1,1-Dichloroethane	0 (9.4)
trans-1,2-Dichloroethene	n.c.
Chloroform	0 (1.9)
1,2-Dichloroethane	0 (9.4)
1,1,1-Trichloroethane	18.4 ppm
1,2-Dichloropropane	87
Trichloroethylene (TCE)	0 (27)
1,1,2,2-Tetrachloroethane	0 (1.7)
Tetrachloroethylene	0 (8)
Chlorobenzene	488
1,2-Dichlorobenzene	400
1,4-Dichlorobenzene	400
Benzene	0 (6.6)
Toluene	14.3 ppm
Ethylbenzene	1.4 ppm
Phthalates	n.c.

[1] U.S. EPA estimate of safe levels of toxicants in drinking water for human health effects (Federal Register 28 November 1980).
[2] EPA has recommended human health effects criteria of zero (0) for carcinogens, but notes that this level may currently be infeasible. The Agency provides criteria for achieving various levels of protection on an interim basis. The levels which may result in a 10^{-5} incremental increase of cancer risk over a lifetime are presented in parentheses in ppb unless noted. These figures would permit one case of cancer per 100,000 people exposed.
[3] Criterion for "halomethanes".
[4] n.c. -- denoted no criteria set for human health due to insufficient data.

ground-water outflow; the main (deeper) body of the Garber-Wellington; or the installation boundary itself). Tinker AFB is within the recharge area of the regional aquifer system (the Garber-Wellington). Where contaminants are recharged to that regional system, they have direct human health implications. Where waters come to the land surface, either as seeps or as ground-water outflow to streams, there exists the potential for human contact and exposure. Within the context of the IRP program, the installation boundary is considered to be a de-facto receptor with human health implications. If alternative (more stringent) limits were to be established specifically for Tinker AFB, a formal risk assessment would be required. Since the formal assessment of environmental and human health risks associated with the occurrence of contaminants is beyond the scope of this program, the use of human health standards and criteria is both reasonable and prudent.

4.2 Results of Phase II (Stage 2) Investigation

This section presents the results of geologic, hydrologic, and analytical data obtained during the Phase II Stage 2 investigation. The discussions are organized by site or activity, with appropriate references to base-wide trends or features common to more than one site. Figure 4-1 shows the areas of investigation for the Phase II Stage 2 investigation. Results from the work performed in each area are presented in terms of the topography, geology and hydrology, and ground-water chemistry observed during the investigation.

4.2.1 Building 3001 Investigation

Work performed in the vicinity of Building 3001 consisted of the installation of seven ground-water monitor wells and the sampling and analysis of water from the monitor wells. The buried pit and tank survey is discussed separately in Section 4.2.3, below. The results and significance of the hydrogeologic and chemical data are discussed in the following paragraphs.

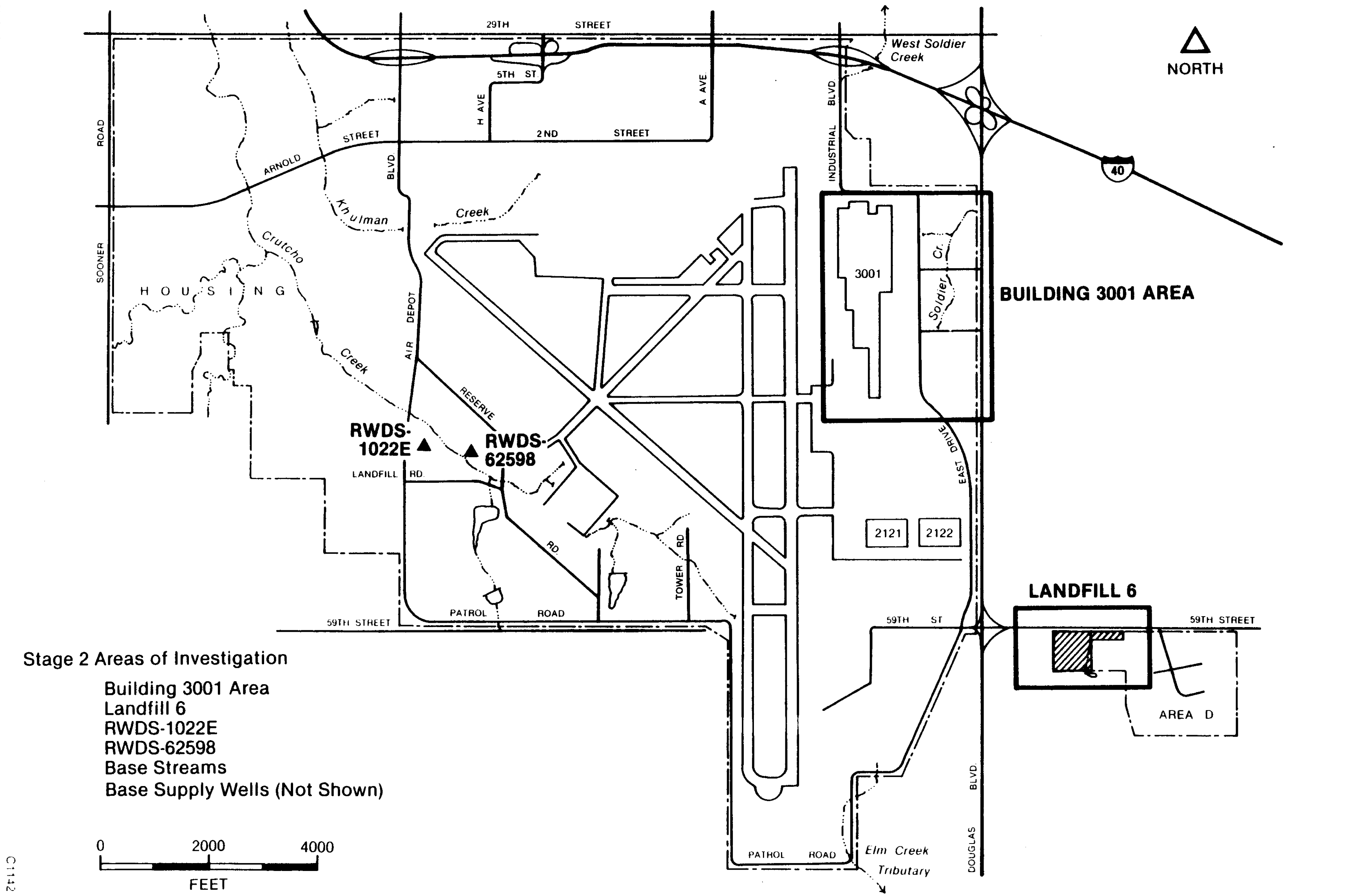


Figure 4-1. Areas of Investigation, Tinker AFB IRP Phase II Stage 2.

Topography

The area in the vicinity of Building 3001 and east to Douglas Boulevard is generally flat. Soldier Creek flows to the north between East Drive and Douglas Boulevard, forming a valley with a maximum elevation drop of 40 feet. Elevations in the area range from about 1230 msl at the wastewater treatment facility at Soldier Creek to about 1275 feet msl at Building 3001.

Geologic Features

Results of monitor well installation show that the geologic setting at Building 3001 is similar to the geologic conditions revealed during the recent Phase II Stage 1 investigation (Radian, 1984), as discussed below. Locations of the monitor wells installed in the vicinity of Building 3001 are shown in Figure 4-2. The major elements of the geologic setting in this area are illustrated in a series of cross-sections (Figures 4-3 through 4-6). The geologic profile within 150 feet of the land surface consists of alternating layers of sandstone and shale that are components of the Permian-age Garber Formation and Hennessey Group. Both of these geologic units contain sandstone and shale; the Garber is dominantly sandstone and the Hennessey is dominantly shale. Near-surface deposits, such as alluvium, were not encountered in the Buiding 3001 investigation.

The Hennessey Shale is composed of red-brown, thinly-bedded to massive shale. Within much of the shale are thin layers and lenses of sandstone. The shale is dry throughout most of the section investigated. Underlying the Hennessey is the Garber Sandstone, which is composed of orange-red, fine to medium grained, friable sandstone. The sandstone contains thin beds of shale, and has a silty matrix throughout the section.

The contact relationship betwen the Garber and Hennessey is reported to be gradational; Wood and Burton (1968) observed that in "the northern part of Oklahoma County, sandstone layers having a lithology similar to the Garber can be observed to grade laterally into shale resembling the Hennessey." The

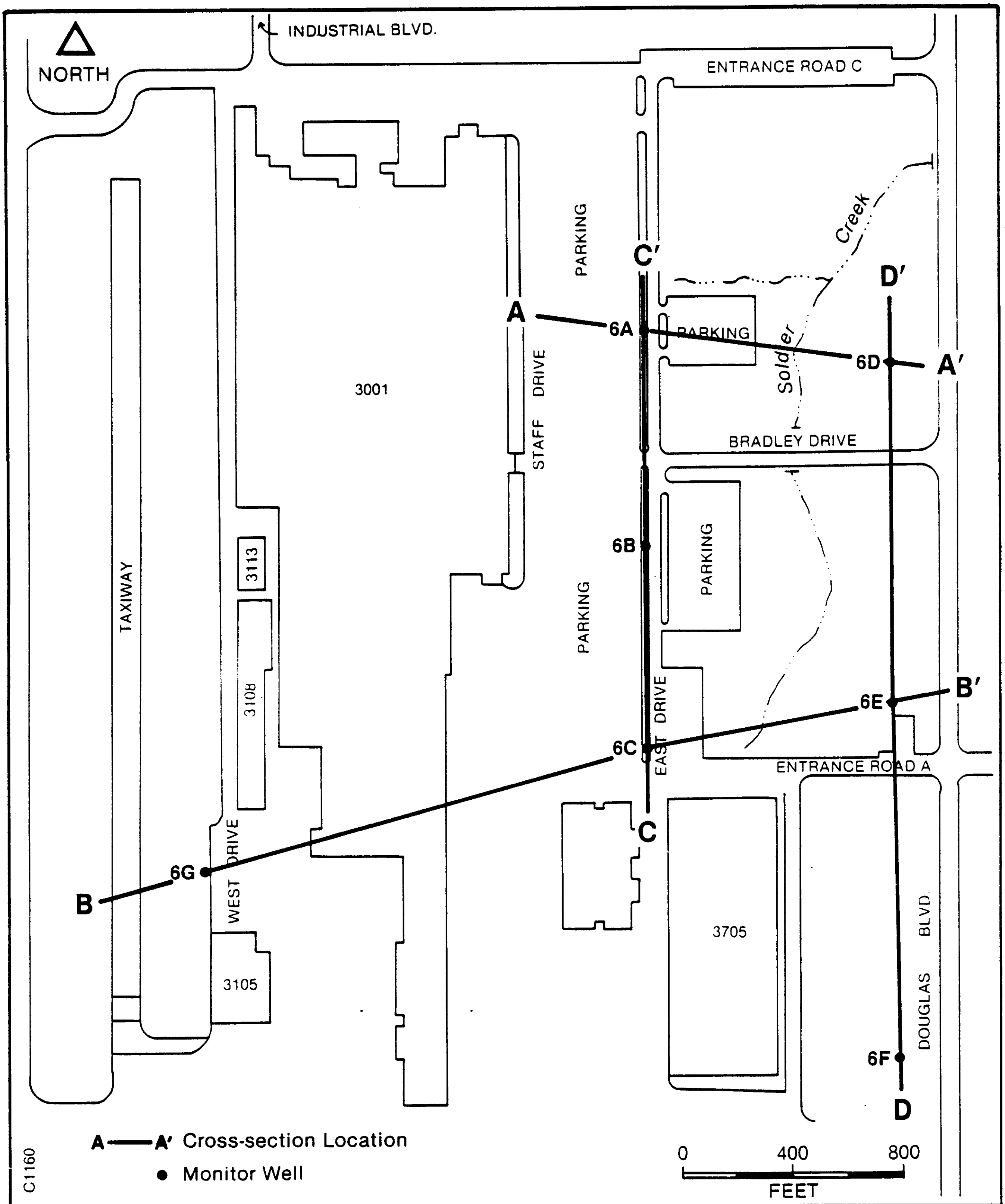


Figure 4-2. Location of Monitor Wells and Geologic Cross-Sections at Bldg. 3001. (Cross-sections on Figures 4-3 through 4-6.)

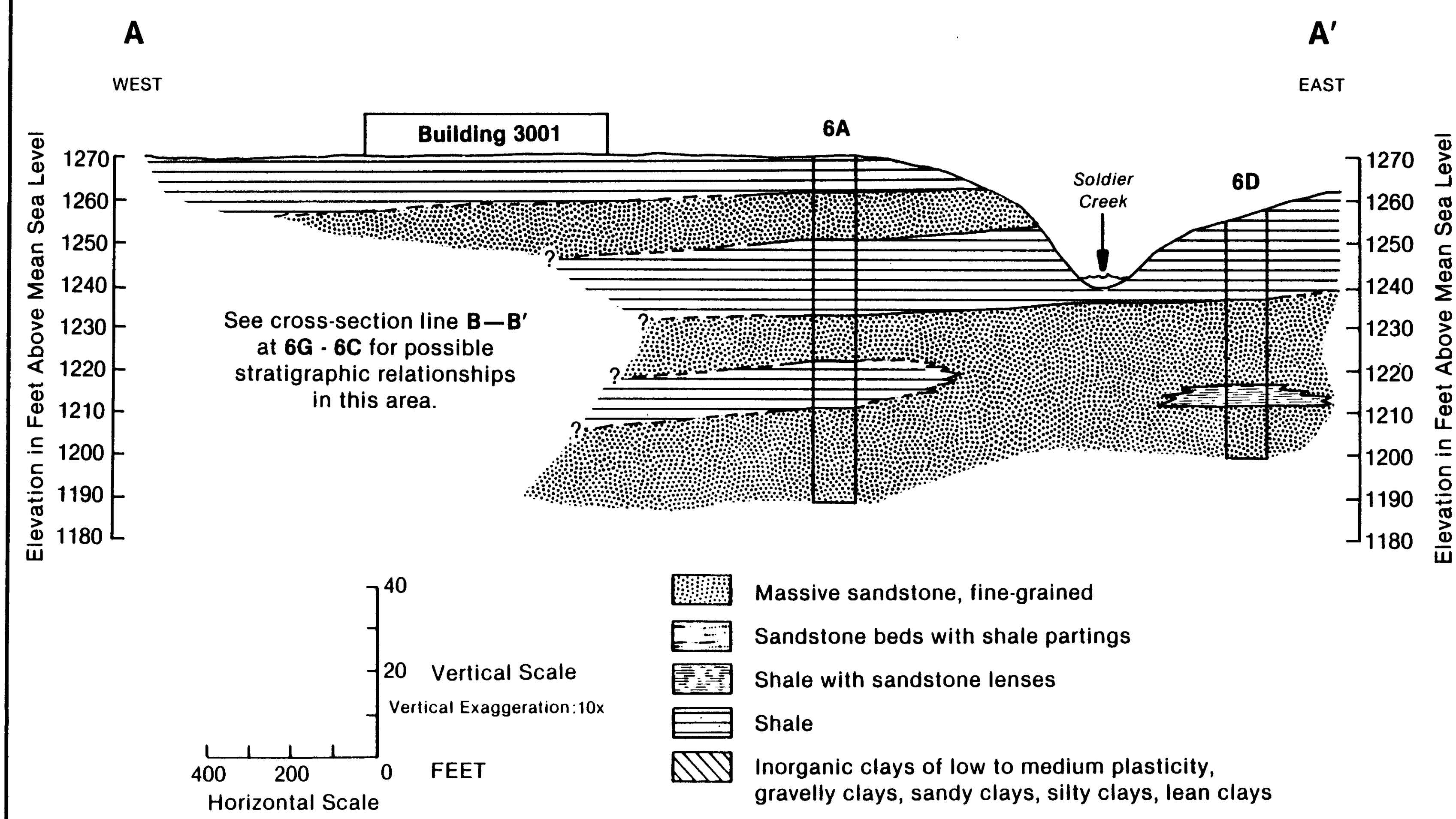


Figure 4-3. Geologic Cross-Section A-A', Building 3001. (Location shown on Figure 4-2).

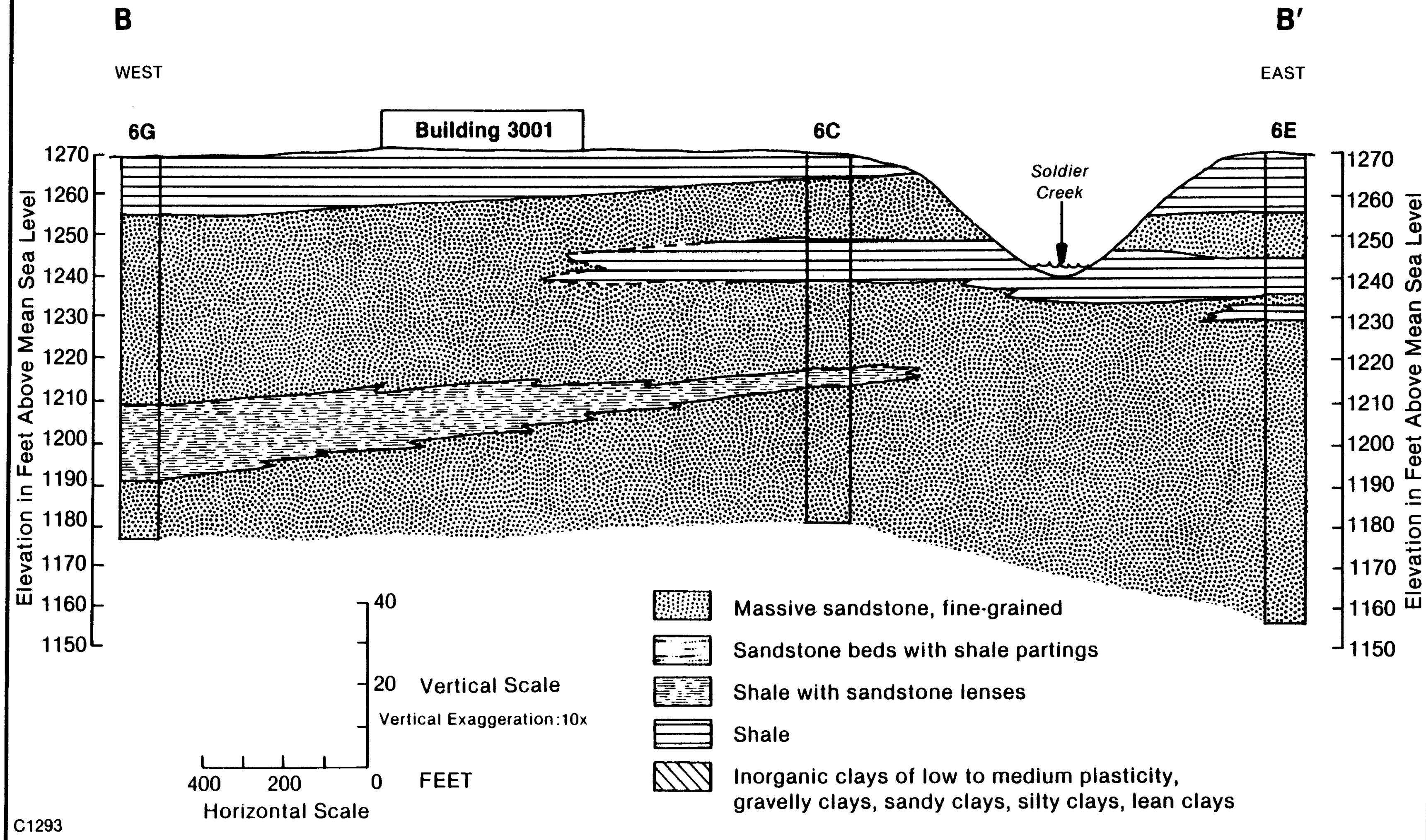


Figure 4-4. Geologic Cross-Section B-B', Building 3001. (Location shown on Figure 4-2.)

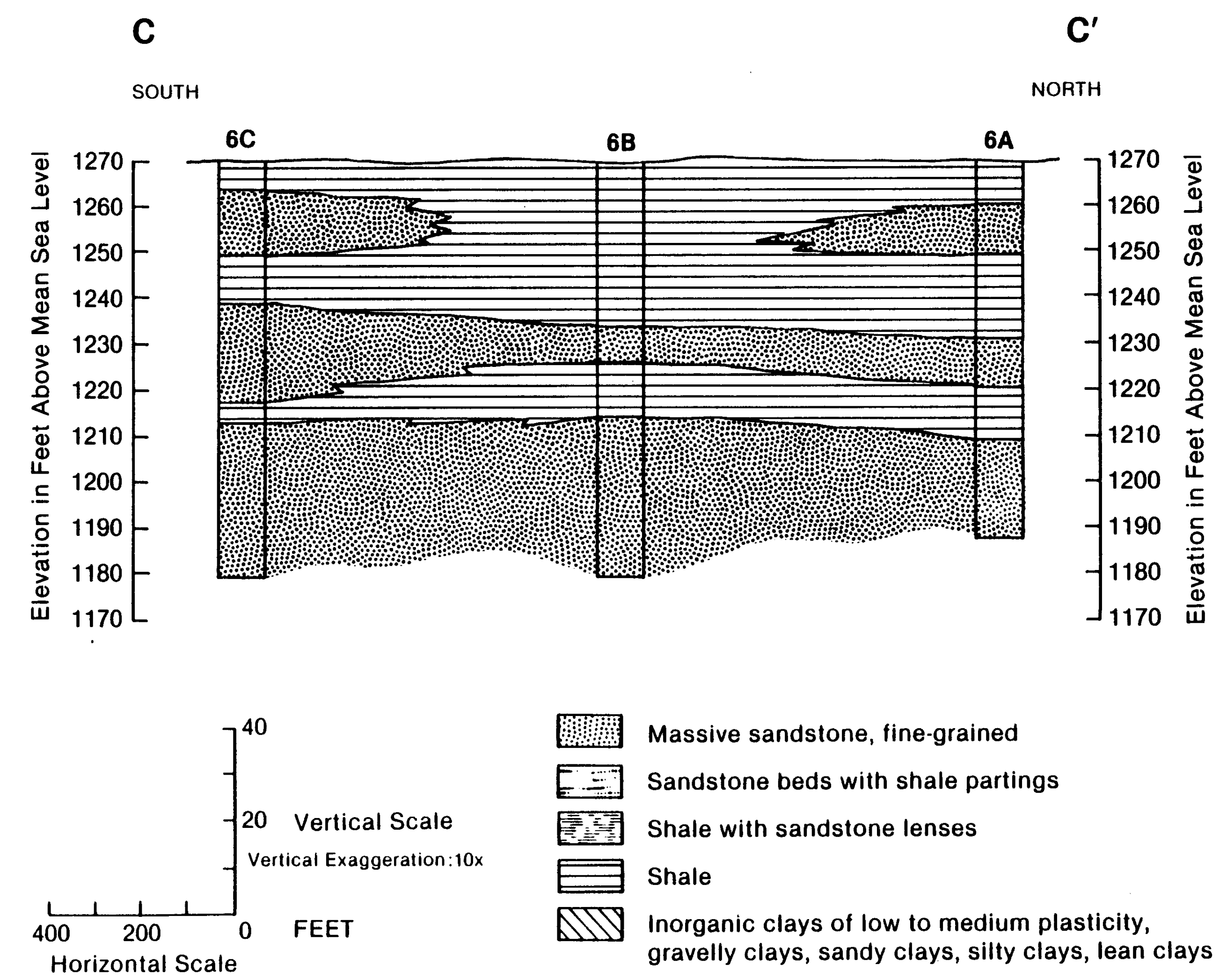


Figure 4-5. Geologic Cross-Section C-C', Building 3001.
(Location shown on Figure 4-2.)

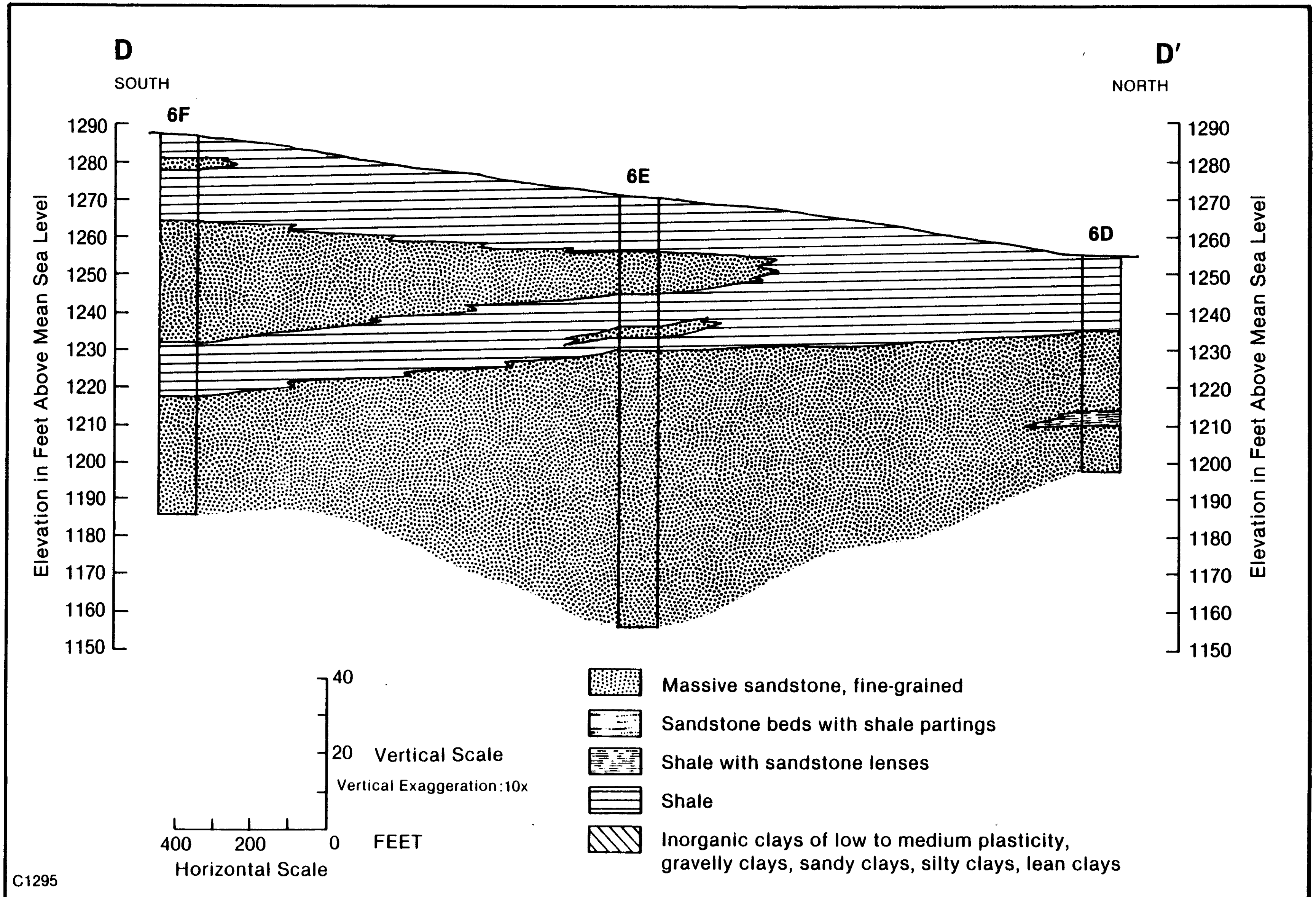


Figure 4-6. Geologic Cross-Section D-D', Building 3001. (Location shown on Figure 4-2.)

sequence of sandstone and shale encounterd in drilling operations, leading to the suggestion of contact relationships illustrated in Figures 4-3 through 4-6, confirm the gradational and interfingering nature of the Garber-Hennessey boundary. The location of Building 3001 (and also Landfill 6, discussed later) near the contact between these formations results in patterns of ground-water occurrence involving perched, and possibly transient, ground-water bodies. However, perched ground water was not encountered further downdip in the western part of Tinker AFB during the Stage I investigation. The character and distribution of shale and sandstone strata in the vicinity of Building 3001 are illustrated on Figures 4-3, 4-4, 4-5 and 4-6. East-west, dip-oriented sections (A-A', B-B') on Figures 4-3 and 4-4 display the shallow regional dip of the strata, which dip to the west and southwest at 30 to 35 feet per mile (Wood and Burton, 1968). North-south, strike-oriented sections (C-C', D-D') on Figures 4-5 and 4-6 illustrate the discontinuous and lens-like character of the strata, particularly in the zone of gradational contact between the Garber and Hennessey.

Occurrence of Ground Water

Ground water was observed in strata underlying Building 3001, both during drilling and monitor well completion activities, and as part of a program to measure water levels and collect samples of ground water for chemical analysis. Throughout most of the area, perched water was observed during drilling activities. This perched water was normally manifested as a mist or spray in the discharge of the air-rotary drilling rig; quite often this water was dried up as the borehole was advanced deeper. The boring was terminated when a sustained production of water was achieved, usually within a predetermined "target depth" based on regional water-level information from the Garber-Wellington aquifer. Each monitor well was constructed in order to achieve at least 10 feet of screen into the zone of saturation. Well completion techniques are discussed in Section 3.0, as are monitor well purging and sampling.

Water-level measurements at the seven monitor wells are summarized on Table 4-3. Ground water occurs at depths ranging from about 33 feet below the surface to about 85 feet below the surface. Based on measurements taken in July and September, 1984, the direction of ground-water flow and the elevation of the water table did not change appreciably during the period. Water-level elevations, based on elevation above mean sea level, have been plotted on a map of the area and contoured at 4-foot intervals to show the configuration of the top of the water table (Figure 4-7). Ground-water flow is to the southwest, as indicated by the inferred flow lines normal to the equipotential lines.

In contrast to the conditions encountered at Landfill 6, discussed below, these wells are considered to be emplaced within the upper portion of the regional aquifer. This evaluation is made on the basis of the regular pattern of water level measurements and on the thickness of saturated materials penetrated by Well 6E.

The equipotential lines illustrated in Figure 4-7 are closely spaced east of Building 3001 near Soldier Creek; the lines near and under Building 3001 are spaced farther apart. The relatively steep gradient near Soldier Creek and flatter gradient under Building 3001 suggest that ground-water flow is affected by aquifer inhomogeneties, recharge or discharge phenomena, or a combination of those factors. However, an evaluation of geologic conditions (Figures 4-3 to 4-6) does not suggest significant changes in aquifer conditions related to faulting, strata thickness variations, or lithology contacts. It appears that a combination of recharge of water from Soldier Creek and discharge of water from Base supply wells west of Soldier Creek could account for the observed pattern of hydraulic gradients. Recharge from Soldier Creek (or from tributaries or storm drains) would create a ground-water "mound" that would elevate the water table surface in the vicinity of the creek. Pumping from Base wells, even at much lower zones in the aquifer, could have the effect of flattening the east-west hydraulic gradient near Building 3001.

TABLE 4-3. WATER LEVEL MEASUREMENTS, BUILDING 3001 MONITOR WELLS

		30 July 1984		24 Sept. 1984	
Monitor Well	Measuring Point Elev.[1]	Depth to Water[2]	Ground-Water Elev.[1]	Depth to Water[2]	Ground-Water Elev.[1]
6A	1271.91	60.00	1211.91	58.96	1212.95
6B	1271.58	67.28[3]	1204.30	66.77	1204.81
6C	1271.03	69.74	1201.29	68.99	1202.04
6D	1256.15	32.85	1223.30	32.60	1223.55
6E	1270.22	63.11	1206.89	62.41	1207.81
6F	1287.29	84.15	1203.14	83.30	1203.99
6G	1279.1	85.00	1194.1	83.89	1195.21

[1] Feet, msl. Elevation of Wells 6A-6F determined by Base Surveyors; elevation at Well 6G estimated from topographic map.
[2] Feet, from measuring point.
[3] Reading on 15 July 1984.

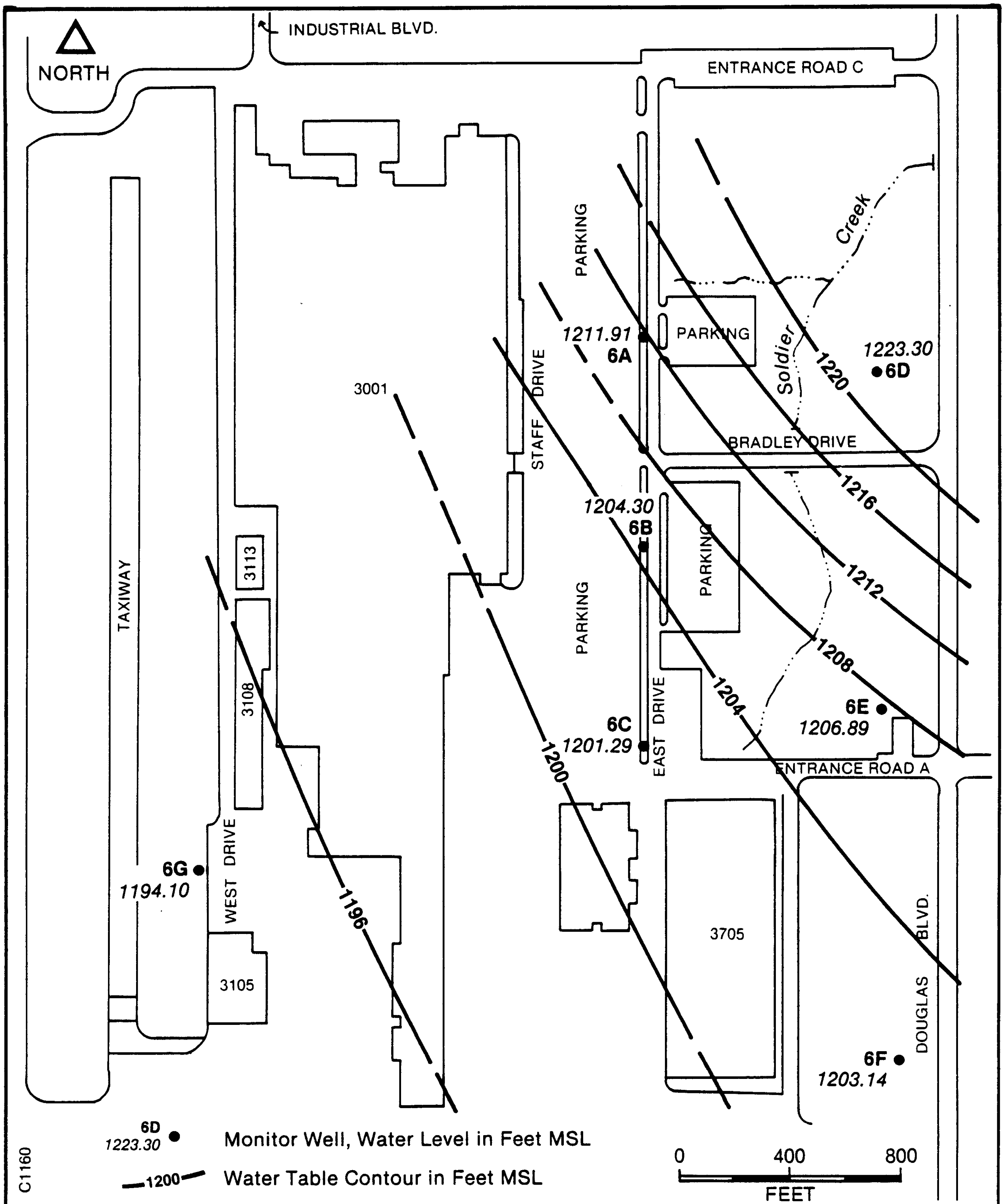


Figure 4-7. Contour Map of the Water Table in Monitor Wells 6A-G Building 3001 (30 July 1984).

Monitor wells 6A through 6G are all completed near the top of the saturated zone (about elevations 1223 to 1194). However, water level data for these wells are at variance with observations of the water surface in the Base water supply wells, discussed in Section 4.2.6, below. These wells, ranging in depth from about 650 to 1100 feet (elevation 600 to 175) display a water surface elevation of about 1035, approximately 190-160 feet below that in the shallow wells. This strong vertical gradient is further suggestive of the lenticular nature of the Garber-Wellington, with shale lenses impeding the vertical flow. A cross-section of the Garber-Wellington at Tinker AFB was presented as Figure 2-7. As would be expected, the water surface in these shallow wells is also above the general level shown by Wickersham (1979) (see Figure 2-8). That report deals more directly with conditions corresponding to observations in the Base water supply wells. Further discussion is contained in Section 4.2.6, below.

Ground-Water Quality

Samples of ground water were collected and analyzed at each of the seven monitor wells established during the Phase II, Stage 2 field program. Wells were purged prior to sampling to insure that fresh formation water was collected for analysis. Samples were collected during two events: mid-July and early-August 1984. The major purpose of the analyses was to determine the presence (or absence) of synthetic organic substances in ground water. The reason behind these analyses was the discovery of trichloroethylene (TCE) and other halogenated organics in ground water from two Base water supply wells, 18 and 19. Samples were subjected to three types of organic analysis: EPA Method 601 (double column), EPA Method 624, and EPA Method 625. Tables 4-4 and 4-5 provide the results of analyes for each of the wells. The following paragraphs provide a summary of the analyses.

Method 601 - Method 601 provides a "screening" of halogenated organic substances in the environment. Based on an evaluation of results, certain substances were detected in relatively high concentrations. Particularly noteworthy are the values of TCE in wells 6A and 6B (642 and 102 ug/L,

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TABLE 4-4. EPA METHOD 601 SAMPLING RESULTS, BUILDING 3001
(All Concentrations Reported in ppb)

Parameter (date sampled)	EPA Toxicity[1] (ppb)	Well 6A		Well 6B		Well 6C		Well 6D			Well 6E		Well 6F		Well 6G		
		July 17	Aug 1	July 18	Aug 1	July 18	July 31	July 16	July 31 - duplicates -	Aug 1 - duplicates -	July 30	Aug 14	July 30	Aug 14	July 16	July 30 - duplicates -	Aug 1 - duplicates -
Chloroethane	0 (9.4)										none	none		none	1.1		0.6
Methylene Chloride	0 (1.9)		1.4	0.9				2.0							1.9		0.6
Trichlorofluoromethane	-	1.2		2.7		3.9	0.4	1.8	22.0				0.5		7.6	1.7	
1,1-Dichloroethene	0 (0.33)	1.7	0.8						2.0								
1,1-Dichloroethane	0 (9.4)	1.4	1.3	1.4		0.3	0.2	1.7		1.8							
trans-1,2-Dichloroethene	-	18.1		33.2		2.9		0.4								3.8	
Chloroform	0 (1.9)		9.9		19.6	0.7	1.6			0.8					4.6		1.6
1,2-Dichloroethane	0 (9.4)	2.6	2.0				0.3								4.9		
1,1,1-Trichloroethane	18,400 ppm	4.2	2.5	0.2													
1,2-Dichloropropane	87	0.3	0.2														
Trichloroethylene	0 (27)	642.0	444.0	102.0	52.8	4.9	3.1	0.6		0.5			0.1		1.3	0.9	0.6
1,1,2,2-Tetrachloroethane	0 (1.7)		2.7														
Tetrachloroethylene	0 (8)	4.7		1.7		0.7	0.2										
Chlorobenzene	488			1.3				20.5	21.8	34.5							
1,2-Dichlorobenzene	400			1.1				8.4	11.0	10.3							

[1] From Table 4-1.

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TABLE 4-5. EPA METHOD 624/625 SAMPLING RESULTS, BUILDING 3001
(All Concentrations Reported in ppb)

Method/Parameter Date Sampled	EPA Toxicity[1] (ppb)	Well 6A 7/17	Well 6B 7/18	Well 6C 7/18	Well 6D 7/16	Well 6D 7/31	Well 6E 7/30	Well 6F 7/30	Well 6G 7/16	Well 6G 7/30
EPA 625 (Acid Extractables)		none	none	none	none	none	none	none	none	none
EPA 625 (Base/Neutrals)		none	none			none	none	none		none
bis(2-ethylhexyl)phthalate	-				13				12	
di-n-octyl phthalate	-			44					12	
EPA 624 (Volatiles)				none				none		
benzene	0 (6.6)								47	39
chlorobenzene	488				21	30				
trans-1,2-dichloroethene	-		48							11
methylene chloride	0 (1.9)								21	
toluene	14,300 ppm						61		670	1886
trichloroethylene	0 (27)	779	134							

[1]From Table 4-1.

respectively); values of chlorobenzene (34.5 ug/L) in 6D, and values of trans-1,2-Dichloroethene in 6A and 6B (18.1 and 33.2 ug/L). The locations of all wells sampled for analysis of Method 601 compounds are shown on Figure 4-7. Several wells showed no or extremely low concentrations of just a few compounds; wells 6E and 6F were virtually "clean" and wells 6C and 6G showed relatively low concentrations (less than 10 ppb) of several compounds. Methylene chloride, 1,1-dichloroethene, chloroform, trichloroethylene, and 1,1,2,2-tetrachloroethane are noted to occur above their respective EPA toxicity limits in various wells. It should be realized that values reported below 5 ppb for Method 601 cannot be expected to show good agreement because they are too near the detection limit.

Many components reported in the Method 601 results are not found in the Method 624 results for the same samples. This is due to the difference in detection limits of the two methods when the values reported are in the 0-5 ppb range. For example, the July 17 Method 601 result for well 6A shows the presence of trans-1,2-dichloroethylene at 18.1 ug/L but it was not found by Method 624. This is due to the fact that this sample was diluted to get the trichloroethylene content within the working range of the gas chromatograph/ mass spectrometer (GC-MS), thus raising the detection limits to 25-50 ppb. This would hold for the Method 624 results for well 6G also.

Method 624 - The major volatile compounds detected by Method 624 are TCE in wells 6A and 6B, toluene in 6E and 6G, methylene chloride in 6G, 1,2-trans-dichloroethylene in wells 6B and 6G, chlorobenzene in well 6D, and benzene in well 6G. In addition to those compounds cited under Method 601, benzene is noted to occur in concentrations above the EPA toxicity limit.

Method 625 - Acid extractable and base/neutral analyses indicate low levels of phthalate compounds. The scattering of phthalates in the data is probably due to the fact that it is extremely difficult to prevent contaminating samples at low ppb concentrations with these ubiquitously distributed compounds. Thus, detection of these compounds is probably not indicative of their occurrence in the ground water.

Significance of Findings

Results of the Phase II, Stage 2 investigation show that the area in the vicinity of Building 3001 is underlain by shale and sandstone strata. These strata vary considerably in thickness and relative percentages of sand and clay. Perched water was observed in several locations (6A, 6C and 6G) during drilling operations; this water appears to occur in relatively small quantities but is believed to contribute recharge to the upper part of the regional aquifer tapped by monitor wells completed at Building 3001.

Several observations can be made about the distribution and character of ground-water contaminants in the vicinity of Building 3001. First, the distribution of organic compounds, both in terms of magnitude and identity, is quite variable. For example, elevated levels of TCE, perchloroethylene and other organic chemicals are hydraulically upgradient from Building 3001 and any presumed sources of contamination. Likewise, relatively isolated locations are reported to have elevated levels of other compounds, with no clear indication of source. Second, the State of Oklahoma Board of Health has gathered data that reportedly indicate the presence of TCE in water from storm drain(s) into Soldier Creek (J. Dunbar, personal communication). Furthermore, it is reported, but not confirmed, that the storm drains underlie the area at the northeast side of Building 3001. It may be that leakage from storm drains or recharge from Soldier Creek, itself, in the vicinity of wells 6A and 6B may account for the high levels of organic compounds. The current stream sediment sampling program (see Section 4.2.4) did not address chlorinated solvents and so does not shed additional light on the occurrence of these compounds in Soldier Creek.

Summary and Conclusions

There now exist several lines of evidence which can be used to summarize existing conditions in the vicinity of Building 3001. While no one item of evidence is conclusive in and of itself, taken together, all provide an acceptably complete evaluation. The evidence consists of the following findings:

- The origin of the trichloroethylene, perchloroethylene and other synthetic organic compounds is not a single, defined source, but rather the cumulative results of 30 or more years of industrial operations (see Section 4.2.4);

- The pattern of occurrence of contaminants in the Stage 2 monitor wells does not clearly suggest a plume from a single, definable source; and

- The occurrence of contaminants is confined to relatively shallow levels of the aquifer, since, as reported in Stage 1, Base production wells in the vicinity, with the exception of Wells 18 and 19, are relatively clean.

The synthetic organic chemicals occurring in the shallow subsurface in the vicinity of Building 3001 pose two threats to human health and the environment. The first is that, due to the existing vertical head gradient and the influence of Base production wells, these contaminants can move downward and enter the strata from which these wells produce water. This constitutes a future threat to the Base water supply. The second is that the contaminants can move laterally to the southwest, in the direction of both the local and regional gradients. As these contaminants move, they will become more widely dispersed in the aquifer. The nearest potential receptors are the Base wells along the western boundary of the Base. Alternatives for dealing with the discovered contamination are discussed in Section 5.

4.2.2 Landfill 6 Investigation

Work performed in the vicinity of Landfill 6 consisted of the installation of six ground-water monitor wells and the sampling and analysis of water from the monitor wells. The results and significance of the hydrogeologic and chemical data are discussed in the following paragraphs.

Topography

Landfill 6 is located at the crest of a low hill, with an elevation of slightly above 1300 feet MSL. The investigation focused principally on the areas to the north and west of the landfill; these areas slope away from the landfill. A normally dry tributary to Soldier Creek originates along the eastern boundary of the landfill, flows north under S.E. 59th Street, and continues northward, adjacent to a motorcycle racetrack. Four monitor wells were installed north of S.E. 59th Street. Other monitor wells were installed along the south side of S.E. 59th Street, at the toe of the landfill east (along the Soldier Creek tributary) and west of the landfill. Topographic relief in the area of investigation is approximately 50 feet.

Geologic Features

Geologic data in the vicinity of Landfill 6 were obtained from examination of outcrop (especially north of S.E. 59th Street), logs of wells installed during 1981 (Finn, 1981) and 1983 (Radian, 1984) during previous investigations at the landfill, and logs of wells installed during July, 1984. A summary of the well data was provided in Table 3-4. Locations of the monitor wells are shown in Figure 4-8.

The overall geologic setting at Landfill 6 is similar to the geologic conditions at other parts of Tinker AFB. However, results of drilling and water-level observations at Landfill 6 reveal a greater occurrence of discontinuous shale lenses and perched ground water than at other areas of the Base. The significance of these shale strata is discussed below.

The primary geologic units are the Hennessey Shale and the Garber Sandstone. At Landfill 6, the Hennessey Shale is quite thin; the landfill's relatively high elevation corresponds to an isolated area of Hennessey Shale bounded on the north, south, and east by outcrop of the Garber Sandstone. Here the Hennessey Shale is quite thin and is absent north of S.E. 59th Street. The maximum thickness of the shale appears to be approximately 20 feet (at 2A), although other bodies of shale with thin beds of sandstone exist within the Garber Sandstone at greater depths.

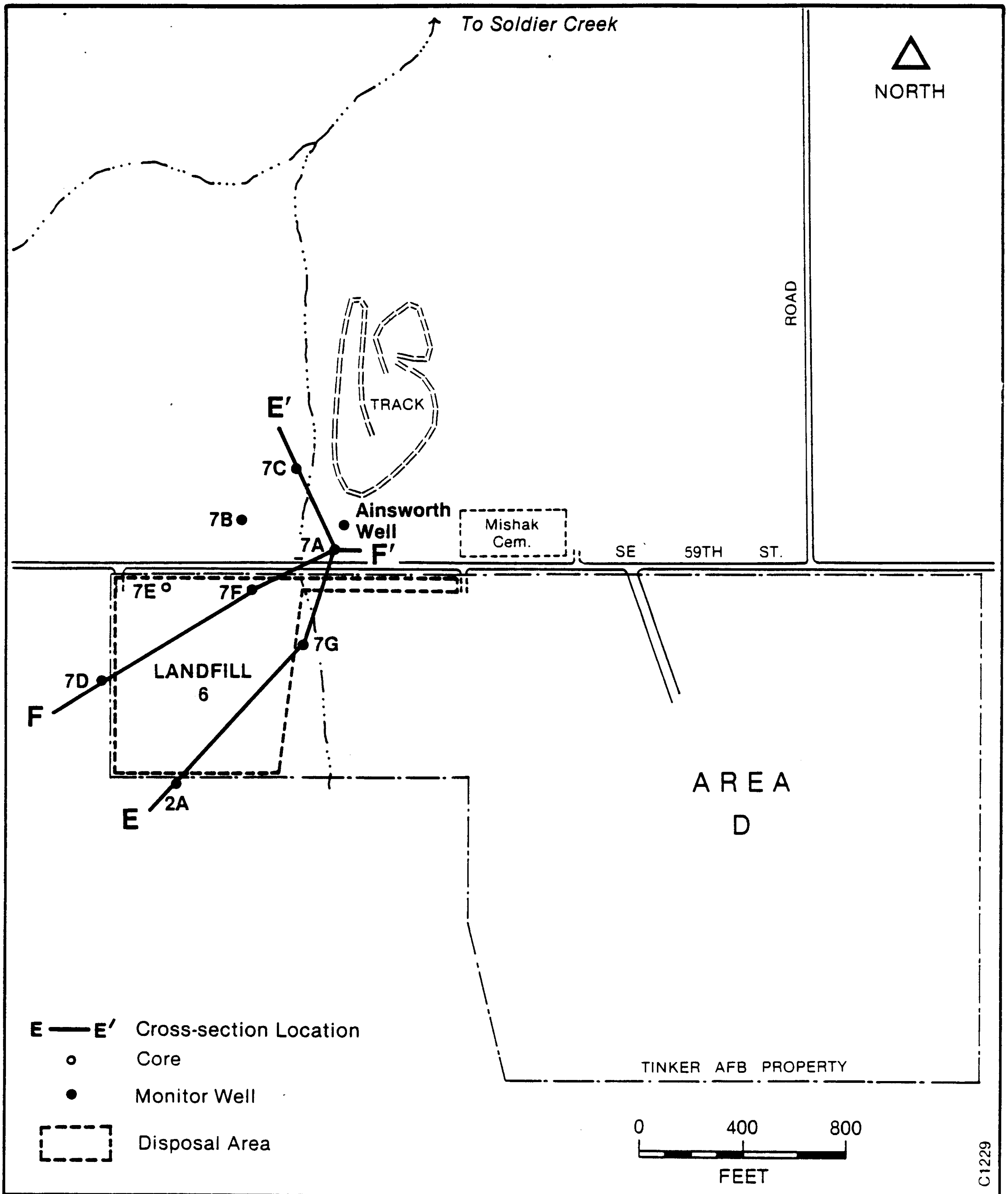

Figure 4-8. Location of Monitor Wells and Geologic Cross-Sections, Landfill 6 (Cross-sections on Figure 4-9 and 4-10).

The Hennessey Shale is composed of red-brown, thinly-bedded to massive shale. Within much of the shale are thin layers and lenses of sandstone. The shale is dry throughout most of the section investigated near the landfill. Underlying the Hennessey is the Garber Sandstone, which is composed of orange-red, fine to medium grained, friable sandstone. The sandstone contains thin beds of shale, and has a silty matrix throughout the section investigated at Landfill 6.

The geologic cross-sections illustrated in Figures 4-9 and 4-10 provide a representative picture of the distribution and character of the sandstone and shale strata. The picture of thin and discontinuous shale strata in the uppermost Garber Sandstone is consistent with the geologic description provided by Wood and Burton (1968) and supported by the results of drilling and monitor well installation at Building 3001.

Occurrence of Ground Water

Results of water-level measurements (Table 4-6) made during drilling operations, monitor well completion and development, and routine observations during ground-water quality sampling, indicate that at least two important ground-water systems exist at Landfill 6. The uppermost body of ground water occurs at relatively shallow depths in scattered and apparently isolated areas; this shallow ground water is perched on the sandy shale stratum at approximately 1250 to 1260 in elevation. Wells that monitor this interval of shallow ground water include 2A, 7F, and 7G. At other locations, no perched ground water or confining layer was discovered. Shallow monitor well 7E was drilled to a depth of 60 feet, approximately to elevation 1,220 feet, without encountering shale zones or ground water. This dry hole was abandoned and grouted.

Two other monitor wells provide data that support the concept of a limited perched aquifer. Monitor wells 7B and 7D were both completed in an initially saturated zone, but are now dry. Significant amounts of water were produced during drilling and monitor well completion activities (Appendix D).

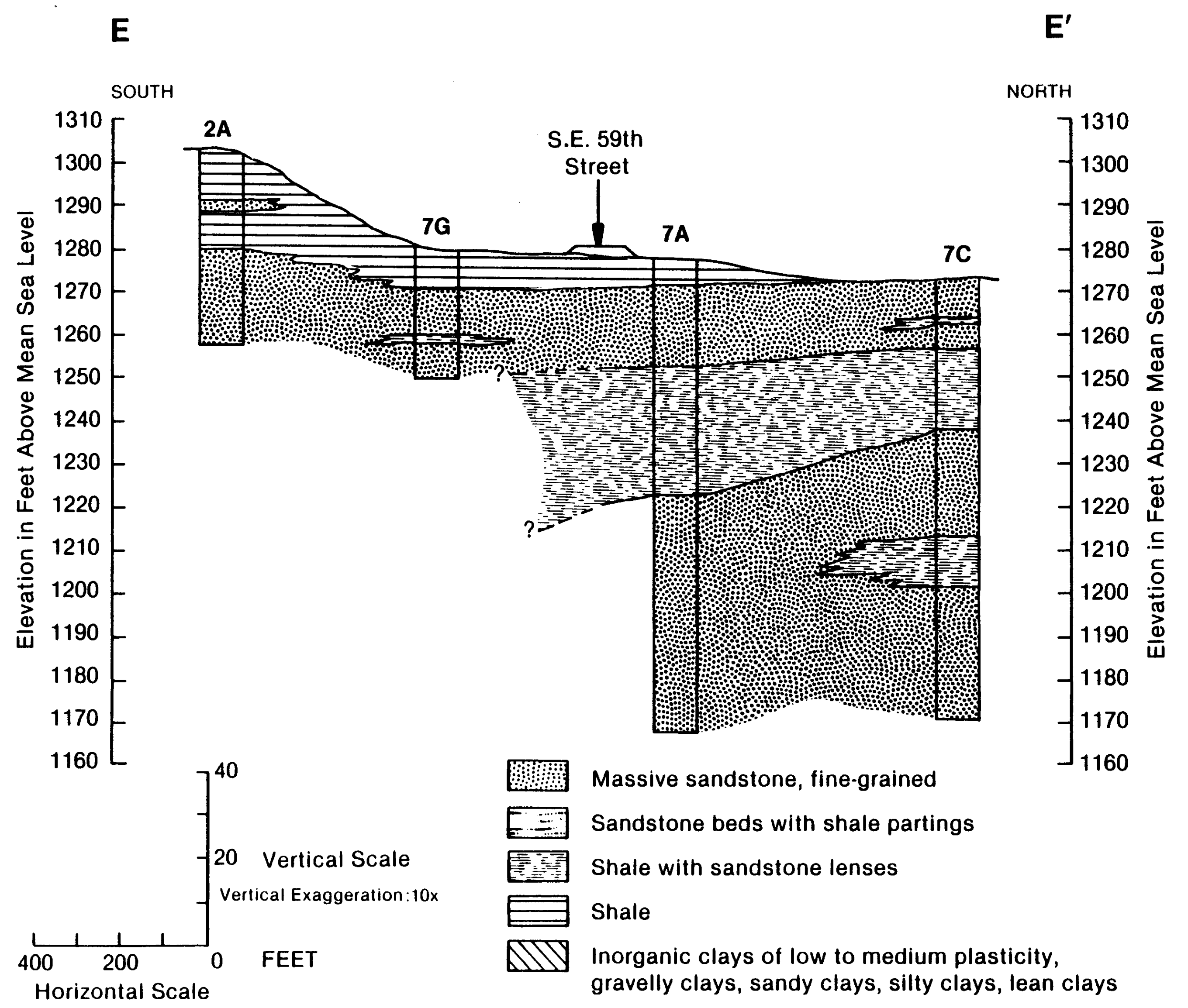

Figure 4-9. Geologic Cross-Section E-E', Landfill 6 (Location shown on Figure 4-8).

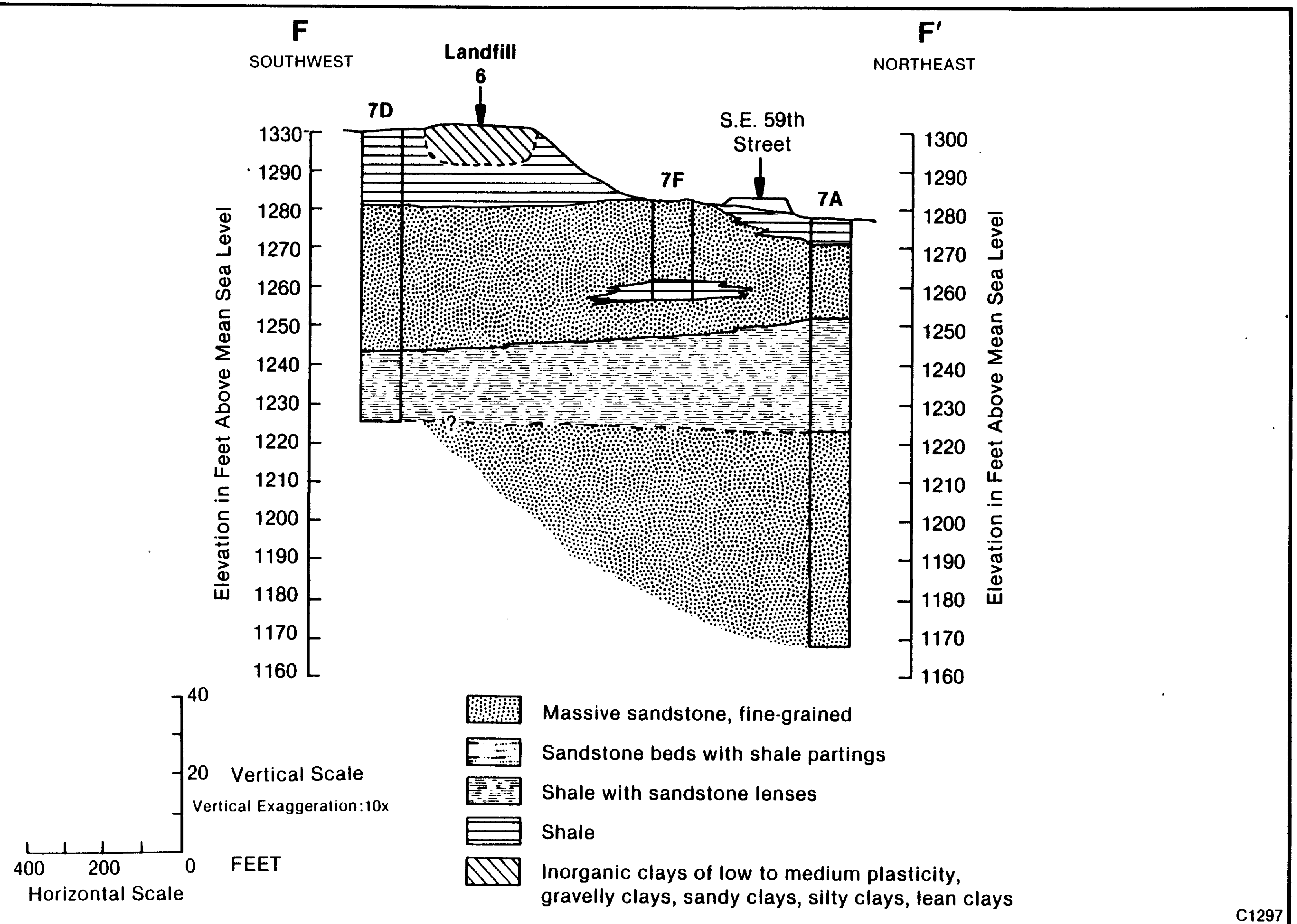

Figure 4-10. Geologic Cross-Section F-F', Landfill 6 (Location shown on Figure 4-8).

TABLE 4-6. WATER-LEVEL MEASUREMENTS, LANDFILL 6

Monitor Well	Measuring Point Elevation[1]	Depth to Water[2]	Ground-Water Elevation[1]
7A	1277.73	79.18	1198.55
7B	1281.68	dry	--
7C	1272.30	72.40	1199.9
7D	1300.00	dry	--
7F	1282.55	20.36	1262.19
7G	1280.48	13.03	1267.45
2A	1306 (est)	39.46	1266.54

[1]Feet, msl.
[2]Feet, from measuring point (30 July 1984).

However, Well 7B was suddenly dewatered during development; Well 7D was discovered to be dry several weeks after completion. Inasmuch as these wells were completely installed before the drainage was noted, it was not possible to deepen them. It is hypothesized that both wells were completed in what was initially a perched aquifer, but that the borehole was advanced through the bottom of the confining layer into the relatively permeable and dry sandstone below the shale. The completion of the borehole through the entire thickness of the confining layer allowed for the drainage of the perched ground-water body into the underlying sandstone. The sequence of events outlined (initial saturation followed by complete drainage) provided the observations necessary to understanding the hydrogeologic setting at Landfill 6. Had these wells been "successfully" completed, as was 2A, the phenomena would have gone unobserved and, perhaps, erroneous conclusions drawn on the basis of available data.

Ground water in wells 7A and 7C occurs at depths of about 72 to 79 feet below the land surface. These depths correspond to an elevation (msl) of slightly less than 1200 feet, which is consistent with the position of the regional (Garber-Wellington) ground-water table. The direction of ground-water flow cannot be precisely determined from these wells; at least three data points are needed to determine the flow direction and hydraulic gradient. However, the data suggest a southerly direction of ground-water flow in comparison to a southwesterly regional flow indicated by data from the wells at Building 3001.

Ground-Water Quality

Water from monitor wells at Landfill 6 was collected and analyzed according to the protocol described for the Building 3001 investigation. Samples were collected during two separate events in mid-July and early August 1984. The major purpose of the analyses was to determine the presence (or absence) of synthetic organic substance in ground water in the vicinity of Landfill 6. It had been noted by the Oklahoma State Department of Health that ground-water obtained from a nearby domestic well (the "Ainsworth" well located just northeast of Landfill 6 across S.E. 59th Street) had shown levels of synthetic organic compounds.

Samples collected from the Stage 1 and 2 wells were subjected to three types of organic analysis: EPA Method 601 (double column), EPA Method 624, and EPA Method 625. Results of the water-quality analyses from the wells are provided in Tables 4-7 and 4-8. In addition, the State of Oklahoma has conducted a limited sampling and analysis program at monitor wells in the vicinity of Tinker AFB. State analytical results from well 2A are provided in Table 4-7. This program also included the Ainsworth well; the results of these analyses are reported in Table 4-9. The following paragraphs provide information on the types of analyses performed on the samples.

Method 601. Method 601 provides a "screening" of halogenated organic substances in the environment. Based on an evaluation of results at the wells at Landfill 6, some organic compounds were detected in relatively

TABLE 4-7. EPA METHOD 601 SAMPLING RESULTS, LANDFILL 6

Parameters (Date Sampled)	EPA Toxicity [1] (ppb)	Well 7A		Well 7C			Well 7F		Well 7G		Well 2A	
		July 31	Aug 15	July 30	Aug 14	Aug 15	July 17	July 31	July 18	Aug 1	July 31	Feb 15[2]
					- duplicates -							
Chloromethane	0 (1.9)				none	none	63.8			none		
Vinyl Chloride	0 (20)						10.8					
Chloroethane	0 (9.4)						15.3	13.3				
Methylene Chloride	0 (1.9)						6.0	6.8			11.5	
Trichlorofluoromethane	-	2.2	0.2	0.5			4.4		2.6		12.2	3.8
1,1-Dichloroethane	0 (9.4)		0.6				2.3				29.9	25.0
trans-1,2-Dichloroethene	-		0.4									
Chloroform	0 (1.9)						15.9	19.2			7.8	
1,2-Dichloroethane	0 (9.4)		0.2									
1,1,1-Trichloroethane	18.4 ppm										3.5	4.2
1,2-Dichloropropane	87										0.6	
Trichloroethylene	0 (27)		0.5				0.9	0.6	0.4		61.0	30.4
1,1,2,2-Tetrachloroethane	0 (1.7)											
Tetrachloroethylene	0 (8)										22.5	12.2
Chlorobenzene	488						5.7	4.5				
1,2-Dichlorobenzene	400							6.5				
1,4-Dichlorobenzene	400						6.0					

[1] From Table 4-1.
[2] GC-MS data from Oklahoma State Environmental Lab.

TABLE 4-8. EPA METHODS 624/625 SAMPLING RESULTS, LANDFILL 6

Method/Parameters Date Sampled	EPA Toxicity[1] (ppb)	Well 7A 31 July 84	Well 7C 31 July 84	Well 7F 17 July 84	Well 7G 18 July 84
EPA 625 (Acid Extractables)		none	none	none	none
EPA 625 (Base/Neutrals)		none	none		none
1,4-dichlorobenzene	400			12	
bis(2-ethylhexyl)phthalate	-			8	
diethyl phthalate	-			32	
EPA 624 (Volatiles)			none		none
benzene	0 (6.6)			8	
trans-1,2-dichloroethene	-			21	
ethylbenzene	1.4 ppm			18	
toluene	14.3 ppm	6			

[1]From Table 4-1.

TABLE 4-9. STATE OF OKLAHOMA GC/MS RESULTS, AINSWORTH WELL[1]

Parameter	Concentration
1,1-Dichloroethane	8.0 ug/L
Trans-1,2-Dichloroethene	7.7 ug/L
Trichloroethylene	8.7 ug/L
1,4-Dichlorobenzene	0.7 ug/L
Bis (2-Ethylhexyl) Phthalate	8.2 ug/L
Diethyl Phthalate	2.4 ug/L
2-Methyl-1,3-Butadiene[2]	1-100 ug/L
1,2-Diethoxyethane[2]	1-100 ug/L
Phthalazinone[2]	1-100 ug/L
N-[1,1-Dimethyethyl]-3-Methylbenzamide[2]	1-100 ug/L
2-Methylbenzenesulfonamide[2]	1-100 ug/L
Benzenemethanesulfonyl Chloride[2]	1-100 ug/L
2-Methylbenzenesulfonyl Chloride[2]	1-100 ug/L
4-Methylbenzenesulfonyl Chloride[2]	1-100 ug/L
4,8,12-Trimethyl-3,7,11-Tridecatrienenitrile[2]	1-100 ug/L
Trichloroethanol Phosphate[2]	1-100 ug/L
Chemical Oxygen Demand	11.6 mg/L
Total Organic Carbon	4.1 mg/L

[1] Sample collected 8 September 1983.
[2] Indicates that the compound was tentatively identified by computer match with the NBS Mass Spectral Data Base. Analyst noted that numerous unidentified hydrocarbons were present in the sample.

high concentrations. Particularly noteworthy are the results from wells 7F and 2A that monitor the shallow and perched ground water in the vicinity of the landfill. All concentrations of organic compounds were less than 65 ppb, although several contaminants were present in levels greater than 10 ppb. Well 2A revealed relatively high concentrations of trichloroethylene, 1,1-dichloroethane, and tetrachloroethylene. Well 7F had relatively high concentrations of chloromethane, vinyl chloride, and trans-1,2-dichloroethane. It should be realized that values reported below 5 ppb for Method 601 cannot be expected to show good agreement because they are too near the detection limit. In general, the 601 (GC) data from 2A agree well with the State of Oklahoma GC-MS data.

Method 624 - The major volatile compounds detected by Method 624 are benzene, 1,2-trans-dichloroethylene, and ethylbenzene in Well 7F, and toluene in Well 7A.

Method 625 - Acid extractable and base/neutral analyses indicate low levels of phthalate compounds in Well 7F. A concentration of 12 ppb of 1,4-dichlorobenzene was also observed in water from Well 7F. The scattering of phthalates in the data is probably due to the fact that it is extremely difficult to prevent contaminating samples at low ppb concentrations with these ubiquitously distributed compounds. Thus, detection of thse compounds is probably not indicative of their occurrence in the ground water.

Significance of Findings

Results of drilling, well construction, and ground-water sampling and analysis at Landfill 6 indicate that the area is underlain by interbedded shale and sandstone that contain two separate ground-water bodies within 100 feet of the land surface. The chemistry data reveal that the shallow and perched ground water near the landfill contains a variety of synthetic organic compounds: the deeper ground water has much lower levels of contamination at greater distances north and away from the landfill.

It appears that the quality of the regional ground water has not been severely affected north of the site. However, water quality results from the Ainsworth well suggest somewhat higher levels of contamination in the regional aquifer. Although the Ainsworth well is hydraulically upgradient from the landfill, the ground-water flow paths in the overlying perched zones may be locally reverse that of the regional aquifer. Figure 4-11 schematically illustrates a model of possible ground-water flow relationships in the vicinity of Landfill 6. It appears that water percolating in and through the landfill would likely encounter one or more series of shale lenses. Insufficient data exist to establish continuity of these shale lenses. In areas investigated during Stage 2, thin zones of perched ground water were encountered in a dominantly dry section. Water in the perched zones may continue to flow down toward the regional water table. Thus, it is likely that contaminants from Landfill 6 have moved north along these shale lenses and entered the Ainsworth well. The quality of water has been observed to be improved with depth, which is consistent with the model outlined on Figure 4-11.

Summary and Conclusions

The available hydrogeologic and chemical data suggest that Landfill 6 is releasing synthetic organic chemicals to the environment. Very near surface ground water or leachate flow is expected to follow weathered zone which follows the topography. Therefore, observations of chemical concentrations in monitor well 7F should define an upper bound to the concentrations being released. These released chemicals are following a circuitous path downward to the regional ground-water body, as illustrated in the conceptual diagram of Figure 4-11. As the contaminants move through the perched ground-water bodies, such as that sampled by well 2A, they are becoming more dilute. Since the data suggest a southward flow in the regional system, there are no data on the occurrence of contaminants downgradient in the regional body. Alternatives for dealing with the discovered contamination are discussed in Section 5.

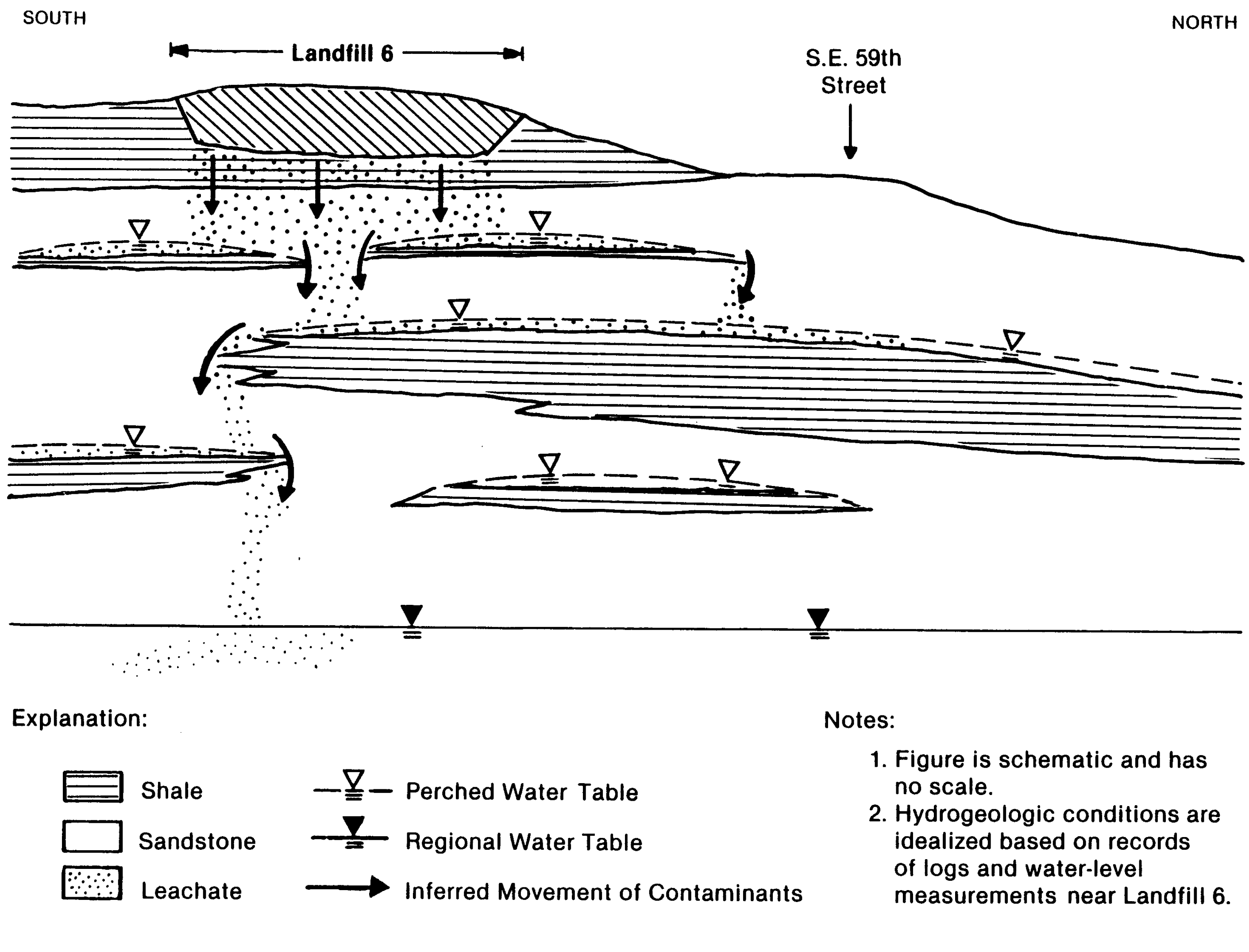

Figure 4-11. Conceptual Model of Hydrogeologic Conditions, Landfill 6.

4.2.3 Buried Pit and Tank Survey

Buried Pits

Table 4-10 summarizes the locations of buried pits beneath Bldg. 3001 together with the visual observations and characteristics noted during the surface inspection tour. Also included are the civil engineering drawing numbers which contain the precise location of the buried pits. The locations described in this table refer to the frame numbering and lettering system used within Bldg. 3001. As previously noted, these pits have all been covered or closed and are no longer in use. Most were covered with a concrete cap. One pit was covered with an old wooden cover and was believed by the nearby shop personnel to be filled with water. Interviews with former base employees indicate that up to fourteen drums of trichloroethylene were used on average every day in these pits during the 1940's, 1950's and 1960's. A majority of this liquid was reportedly lost to evaporation during the degreasing process.

Disposal practices were not recorded in detail although in some cases engineering drawings are available which show that interconnections were provided to the below-floor storm sewer system from these pits. Presumably, these inteconnections were designed for cooling water return or ease of cleaning of the degreasing pits following the removal of solvent sludges. However, the possibility that waste, spent solvents or sludges were periodically washed to the storm sewer system exists. Also it is hypothetically conceivable that condensation of trichloroethylene vapor on walls, floors, pipes, equipment and subsequent cleaning of these surfaces could have, over time, also washed trichloroethylene laden waters into the storm sewers (an industrial waste sewer system was extended to all the shops in the Bldg. 3001 during the early 1970's). Another possibility was that these degreasing tanks were leaking trichloroethylene through holes in the metal tanks or valves left open in the storm sewers. Pure or relatively concentrated trichloroethylene (and tetrachloroethylene) has been shown to leach or travel through very impermeable clay soils due to dehydration or chemical dessication of the clay lattices.

TABLE 4-10. BURIED PITS BENEATH BUILDING 3001, TINKER AFB

Pit	Location[1]	Purpose	Visible Evidence	Reference Drawings
1	81-91, P-W	Old plating shop below ground pit	None	DWG-3001-F-125, 124
2	106,K	Vapor degreaser	Concrete cap	DWG-3001-G-58, 59
3	107-103,G	Chemical cleaning pit, jet engine overhaul	Possible cement cover	Proj. No. OC-148-59 As-Built DWG, DTD 2/10/54
4	109-104, F-H	Vapor degreasing pit	Possible concrete cover, metal latch	DWG-3001-G-48
5	99,K	Pit with trenches	Trenches visible with poured-in concrete	--
6	91,L	Pit "B"	Pit cap visible	OCBA-F-63114-2
7	87,I	Pit "A"	Possible 2 pit caps	OCBA-F-63114-2
8	99,A	Pit "C"	Possible 2 pit caps	OCBA-F-63114-2
9	88-89, E-F	Pit "D"	8'x16' caps grouted with rubber trenches covered with metal plates	OCBA-F-63114-2
10	87,A	Pit "E"	Currently a foundation for a large lathe	OCBA-F-63114-2
11	77-78, F-E	Buried tank pit	No visible indications, new floor has been poured	DWG 3108-F-16-71
12	36,N	2 degreaser pits	Concrete caps visible	DWG 3001-C-44
13	56,M	Pit	Concrete cover visible	DWG 3001-D-12
14	43-42, N-O	2 degreaser pits	Pit covers visible	DWG 3001-C-44
15	51,Q	Degreaser pit	Wooden cover visible	Ref. DWG BC-U-D-22-4 (Sheet No. G-302)
16	37, S-T	Degreaser pit	Metal lined cap	"
17	North wall, Col. J	Slaked lime pit	None	BC-U-D-22-4 (Sheet No. G-303)
18	10,G	Pit covered with concrete	NCR bldg. foundations	"
19	97, F&H	King lathe foundation pits	Concrete cap	OCBA-F-63114-2

[1]Keyed to Bldg. 3001 internal row and column coordinate system.

Table 4-11 provides the location of vapor degreasing machines currently in use in the Bldg. 3001 area. Spent solvents are currently drummed and sent to DPDO for disposal.

Buried Tanks

Table 4-12 is an inventory of abandoned or inactive buried or underground storage tanks in the Bldg. 3001 area. It includes the location, capacity, purpose, reference drawing number, and any visible observations. This inventory was developed in the process of correlating information from the records reviewed for this task. As a by-product of that review, Tables 4-13, 4-14, 4-15 were prepared which are inventories of currently active underground storage facilities in the Bldg. 3001 area according to three different Air Force records: Tinker AFB OPLAN 19-2, Civil Engineering Drawing OCBA-K-1017-A (Building and Street Layout), and the USAF Real Property Inventory Detail Report. The fact that there are inconsistencies among these records is not surprising since they were prepared at different times by different people and for different purposes, none of which was specifically to inventory underground tanks. In addition, the presence of these tanks was noted in the surface inspection tour. The physical evidence of inactive tanks or tanks not listed on these records was typically the presence of a vent pipe or line which emerged from the ground and was completed with a characteristic u-type fitting at the top. The location of these inactive tanks could then be compared to the appropriate drawings to see if there had ever been a tank at that location. If there had (and in almost all of the instances this was the case), then the real property records could be researched to see if and when the particular tank had been abandoned. Also, the real property records provided an indication of the purpose or use of the tank from which it was possible to deduce whether or not the tank may have been used to store trichloroethylene.

In no case was there a record or any evidence that an underground storage tank in the Bldg. 3001 area was designed or used for bulk storage of trichloroethylene or other halogenated solvent. There was evidence that

TABLE 4-11. CURRENT VAPOR DEGREASER LOCATIONS, BLDG. 3001, TINKER AFB

Building	Location[1]	Estimated Annual Quantity (gallons)	Solvent[2]
3001	K106	3960	P
	M82	3960	P
	M82	3960	P
	L95	1650	P
	Q61	11,880	P
	Q61	3575	P
	M63	1045	P
	X65	1045	P
	X65	1045	P
	A76	3960	P
	Ka51.1	660	P
	O59	1320	T
	N37	660	P
	U45	660	P
	X69	2860	P
	S54	225	P
3105		3960	P

[1]Keyed to Bldg. 3001 internal row and column coordinate system.
[2]T - Trichloroethane
P - Perchloroethylene

TABLE 4-12. ABANDONED OR UNUSED UNDERGROUND STORAGE TANKS IN THE BLDG. 3001 AREA

Tanks	Location	Capacity	Purpose	Former USAF Facility No. or DWG No.	Visible Inspection
1	NW Corner of Bldg. 3117	500 (est) waste oil tank	Tank was designed to store chemical spills inside Bldg. 3117. Chemicals are no longer stored in Bldg. 3117.	--	Free standing 4" PVC vent/fill pipe on west side of 3117.
2	SW Corner of Bldg. 3215	500 (est) gal. Reportedly now filled with water.	Tank was designed to store chemical spills inside the 3215. This building no longer used for chemical storage.	--	8" PVC vent pipe and access pit visible on south side of 3215.
3	SE Corner of Center Section of Bldg. 3108	500 gal. waste oil tank	Waste oil tank for the fuel testing system in the 3108 Hazardous Test Area.	USAF DWG No. 3108-F-16-53 Rev. 8 1/18/56	2" steel vent pipe visible extending to roof.
4	South 6' and 2' east of the SW corner of Bldg. 3108	1000 gal.	JP-1 supply tank for engine accessories overhaul.	3108-F-16-81 relocation of engine accessories overhaul & testing Bldg. 2108. (Possibly Facility No. 3151, 3152, 3153, 3154).	Outline of concrete pump pit & cover. Vertical lines visible on SW corner of 3108.
5		1000 gal.	JP-1 return tank for engine accessories overhaul.		
6		1000 gal.	Naphtha supply tank for engine accessories overhaul.		
7		1000 gal.	Naphtha return tank.		

(Continued)

TABLE 4-12. (Continued)

Tanks	Location	Capacity	Purpose	Former USAF Facility No. or DWG No.	Visible Inspection
8	8' N of the SE corner of the North Addition of Bldg. 3108	500 gal.	Waste fill tank for shop A/C engine depot addition (relocated).	USAF DWG NO. 3108-13-25-176 Rev. 27 Jan 72. (Shop A/C Engine Depot Addn./Alt., Mechanical, plan of piping outside Bldg. addn.	2" vent line visible.
9	90' N of the SE corner of the North Addition of Bldg. 3108	1000 gal.	Waste oil tank for shop A/C Engine Depot addition.		2" vent line visible.
10	50' W of 215' N of SW corner of Bldg. 3108	3000 gal.	Motor pump and subsurface fuel tank adjacent to railroad tracks west of Bldg. 3108.	USAF DWG.No.OCBA-F-6152-1 dated 24 Jan 1961.	Motor pump and piping visible at surface.
11-17	60' W and 80' to 160' S of SW corner of Bldg. 3108.	2-9000 gal. 5-20,000 gal.	Originally Air Corps gasoline storage tanks, listed on real estate records as solvent tanks in late 1960's.	Formerly 3140, 3141, 3142, 3144, tank 5, 3146*, 3147* Abandoned in place in 1972.	None.
18	6' W and 180' S of SW corner of Bldg. 3108.	20,000 gal.	Originally a lubricating oil storage tank which was listed on real property records as being converted to solvent storage in the late 1960's.	Austin Co. DWG No. G-341, G-342. A.C. gasoline & lubricating oil system, layout & retail (12/30/42). Formerly 3145*. Abandoned in place in 1972.	None.
19-20	15' E and 15' S of the NE corner of the Paint Bldg. (Bldg. 3105).	2-3800 gal.	1-Naphtha tank 1-Stoddard solvent tank Tank for Paint Bldg. (3105). Abandoned in place.	Formerly 3132, 3133. Austin Co. DWG. No. PB 302 Oct. 7, 1942.	Vent line visible.

* Shown on current USAF DWG OCBA-K-1017-A (Tinker AFB Building and Street Layout).

TABLE 4-13. LIST OF ACTIVE UNDERGROUND STORAGE TANKS CARRIED ON USAF REAL PROPERTY INVENTORY DETAIL REPORT IN BLDG. 3001 AREA

Facility	Capacity	Type	Location	OPLAN 19-2	Building & Street Lay-out DWG
3001	20,000 gal.	Fuel Oil	S of Boiler House	Yes	Yes
3002	1,000 gal.	Diesel	"	No	Yes
3003	1,000 gal.	Diesel	S of Bldg. 3406 (3001G)	No	Yes
3010	28,000 gal.	AVGAS	W of Bldg. 3001 (Col 101)	Yes	Yes
3011	28,000 gal.	AVGAS	"	Yes	Yes
3012	25,000 gal.	AVGAS	"	Yes	Yes
3100	15,000 gal.	Misc. Solvents	W of Bldg. 3108 (Bldg. 3001 Col. 56)	Yes	Yes
3104	15,000 gal.	"	"	Yes	Yes
3106	30,000 gal.	"	"	Yes	Yes
3130	12,000 gal.	Solvent	S of Bldg. 3108	Yes	Yes
3131	12,000 gal.	"	"	Yes	Yes
3401	20,000 gal.	Diesel	N of Bldg. 3001 (Row F)	Yes	Yes
3404	235,000 gal.	HTG Fuel Oil	"	Yes	Yes
3405	13,500	MOGAS	"	Yes	Yes

TABLE 4-14. LIST OF ACTIVE UNDERGROUND STORAGE TANKS IN THE BLDG. 3001 AREA CONTAINED IN ATTACHMENT 1 TO APPENDIX 1 TO ANNEX A (INSPECTION REPORT) OF TAFB OPLAN 19-2, "OIL, HAZARDOUS SUBSTANCE, AND HAZARDOUS WASTE SPILL PREVENTION, CONTROL AND COUNTER MEASURES"

Facility or Bldg. No.	Capacity	Type of Storage	Location	ORG Symbol	OPLAN 19-2 Reference Page No.	Bldg. Street DWG	Real Property
3001	20,000 gal.	#2 Diesel Fuel	Boiler Plant	DEMMH	A-1-67	No	Yes
3001	2,500 gal.	Solvent Waste Dump	West of Bldg. 3001, G-50	MA	A-1-69	No	No
3001G	20,000 gal.	#2 Diesel Fuel	3001 G ASC Power Plant	1985 CS	A-1-71	No	No
3010	15,000 gal.	Jet Fuel	SW of NW Corner of Bldg. 3001	DSDP	A-1-72	Yes	Yes
3011	15,000 gal.	Jet Fuel	SW of NW Corner of Bldg. 3001	DSOP	A-1-72	Yes	Yes
3012	30,000 gal.	Jet Fuel	SW of NW Corner of Bldg. 3001	DSOP	A-1-72	Yes	Yes
3100	15,000 gal.	Type 2 Calibrating Fluid	W of Bldg. 3108	MA	A-1-73	Yes	Yes
3104	15,000 gal.	"	"	MA	A-1-74	Yes	Yes
3106	30,000 gal.	"	"	MA	A-1-75	Yes	Yes
3108	500 gal.	"	E of Bldg. 3108 (center)	MA	A-1-76	No	No
3108	1000 gal.	"	E of Bldg. 3108 (north)	MA	A-1-77	No	No
3130	12,000 gal.	PD680 Solvent	S of Bldg. 3108	DSDP	A-1-80	Yes	Yes
3131	12,000 gal.	"	"	DSDP	A-1-81	Yes	Yes
3401	20,000 gal.	Diesel Fuel	N of Bldg. 3001	DEMME	A-1-85	Yes	Yes
3404	235,000 gal.	#2 Fuel Oil	N of Bldg. 3001	DEMMH	A-1-86	Yes	Yes
3405	13,500 gal.	87 Octane Automobile Gasoline	N of Bldg. 3001	DSDP	A-1-88	Yes	Yes

TABLE 4-15. LIST OF ACTIVE UNDERGROUND STORAGE TANKS IN THE BLDG. 3001 AREA SHOWN ON THE TINKER AIR FORCE BASE BUILDING AND STREET LAYOUT (DRAWING NUMBER OCBA-K-1017-A, GENERAL UPDATE 30 SEP 81)

Facility Number	Real Property	OPLAN 19-2
3003	Yes	No
3010	Yes	Yes
3011	Yes	Yes
3012	Yes	Yes
3017	Yes	No
3100	Yes	Yes
3104	Yes	Yes
3106	Yes	Yes
3130	Yes	Yes
3131	Yes	Yes
3145	Yes[1]	No
3146	Yes[1]	No
3147	Yes[1]	No
3401	Yes	Yes
3404	Yes	Yes
3405	Yes	Yes

[1]Real property records indicate that these tanks were abandoned in place.

storage tanks were found to be leaking and that this was the primary reason that old storage tanks were abandoned. The tanks listed in Tables 4-13, 4-14, and 4-15 are known (by current Tinker AFB personnel) to contain and have contained materials other than the solvents of interest. The abandoned tanks listed in Table 4-12 are unlikely but possible candidates for unauthorized storage or disposal of spent solvents or sludges.

Significance of Findings

Figure 4-12 summarizes the locations of the buried pits and tanks relative to the location of wells 18 and 19 beneath the floor of Bldg 3001. Although each of the pits and tanks would be considered candidates for possible sources of contamination, the survey results suggest that the trichloroethylene contamination is most likely the result of past industrial operations which occurred in degreasing pits throughout Bldg 3001 and over a period of up to 30 years.

4.2.4 Sediment Sampling

Sediment samples collected at Tinker AFB (Figure 4-13) were submitted for the analyses shown on Table 1-2. Results of analyses are shown on Table 4-16. The analytical data were evaluated for internal consistency and the existence of trends (systematic downstream changes in composition), rather than comparison to an outside set of standards or criteria. Where the concentration of a given species is noted to be higher or to "stand out" in the analytical results, it is discussed below. Results of sampling along each Base stream are presented below.

Crutcho Creek

Crutcho Creek drains the western portion of Tinker AFB and also receives some discharge from areas south of the installation. The creek drains a relatively large portion of the Base which includes several landfills and fire training areas. The Base housing area and golf course are also drained by this creek.

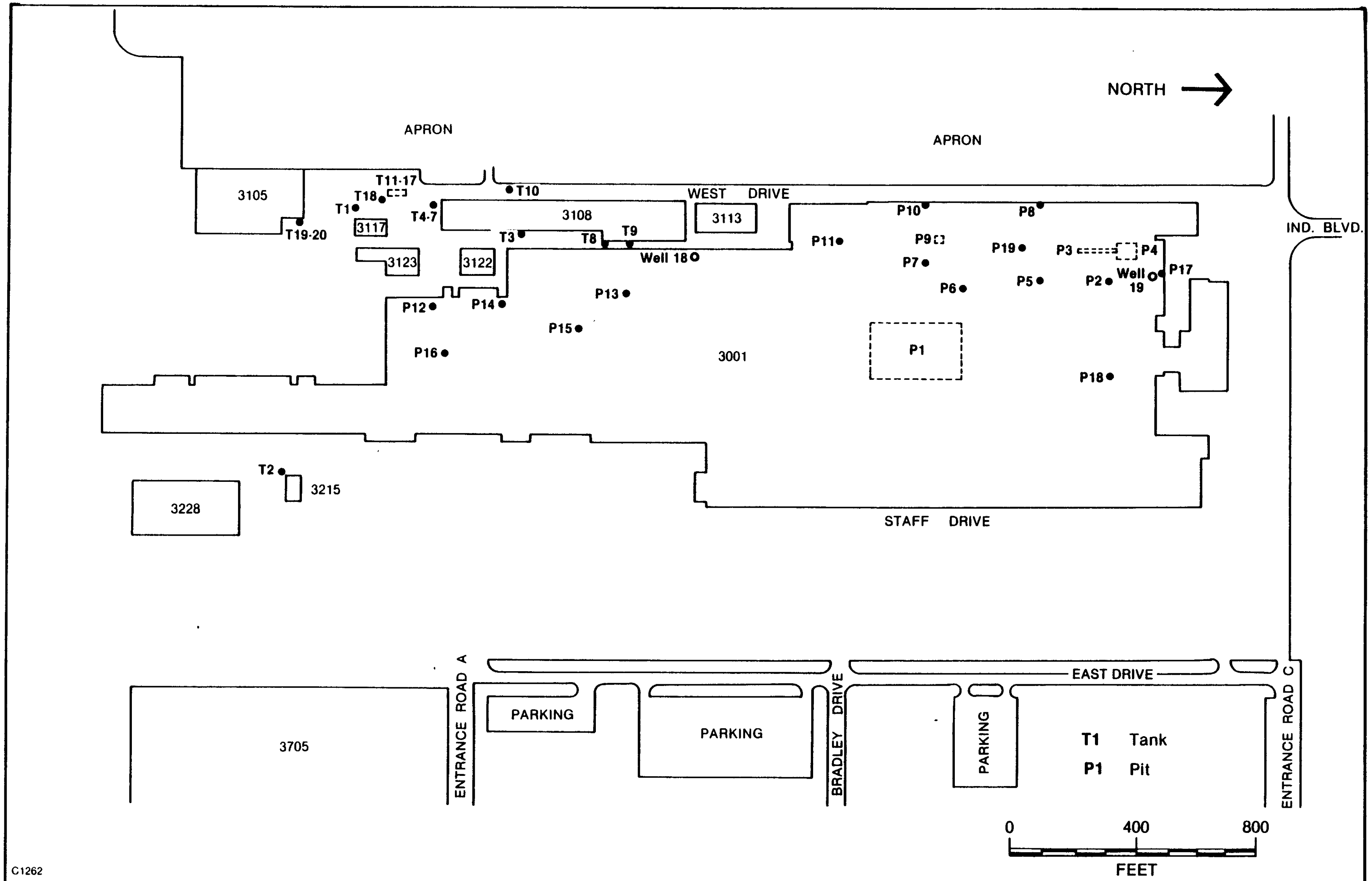

Figure 4-12. Locations of Buried Pits and Tanks Relative to Wells 18 and 19 in the Building 3001 Area.

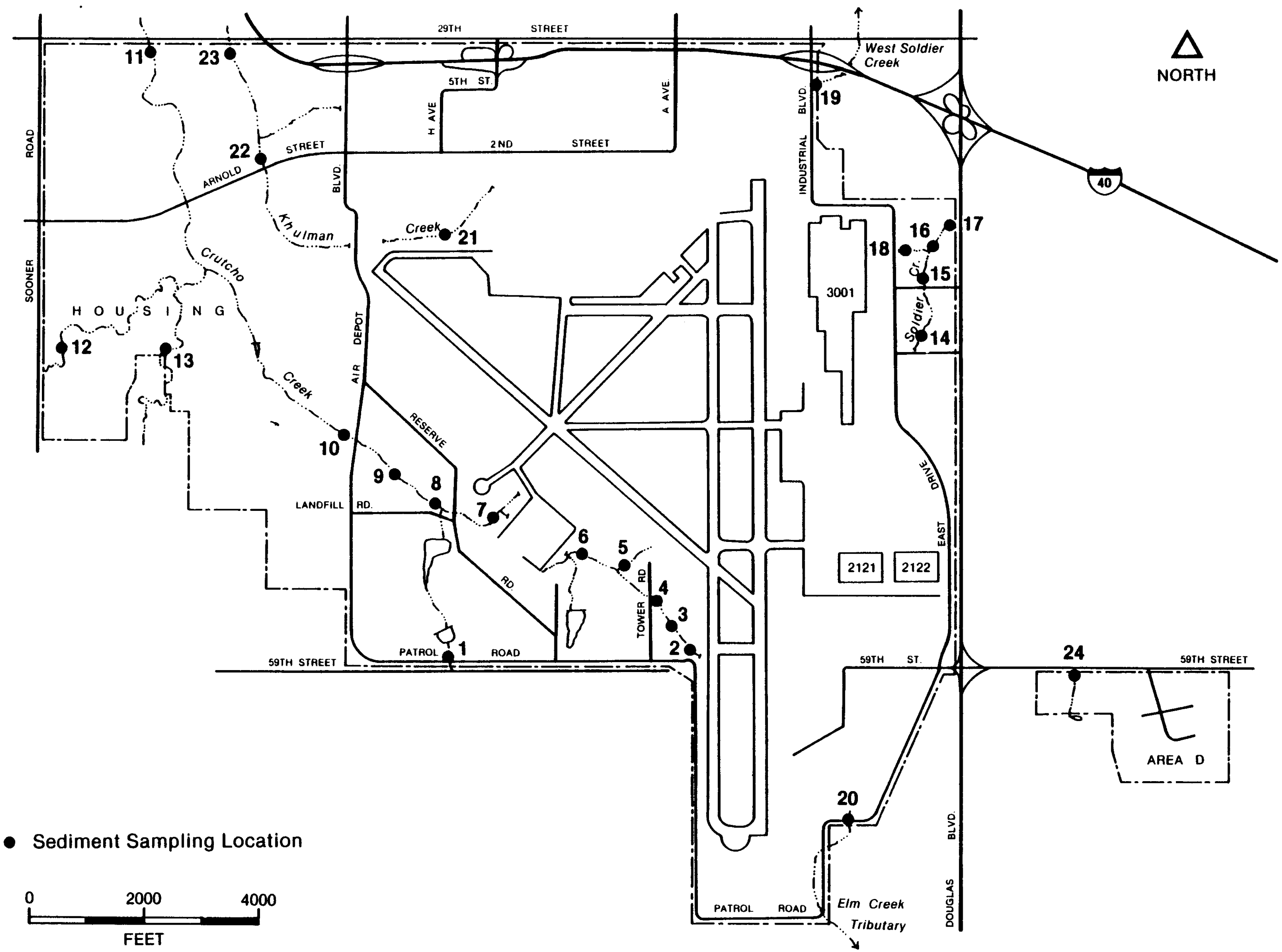

Figure 4-13. Locations of Stream Sediment Sampling Stations, Tinker AFB IRP Phase II Stage 2.

RADIAN CORPORATION

TABLE 4-16. RESULTS OF STREAM SEDIMENT ANALYSIS, TINKER AFB IRP PHASE II STAGE 2

Sampling Station (see Figure 4-13)	1	2	3	4	4	5	6	7	8	9	9
Sample Number	T-SED-01	T-SED-02	T-SED-03	T-SED-04	T-SED-05 (duplicate)	T-SED-25	T-SED-24	T-SED-23 (follow-up sample)	T-SED-20 (follow-up sample)	T-SED-21	T-SED-22
Laboratory Batch Number	84-06-166	84-06-166	84-06-166	84-06-166	84-06-166	84-06-206	84-06-206	84-06-113	84-06-113	84-06-206	84-06-206
Date of Sample	6/19/84	6/19/84	6/19/84	6/19/84	6/19/84	6/21/84	6/21/84	7/19/84	7/19/84	6/21/84	6/21/84
Parameter[1,2]											
Silver	<1.8	<1.7	<2	<2	<2	<2	<2	<1	<1	<2	<2
Arsenic	0.35	0.41	0.31	0.36	0.52	0.64	2.3	<0.1	<0.1	1.5	2.7
Barium	480	.240	290	410	450	310	480	610	230	390	370
Cadmium	<.050	<.41	4.7	2.2	<.063	2.4	2.7	0.97	2.4	3.0	1.5
Total Cyanide	<.01	<.01	<.01	<.01	<.01	<.02	<.02	<.01	<.01	<.02	<.02
Chromium	11	55	320	43	48	51	150	30	38	80	71
Copper	2.8	5.7	24	3.6	5.9	8.3	13	8.2	15	12	11
Fluoride	0.5	0.33	0.33	0.23	0.30	0.54	0.38	33	8	0.23	0.31
Mercury	0.049	0.061	0.051	0.060	0.038	0.094	0.090	0.23	0.37	0.06	0.12
Manganese	900	920	270	410	630	310	720	520	470	790	1000
Nickel	9.7	7.8	9.5	15	13	12	14	8.5	7.0	10	8.3
Nitrate	1.4	<.6	<.6	<.6	<.6	1.4	<.1	3.2	1.9	<.1	0.46
Lead	10	0.36	23	14	21	11	45	8.7	55.8	49	23
PCBs[3]	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.025	0.036	<0.5	<0.5
Phenolics	<.01	0.18	0.11	0.05	0.02	<.01	<0.01	<0.01	<0.01	<0.01	<0.01
pH	7.10	6.90	7.10	6.75	6.71	6.39	7.34	7.30	7.30	7.26	6.34
Selenium	0.55	0.61	0.39	0.48	0.53	0.71	0.63	<.002	<.002	0.65	0.48
Total Organic Carbon	0.52	0.38	0.63	1.03	0.42	1.32	0.44	0.30	1.30	1.48	1.01
Zinc	18	24	54	24	24	22	42	20	53	33	31

(Continued)

TABLE 4-16. (Continued)

Sampling Station (see Figure 4-13)	10	11	12	13	14	15	15	16	17	18	19
Sample Number	T-SED-19	T-SED-26	T-SED-07	T-SED-08	T-SED-15	T-SED-13	T-SED-18 (duplicate)	T-SED-14	T-SED-11	T-SED-12	T-SED-16
Laboratory Batch Number	84-06-206	84-06-206	84-06-190	84-06-190	84-06-190	84-06-190	84-06-190	84-06-190	84-06-190	84-06-190	84-06-190
Date of Sample	6/21/84	6/21/84	6/20/84	6/20/84	6/20/84	6/20/84	6/20/84	6/20/84	6/20/84	6/20/84	6/20/84
Parameter[1,2]											
Silver	<2	<2	<2	<2	<2.8	<2	<2	<2	<2	<2	<2
Arsenic	0.81	1.6	1.9	2.1	0.28	1.6	0.51	0.54	0.66	0.31	0.62
Barium	330	320	430	480	330	220	200	320	170	410	220
Cadmium	3.9	1.8	1.1	0.36	30	1.3	4.9	0.70	50	12	11
Total Cyanide	<.02	<.02	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Chromium	68	13	37	12	140	190	120	27	1300	130	300
Copper	12	4.3	5.1	4.4	52	230	54	3.8	45	160	69
Fluoride	0.2	<.1	0.22	0.20	0.16	0.20	0.31	0.37	0.31	0.23	0.33
Mercury	0.45	0.036	0.038	0.048	1.6	1.0	0.33	0.034	0.35	0.10	0.14
Manganese	250	500	1000	940	140	250	250	530	790	330	170
Nickel	7.4	3.7	9.5	9.4	19	43	12	6.4	230	83	170
Nitrate	2.8	<.1	<.6	<.6	<.6	<.6	<.6	<.6	<.6	<.6	<.6
Lead	40	17	27	15	530	140	97	7.1	46	700	52
PCBs[3]	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2.20
Phenolics	<.01	<.01	0.13	0.10	0.06	0.10	0.10	0.11	0.04	0.09	0.14
pH	7.62	7.68	7.19	7.32	7.01	7.19	7.15	7.25	7.73	7.54	7.16
Selenium	0.67	0.63	0.93	1.0	0.21	0.93	0.31	0.21	0.28	0.12	0.32
Total Organic Carbon	0.81	0.25	0.41	0.59	3.80	1.32	0.65	0.25	0.87	0.43	1.68
Zinc	43	11	32	17	160	210	77	16	83	88	60

(Continued)

TABLE 4-16. (Continued)

Sampling Station (see Figure 4-13)	20	21	22	23	24
Sample Number	T-SED-06	T-SED-10	T-SED-09	T-SED-27	T-SED-28 (follow-up sample)
Laboratory Batch Number	84-06-166	84-06-190	84-06-190	84-06-206	84-06-113
Date of Sample	6/19/84	6/20/84	6/20/84	6/21/84	7/19/84
Parameter[1,2]					
Silver	<2	<2	<2	<2	<1
Arsenic	0.49	0.91	3.5	1.0	<.1
Barium	520	230	380	240	110
Cadmium	2.4	0.54	1.6	2.1	0.83
Total Cyanide	<.01	<.01	<.01	<.02	<.01
Chromium	5100	80	33	35	12
Copper	23	25	10	0.12	5.0
Fluoride	0.62	0.31	0.51	<0.01	2.5
Mercury	0.049	0.33	0.19	0.30	0.25
Manganese	710	180	4700	290	250
Nickel	47	12	11	5.9	5.9
Nitrate	2.14	<.6	<.6	1.9	3.2
Lead	100	39	44	64	8.1
PCBs[3]	<0.5	<0.5	<0.5	<0.5	<0.025
Phenolics	0.09	0.11	0.08	<.01	<.01
pH	8.53	7.03	7.24	7.16	6.37
Selenium	0.61	0.32	1.8	0.43	<.002
Total Organic Carbon	2.28	0.41	0.54	0.85	0.85
Zinc	68	66	35	49	8.3

(Continued)

[1] In addition to these parameters, analyses for RCRA pesticides and herbicides were performed. Results were everywhere less than detection limits noted.

RCRA Herbicides
- 2,4-D (<0.2 μg/g)
- 2,4,5-TP (Silvex) (<0.2 μg/g)

RCRA Pesticides
- Lindane (<0.002 μg/g)
- Endrin (<0.002 μg/g)
- Methoxychlor (<0.002 μg/g)
- Toxaphene (<0.02 μg/g)

[2] Expressed in μg/g unless specified otherwise.

[3] In contrast to the information supplied in Appendix H, the actual detection limit for PCBs is 0.5 μg/g (0.025 μg/g for Batch 84-07-113).

Samples were collected from 13 stations along Crutcho Creek and its tributaries. In a downstream direction, the sampling stations along Crutcho Creek and its tributaries are Stations 2, 3, 4, 5, 6, 7, 1, 8, 9, 10, 13, 12 and 11, as shown in Figure 4-13.

Station 2 lies just upstream of landfill No. 5 along Crutcho Creek. This station receives runoff from the southern part of the North-South runway. Chemical parameters for this sampling station appear to be indicative of natural conditions although phenolics were detected at a concentration of 0.18 ug/g. It should be noted that low concentrations of phenolics were detected in 16 of the 27 samples collected during this study.

Sediment sampling stations 3 and 4 are downstream of Station 2, adjacent to Landfill No. 5. No elevated concentrations of industrial contaminants were found at this station. A duplicate sediment sample was collected for Station 4 as a field quality control sample. The analysis for the Station 4 field duplicate is comparable to that of the station sample.

Downstream, to the west of Tower Road and downstream of Landfill No. 5, are Stations 5, 6, and 7. During sampling operations, a phenolic odor was noted at Station 7, but analysis for phenolics at Station 7 show them to be below detection limits.

Station 8 lies downstream of Station 7, below the confluence of Crutcho Creek and a tributary. Station 1 lies on the tributary as it enters the installation from the area south of the Base. Of the two stations, only Station 8 showed an elevated concentration of a potential industral contaminant, Fluoride, which was detectd at 8 ug/g.

Station 9 lies downstream of Station 8 and Landfills 2, 3, and 4. Station 10 is located just downstream of Patrol Road, Station 9 and Landfills 1 through 4. Both stations showed no elevated concentrations of industrial contaminants. A duplicate sample was collected at Station 9 as a field quality control sample. Results for the quality control sample collected at Station 9 are consistent with the station sample.

Stations 12 and 13 lie near the southwestern corner of the installation along two tributaries to Crutcho Creek. These stations are located close to the installation boundary within the Base housing area. Analysis for samples collected from these stations do not indicate the presence of contamination.

Station 11 is located near the northern installation boundary where the creek leaves the Base. There is no direct indication of industrial contamination from the analysis of sediments at this station.

Khulman Creek

Khulman Creek drains the north-central portion of the Base. The creek receives runoff from the area north of the airfield which is predominantly office and warehouse buildings.

Samples were collected from three stations along Khulman Creek. In a downstream direction, these stations are Station 21, 22, and 23 as shown in Figure 4-13. Analysis for Station 22 show manganese at a concentration of 4700 ug/g. No evidence of industrial contamination was found at Stations 21 and 23.

West Soldier Creek

West Soldier Creek is located near the northeastern corner of the installation and drains an open area north of Building 3001, adjacent to the main runway. One station, Station 19, was sampled at this creek, just before it passes off-Base to the northwest. Cadmium and nickel were found at concentrations of 11 and 170 ug/g at this station. Total PCB's were detected at a concentration of 2.20 ug/g here.

Soldier Creek

Soldier Creek is located in the eastern portion of the Base between Building 3001 and the installation boundary. The creek drains an area where industrial operations are conducted. In a downstream direction the stations sampled on Soldier Creek are Stations 14, 15, 18, 16 and 17.

At Station 14, cadmium, lead and zinc were detected at concentrations of 30, 530, and 160 ug/g, respectively. Downstream at Station 15, copper, lead and zinc were found at concentrations of 230, 140 and 210 ug/g. A field quality control duplicate was collected at Station 15. Analytical results for the field duplicate are consistent with that of the station sample. At Station 18, located on a small tributary to Soldier Creek, near Building 3001, cadmium and lead were found at concentrations of 12 and 700 ug/g.

Station 16 is located below the confluence of Soldier Creek and the small tributary on which Station 18 is located. Station 16 is also located just upstream of the Base Industrial Wastewater Treatment Plant (IWTP) discharge point into Soldier Creek. No significant levels of industrial contaminants were found at this station.

Station 17 lies downstream of Station 16 and the IWTP discharge point, just before Soldier Creek leaves the installation to the east. Cadmium, chromium and nickel were found at this station at concentrations of 50, 1300 and 230 ug/l.

Area D

A small drainage channel exists at Area D. This channel receives runoff from the area of Landfill No. 6. Sediment sampling Station 24 is located at the northen boundary of Area D where the channel leaves the area to the north. The analysis of the sediment sample collected at this station does not indicate the presence of industrial contaminants.

Elm Creek Tributary

The Elm Creek tributary drains the southern area of the Base as shown in Figure 4-13. This drainage receives runoff from the open area and runway which constitutes the southern extension of the Base. Station 20 is located on Elm Creek Tributary where the channel leaves the installation to the south. Chromium was found at a concentration of 5100 ug/g at this station. Lead was also found at a concentration of 100 ug/g. There is no apparent current source for the elevated levels of chromium and lead found at this station. However, the observations may be related to the apparent overflow feature associated with Industrial Waste Pit No. 2. This feature was identified during the Phase I (Stage 1) investigation.

Significance of Findings

In general, analyses of sediment show no evidence of widespread or elevated levels of industrial contaminants. The observations at Station 17 (downstream of IWTP discharge) should be evaluated in light of the Base discharge permit limitations. No other follow-up action is deemed necessary.

4.2.5 Radiological Waste Disposal Sites

This section presents the results and significance of findings of the geophysical surveys performed at two suspected radiological waste disposal sites. The sites, RDWDS-1022E and RWDS-62598, are located near Crutcho Creek on the west side of Tinker AFB (Figure 4-14). The following paragraphs present the results for each site and the significance of those results.

RDWS-1022E

RWDS 1022E, is located adjacent to the northwest corner of Landfill 3 south of West Crutcho Creek. During the mid-1950's approximately 8 to 10 containers of radioactive material from Building 230 were disposed of at the site. It is reported that the material was placed in a hole approximately 30 feet deep; the area was marked with radiation warning signs but none are now present. A survey in November 1981 detected radiation levels slightly above background, too low to cause public health concerns (Engineering-Science, 1982).

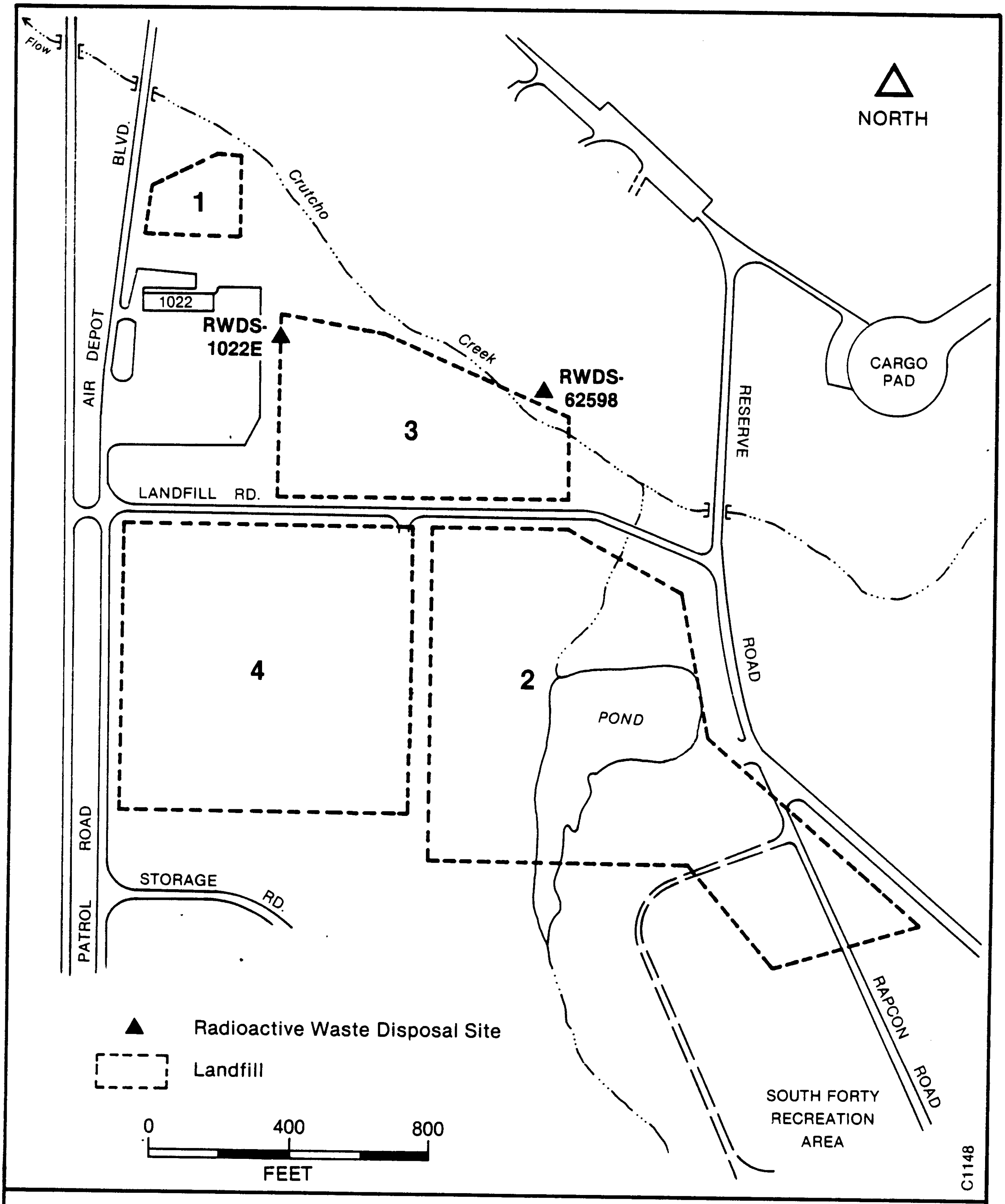

Figure 4-14. Location of Geophysical Surveys at Radiological Waste Disposal Sites.

The apparent conductivities measured with the EM 31 with vertical and horizontal dipoles are contoured in Figures 4-15 and 4-16, respectively. Both EM 31 dipole orientations show an anomolous area in the west central part of the grid. The EM 31 with a vertical magnetic dipole shows background values between 40 and 60 millimhos/m away from the anomaly and values as low as 0 millimhos/m over the anomaly (Figure 4-15). The EM 31 with a horizontal magnetic dipole shows background values from 30 to 50 millimhos/m away from the anomaly and values as high as 150 millimhos/m over the anomaly (Figure 4-16). Figure 4-17 displays the data in profile format, indicating the anomaly on one line for both EM data and magnetometer data.

The EM 34 (20 m) data show background values from 50 to 70 millimhos/m throughout the grid with the exception of a high area in the southeast which is not believed to be related to buried objects. These data are presented in Appendix L.

The response over the anomaly of the EM 31 contour maps with vertical and horizontal dipoles is typical of responses seen over buried metal objects. The magnetometer readings support the conductivity data showing a high at the same location. There is some evidence that the metal is buried in two adjacent rows (perhaps in the same trench). This evidence is found in two visible peaks in both magnetometer and conductivity data (see Figure 4-17).

The meter readings with the EM 31 and EM 34 over metal objects are not related to ground conductivity. Depending on dipole orientation and depth of burial a metal object can cause either increase or decrease from background conductivity. This is the reason for the anomaly lows on Figure 4-15 (vertical dipole) and anomaly highs on Figure 4-16 (horizontal dipoles). The depth of burial can be estimated from the fact that the anomaly is seen with the EM 31 with both vertical and horizontal dipoles. The horizontal dipole has an effective depth of exploration of about 5 feet. Depth of burial is expected to be less than 5 feet.

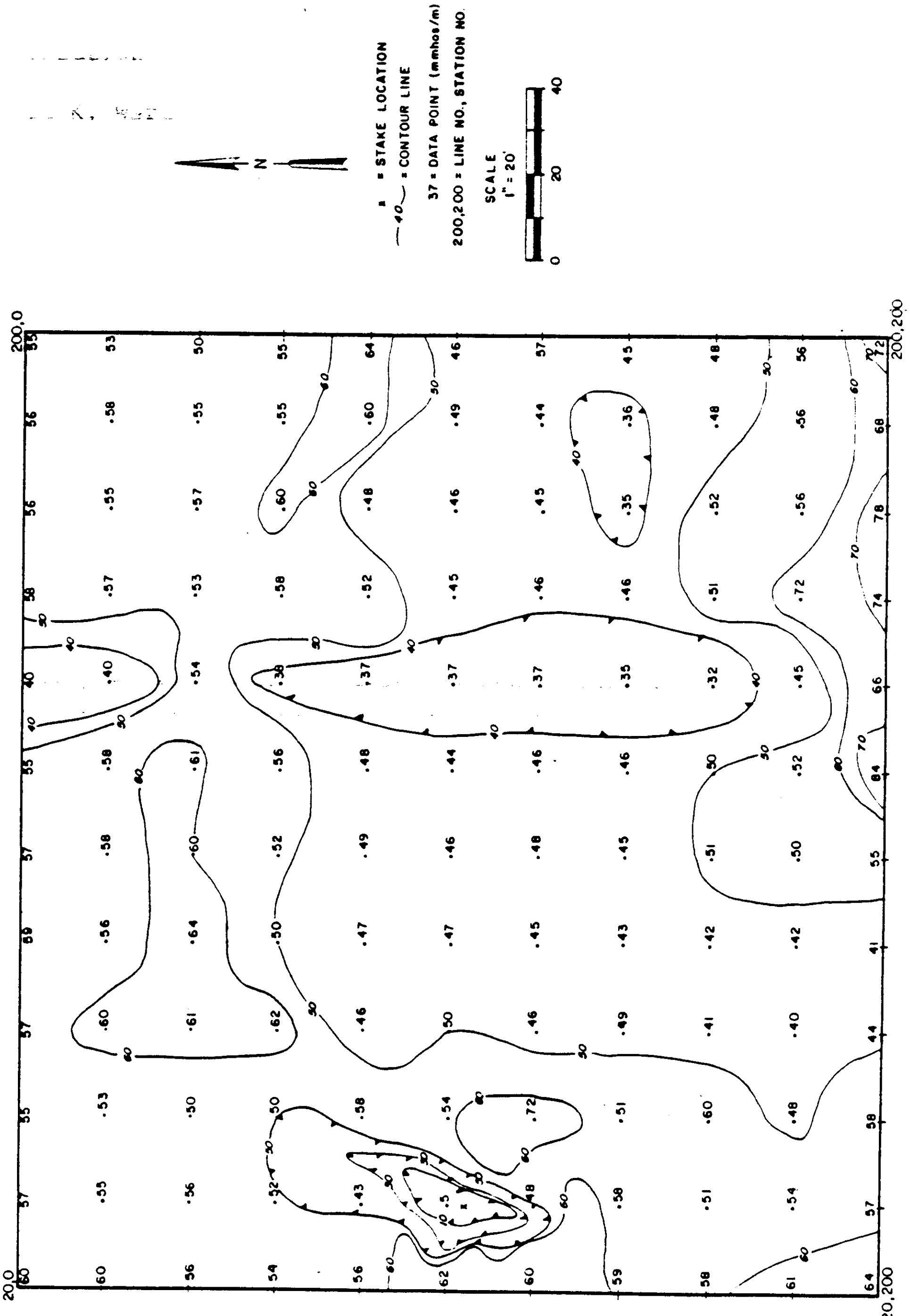

Figure 4-15. Geophysical Survey of RWDS-1022E EM-31 (Vertical Dipole).

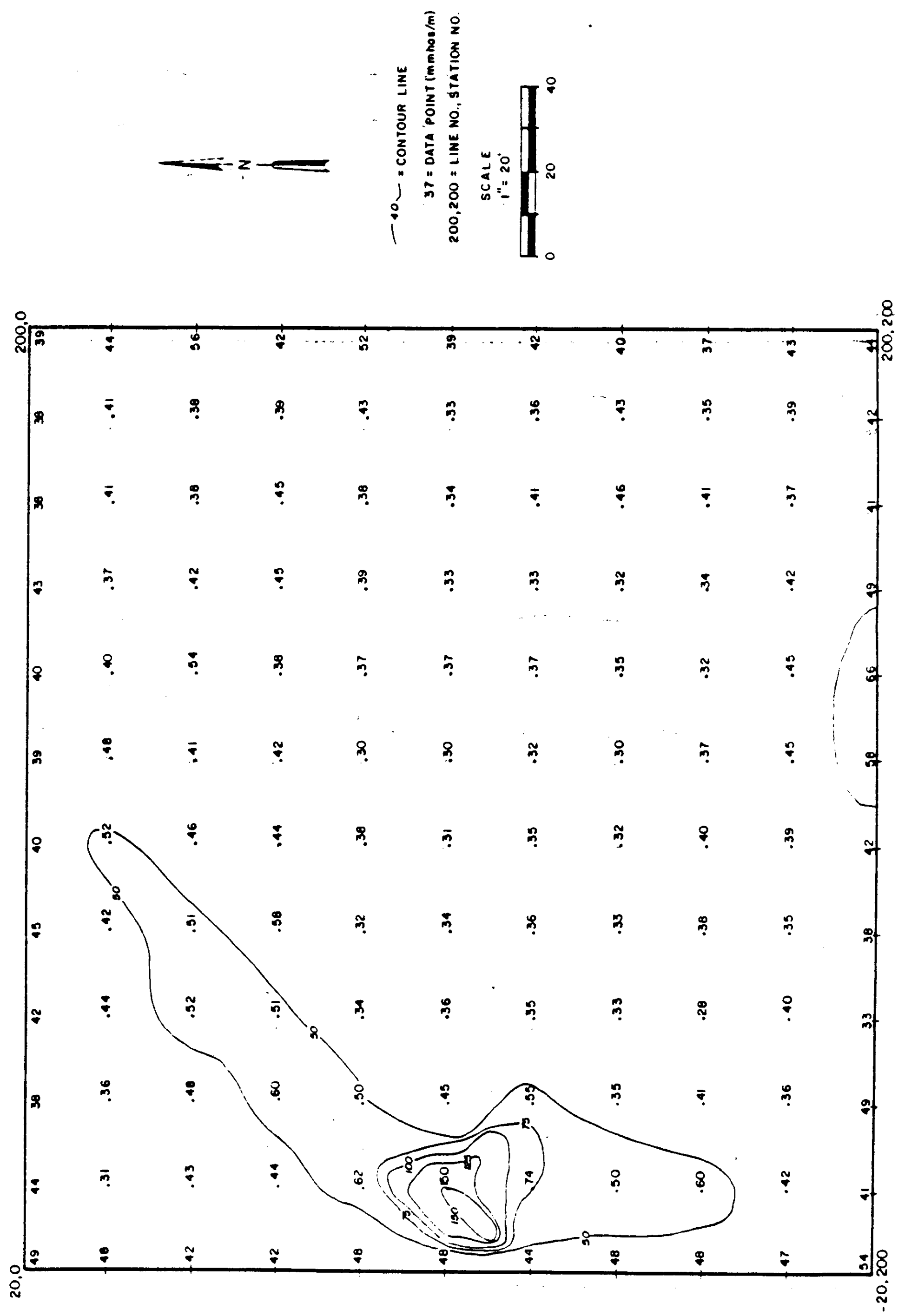

Figure 4-16. Geophysical Survey of RWDS 1022E EM-31 (Horizontal Dipole).

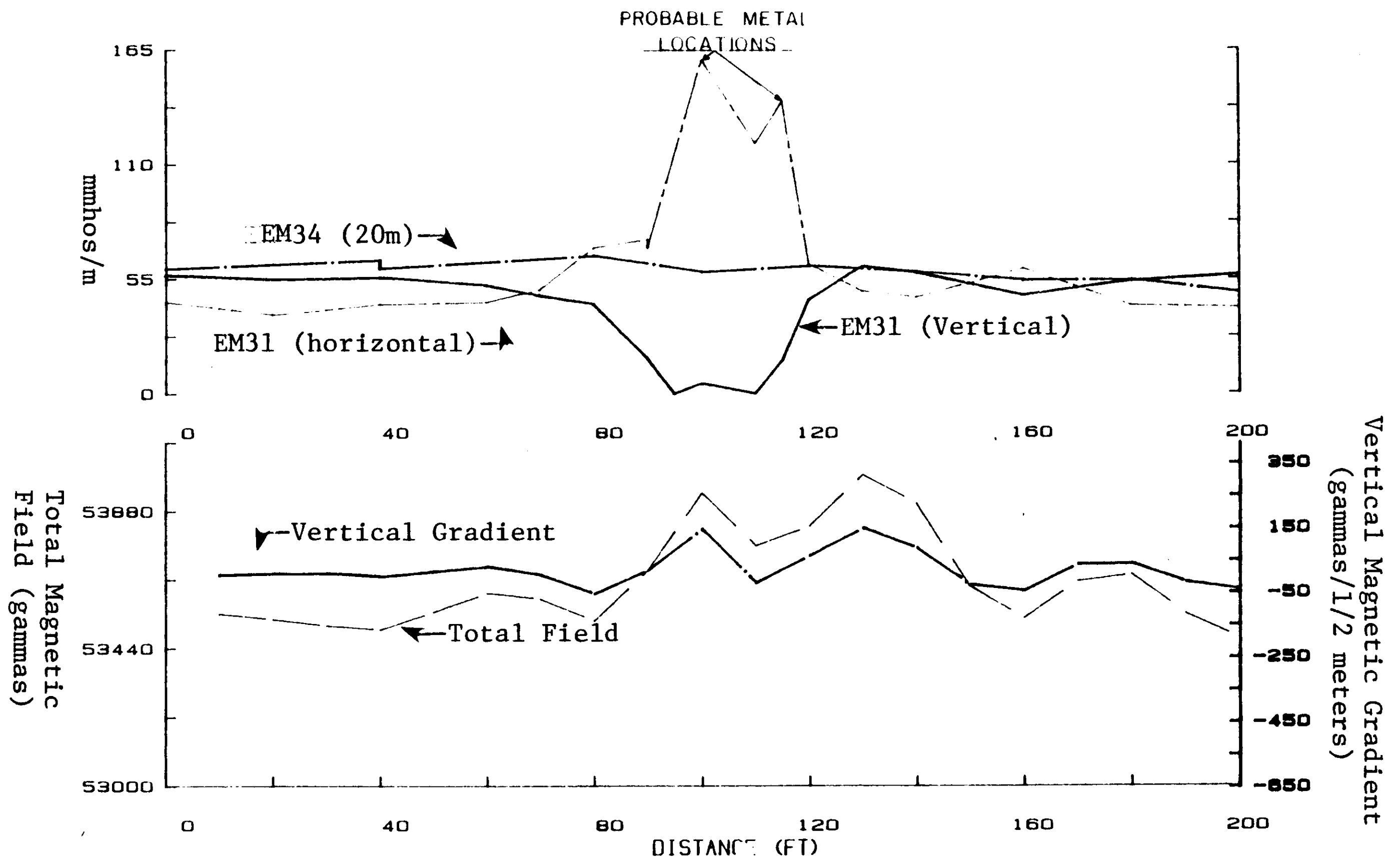

Figure 4-17. Geophysical Profiles over Buried Anomaly, RWDS-1022E.

RDWS-62598

RWDS 62598 is located south of Facility 1025 and north of Crutcho Creek. A concrete post with attached radiation warning sign marks the general disposal area. The site reportedly contains a "lead still" made of sheet lead used to evaporate methyl ethyl ketone (MEK) or acetone for reuse. In the early 1950's, the lead still, contaminated with a residue of radium paint solids, was reportedly buried in the general area marked by the concrete post. The depth of burial is not known. One Air Force document states the waste may later have been removed; however, no conclusive evidence exists for either the presence or absence of the waste. Recent radiological monitoring has identified no area of increased radioactivity near the site (Engineering-Science, 1982).

The apparent conductivities measured with the EM 31 with horizontal and vertical diples and with the EM 34 (20 m) are contoured in Figures 4-18, 4-19, and 4-20. Magnetometer data were collected and are presented in Appendix L. With the exception of a buried pipe seen in the northern part of the grid with the EM31 with a vertical dipole, the conductivity and magnetometer data display background values.

Significance of Findings

Results of the geophysical survey at RWDS-1022E were used to locate and identify the disposal site. The site was marked in the field with metal stakes. The survey at RWDS-62598 did not provide conclusive information regarding a buried lead still. It is likely that the site does not contain a buried object, as suggested in the IRP Phase I report (Engineering Science, 1982). No follow-on investigations are recommended.

4.2.6 Base Water Supply Wells

As described in Section 3, depths to water were measured in Base water supply wells during the period 1 October to 13 December 1984. During

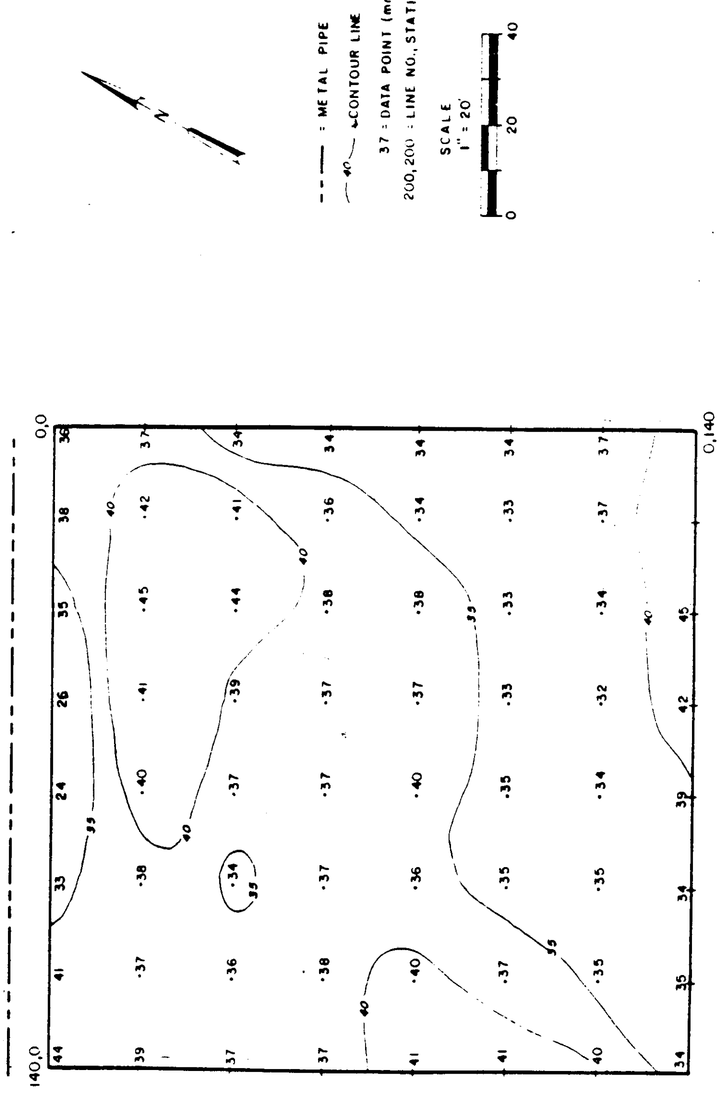

Figure 4-18. Geophysical Survey of RWDS 62598 EM31 (Horizontal Dipole).

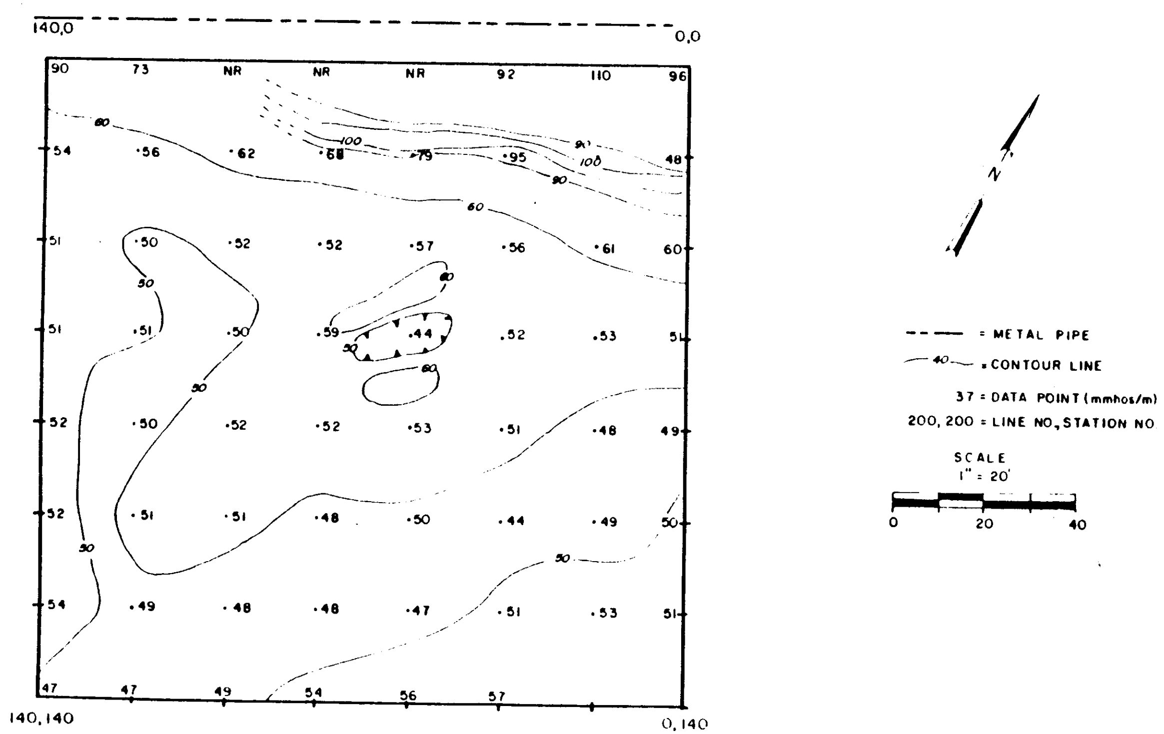

Figure 4-19. Geophysical Survey of RWDS 62598 EM31 (Vertical Dipole).

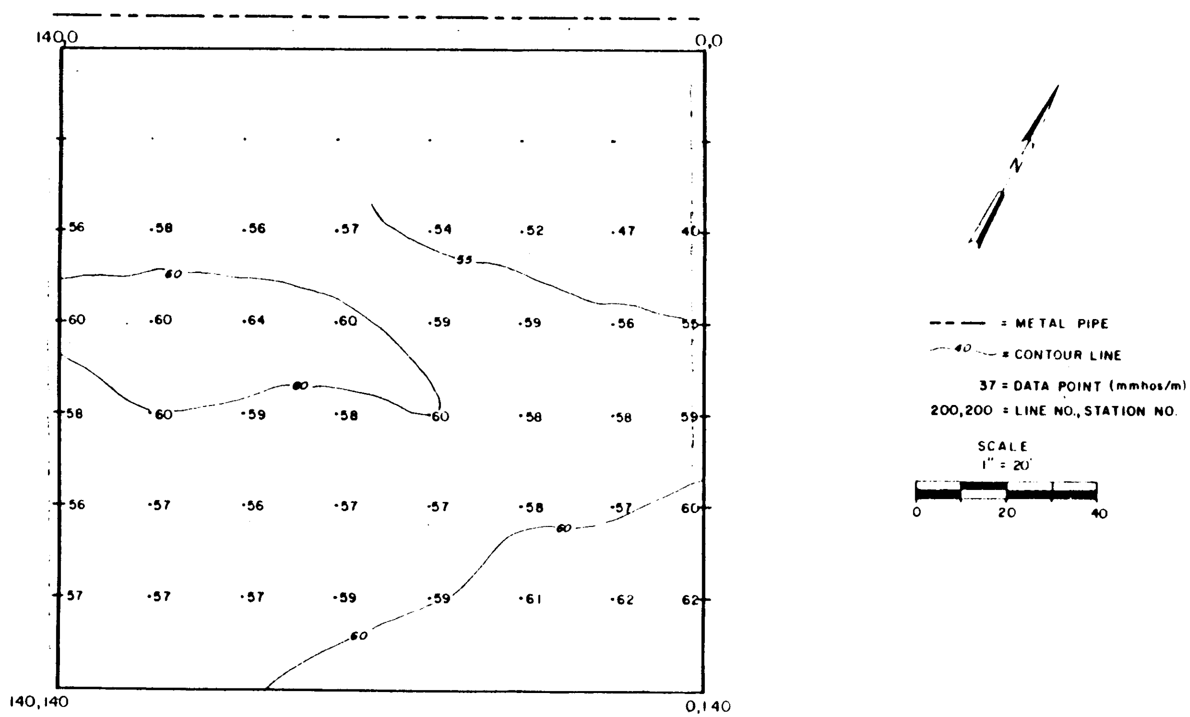

Figure 4-20. Geophysical Survey of RWDS 62598 EM34 (20 Meter Spacing).

this same time, data on private wells in the area east of the Base were obtained from the Oklahoma Department of Health. Within the area directly east of Building 3001, north of S.E. 44th Street, no private wells are known to exist. This area has been supplied with city water from the inception of building, so it is likely that there are no wells. Between S.E. 44th and 59th Streets, large numbers of wells were found. Reported depths range from about 100 feet to about 200 feet. However, depths to water were not measured.

Wickersham (1979) reported the results of a survey of water levels in the Garber-Wellington aquifer, which includes the Tinker supply wells. The geologic complexity of the Garber-Wellington, in which ground water occurs in isolated and hydraulically-distinct sand lenses, is believed to be the major factor in the observed variability of water levels. Wickersham further concluded that the thickness, porosity and productive ability of the individual sand bodies affects the hydraulic head observed in the Garber-Wellington aquifer.

The results of the on-Base measurements are shown on Table 4-17 and Figure 4-21. The data do not provide a clear and unambiguous pattern of occurrence. Values from adjacent wells vary by as much as 150 feet. The cause of this variability is not readily apparent. A portion of the variability may be ascribed to incomplete recovery from the effects of pumping in any particular well. Another portion may be ascribed to the effects of nearby wells which were in service at the time of measurement.

The variability in the observations preclude attempts to contour the data. However, there is some suggestion of a general decline in elevation from east to west. This indicates a regional ground-water flow component toward the west. It is probable that, in accordance with Wickersham's (1979) interpretation of the regional system, there is a southerly component, as well. However, there are insufficient data to resolve any such southerly component. In general, these water levels observed are about 100 feet lower than those shown on Figure 2-8, which are regionalized data from 1976.

TABLE 4-17. WATER LEVEL OBSERVATIONS IN BASE WATER SUPPLY WELLS

Well Number	Total Depth (ft)	Floor Elevation (ft msl)	Height of Measuring Point (ft)	Depth to Water (ft)	Date of Measurement	Elevation of Water (ft msl)	Comments
1	750	1223.86	-	no access	-	-	
2	741	1214.46	0	263.67	11/5/84	950.79	
3	939	1227.0	0	93.17	12/13/84	1133.83	
4	932	1217.0	0	no access	-	-	
5	920	1219.0	-	water interferes	-	-	
6	755	1227.0	0	72.25	12/13/84	1154.75	
7	792	1225.5	0	218.67	12/13/84	1006.83	
8	800	1259.8	-	off-base			
9	800	1238.2	-	off-base			
10	plugged and abandoned						
11	1070	1296.84	0.83	259.6	10/8/84	1038.1	
12	1060	1271.90	-	no access	-	-	
13	659	1258.21	-	no access	-	-	
14	935	1263.92	-	no access	-	-	
15	750	1253.35	1.71	220	10/1/84	1035.1	Cascading water interferes
16	1053	1269.07	1.29	235	10/1/84	1035.4	Cascading water interferes
17	1102	1275.50	0.17	202.8	10/8/84	1072.9	
18	1070	1275.50	0.33	100.34	10/1/84	1175.5	
19	1101	1275.50	0.33	239.33	10/1/84	1036.5	
20	850	1293.80	0.58	308.4	10/8/84	986.0	
21	800	1297.20	0.67	229.3	10/8/84	1068.6	
22	800	1283.10	-	no access	-		
23	790	1297.54	0.58	228.1	10/15/84	1070.0	Cascading water
24	796	1279.57	-	no access	-		
25	764	1257.04	-	no access	-		
26	760	1243.57	-	no access	-		
27	-	1320[1]	-	-	-		
28	-	1260[1]	0	278.83	12/3/84	981	

[1] Estimated from USGS topographic map.

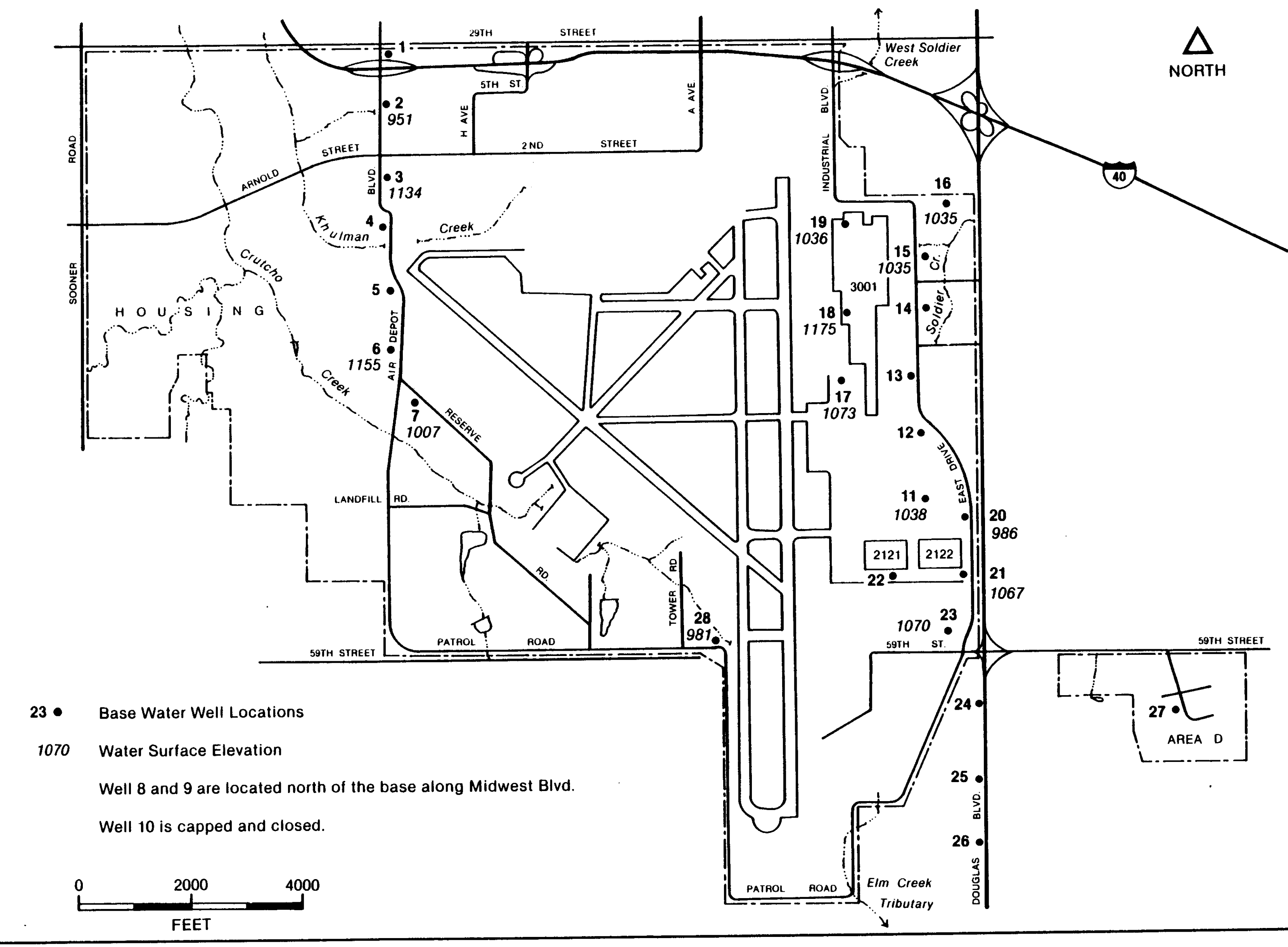

Figure 4-21. Elevation of Water Surface Base Water Supply Wells.

Within the vicinity of Building 3001, water levels are generally 160-190 feet below the water levels in the shallow monitor wells (6A through 6G). The significance of this observation was discussed in Section 4.2.1. Similar comments can be made concerning the wells along the west side of the Base. Levels of water in monitor wells 1A through 1C were at about elevation 1200 feet (Radian, 1984) during Stage 1 activities. Production well levels range from elevation 950 to 1150, suggesting that strong vertical gradients exist in this portion of the Base as well.

In summary, observations in the Base water supply wells suggest flow from east to west in the regional system. They also document strong downward gradients within the ground-water system. The overall findings of the Base water supply well measurements are also consistent with the conclusions of Wickersham (1979) regarding the variability of water levels in the Garber-Wellington aquifer.

5.0 ALTERNATIVE MEASURES

This section discusses the alternative measures available for actions at each of the areas investigated. Measures are discussed in the context of threats to the primary candidate receptor, the regional Garber-Wellington aquifer.

5.1 Building 3001 Area

Conditions in the vicinity of building 3001 consist of a loosely defined area of contamination by synthetic organic chemicals confined to relatively shallow depths in the aquifer. These synthetic organic chemicals pose two threats to human health and the environment. The first is that, due to the existing vertical head gradient and the influence of Base production wells, these contaminants can move downward and enter the strata from which these wells produce water. This constitutes a future threat to the Base water supply. The second is that the contaminants can move laterally to the southwest, in the direction of both the local and regional gradients. As these contaminants move, they will become more widely dispersed in the aquifer. The nearest potential receptors are the Base wells along the western boundary of the base.

The alternative measures to be considered are:

- o Long-term monitoring of the current monitor and production well system;
- o Installation and sampling of additional monitor wells; and
- o Initiation of remedial actions.

A discussion of alternative measures relating to the pit and tank survey in the Building 3001 area is presented in section 5.3, below. In addition, Radian continues to recommend rehabilitation of Well 18, as discussed in the Stage 1 report.

Continued sampling and analysis of the current system will provide a more reliable estimate of the degree of contamination within the current study area. Additionally, periodic monitoring of the Base production wells will provide for the health protection of those utilizing the water if appropriate response is taken if contamination reaches levels of concern. However, these measures alone will not provide early warning of the migration of contaminants.

If additional wells were to be installed, the most useful locations would be west and southwest of Building 3001, in the direction of the local and regional gradient. These wells could document the extent of downgradient occurrrence of contaminants. However, the main, active runway at Tinker AFB borders the building immediately to the west. Monitor well installation activities within this area would seriously impact air operations, although for a limited period of time.

While the complete area of occurrence of contamination is not known, Radian considers that the current system is sufficiently well defined to allow activities to proceed to remediation. The most obvious method of remedial action is a pump-out-and-treat system of relatively shallow (approximately 200 foot depth) production wells, followed by appropriate treatment or consumptive use in industrial processes. Gaps in the data concerning the occurence of contaminants may be filled in during drilling for remediation. Well drilling should be initiated adjacent to the building (east and west sides), substantially along its full north-south length. Pumping for remediation can begin, with continued testing for the occurrence of halogenated organics as the program progresses. If a complete system of wells on the west side of Build. 3001 shows extensive contamination, consideration will have to be given to well installation within the airfields, active runways, and taxiways, with the installation activities carefully coordinated with the ongoing needs of base operations. Since the current purpose is not to define or design the most appropriate remedial action, this discussion should not be taken as such.

5.2 Landfill 6

The available hydrogeologic and chemical data suggest that Landfill 6 is releasing some synthetic organic chemicals to the environment, with observations of chemical concentrations in monitor well 7F defining an upper bound to the concentrations being released. These released chemicals are following a circuitous path downward to the regional ground-water body. As the contaminants move through the perched ground-water bodies, they are becoming more dilute. Since the data suggest a southward flow in the regional system and there are no wells to the south there are no data on the occurrence of contaminants downgradient in the regional body. Landfill 6 is the current subject of an IRP Phase III/IV remedial action under control of the Base Civil Engineers. Alternatives for dealing with the discovered contamination are:

- Long-term monitoring of the current monitor well system;
- Installation and sampling of additional monitor wells; and
- No further action.

Sampling and analysis of the present system (pre-existing monitor wells 9 and 10 and the Ainsworth well, as well as the Stage 1 and Stage 2 wells) will adequately document the impacts of the landfill on the near-surface and perched ground-water systems. However, if the local and regional gradient is to the south, the present system provides no data on the occurrence or impacts of contaminants downgradient in the regional body.

Additional monitor wells should be located south and west of the landfill and be of sufficient depth to monitor the top of the regional system. Unlike the strategy of Stages 1 and 2, these wells should be drilled to a depth equivalent to approximate elevation 1200 feet, without regard for the occurrence of perched ground-water bodies. In order to avoid the effect of the contaminants moving laterally along shale zones above the water table, these wells should be located away from the landfill by 100-200 feet. Once the remedial action is complete, the wells can become part of an ongoing, post-closure monitoring system.

If no further actions are taken at Landfill 6, the effects of the contaminant release will not be documented. Radian considers that installation of additional monitoring wells is the most appropriate option.

5.3 Pit and Tank Survey

The available measures relating to the buried pits beneath Bldg. 3001 are:

- o Inspect, and obtain samples for analysis of any liquid or fill material contained within each of the identified pits;
- o Select one or two pits that can be easily entered for inspection/sampling; and
- o No further activities.

Access to these buried pits will require either removal of the concrete cap (and temporary removal of any utilities or shop equipment which have subsequently been emplaced) or drilling one or more inspection ports through six inches of the concrete caps and possible coring through fill materials or depth-integrated sampling through any liquids to obtain a representative sample. Alternatively, pits with wooden covers may be selected for sampling. Given the age of these pits and the length of time since their closure, it appears unlikely that much useful information can be gained from entering and sampling all of the pits identified. However, since these pits are known to have contained the solvents it would be of interest to verify the method of closure and the condition of the concrete subsurface flooring/storm sewer connections in at least one or two of these pits. Also, analysis of soil samples from below the pit floor would provide an indication of historical contamination, if it exists.

The available alternative measures relating to the buried tanks in the Bldg. 3001 area are similar although in the case of the tanks there may be less difficulty in terms of access. In a majority of the cases, the tanks identified were noticed by the presence of a vent tube or pipe which could provide access for the detection and sampling of any liquids remaining in the tanks. Access to those old tanks for which surface connections had been removed could be accomplished by coring either into the tank (filled with sand) or in the vicinity to obtain soil samples for analysis which would indicate the presence or extent of contamination from leaking tanks.

5.4 Stream Sediment Sampling

This action is considered complete. No follow-up activities are contemplated.

5.5 Radiological Waste Disposal Sites

The most probable location of RWDS-1022E was identified and marked in the field. The Base civil engineers are to construct a permanent concrete marker at the site. No indication of the location of RWDS-62598 was found. It is probable that, as previously reported, the materials have been removed. No further actions are contemplated at either of these sites.

5.6 Base Water Supply Wells

With the completion of the measurements of depth-to-water in these wells, this action is complete. No further actions are contemplated.

6.0 RECOMMENDATIONS

This section presents Radian's recommendations concerning actions at each of the Stage 2 study areas. The recommendations are organized by category, as follows:

Category I	Sites where no further action is required.
Category II	Sites requiring additional Phase II investigations to fully describe or quantify conditions.
Category III	Sites which require remedial action and are sufficiently well known for Phase III/IV actions to begin.

The Stage 2 study areas fall into all three categories.

6.1 Category I Sites

No further actions will be required at three Tinker AFB study areas. These are:

Radiological Waste Disposal Sites

The most probable location of RWDS-1022E was identified and marked in the field. The Base civil engineers are to construct a permanent concrete marker at the site. No indication of the location of RWDS-62598 was found. It is probable that, as previously reported, the materials have been removed. No further actions are contemplated at either of these sites.

Base Water Supply Wells

With the completion of the measurements of depth-to-water in these wells, this action is complete. No further actions are contemplated.

Stream Sediment Sampling

This action is considered complete. No follow-up activities are contemplated.

6.2 Category II Sites

The buried pits and tanks in the Building 3001 area are classed as Category II. Additional work will be required to assess the potential environmental impacts of these facilities. The recommended actions are as follows:

- o Enter, inspect, and obtain samples from the contents of selected pits buried beneath Bldg. 3001. Analyze samples for the presence of chlorinated solvents by EPA Method 601.

- o Obtain samples of any liquids from abandoned tanks buried in the vicinity of Bldg. 3001 where access is possible through vent pipes or surface connections. Analyze these samples for the presence of chlorinated solvents and hydrocarbon content.

6.3 Category III Sites

Both Landfill 6 and the Building 3001 area constitute Category III sites where remedial actions may begin.

Building 3001

While the complete area of occurrence of contamination is not known, Radian considers that the current system is sufficiently well defined to allow activities to proceed to remediation. The most obvious method of remedial action is a pump-out-and-treat system of relatively shallow (∿200 foot depth) production wells, followed by appropriate treatment or consumptive use in industrial processes. The following guidance is offered concerning the execution of this remedial action:

- o Well drilling should be initiated adjacent to the building (east and west sides), substantially along its full north-south length. Gaps in the data concerning the occurrence of contaminants may be filled in during drilling for remediation.

- o Pumping for remediation can begin as soon as a substantial number of the wells are in place, with continued testing for the occurence of halogenated organics as the program progresses. If a complete system of wells on the west side of Building 3001 shows extensive contamination, consideration will have to be given to production well installation within the airfields, active runways, and taxiways.

- o The renovation of Well 18 should also be accomplished at the time.

Landfill 6

Radian recommends that two to three additional monitor wells be installed to test the impact of the landfill on the regional aquifer to the south and southwest. These wells should be of sufficient depth to monitor the top of the regional system, a depth equivalent to approximate elevation 1200 feet. In order to avoid the effect of the contaminants moving laterally along shale zones above the water table, these wells should be located away from the landfill 100-200 feet.

6.4 Priority of Actions

Ranged in order of priority, the recommended actions are:

1. Install additional monitor wells at Landfill 6;

2. Initiate remedial actions at Bulding 3001, including Rehabilitation of Well 18; and

3. Conduct limited sampling of identified pits and tanks within Building 3001.