Remedial Investigation/Feasibility Study of the Soldier Creek/IWTP Groundwater Operable Unit at Tinker Air Force Base

Work Plan

Final

Prepared for

Oklahoma City Air Logistics Center

Tinker Air Force Base, Oklahoma

May 1994

AU405

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Prepared by
Engineering-Science, Inc.
Austin, Texas

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ACRONYMS AND ABBREVIATIONS

ACL	Alternate concentration limit
AFB	Air Force Base
ARAR	Applicable or relevant and appropriate requirements
AOC	Area of contamination
BGL	Below ground level
BNA	Base/neutral/acid-extractable
BTEX	Benzene, toluene, ethyl benzene, and xylenes
B&V	Black & Veatch Waste Science and Technology Corporation
CAL	Caliper
Cd	Cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	Cubic feet per second
cm/sec	Centimeters per second
COI	Compounds of interest
Cr	Chromium
DCE	Dichloroethene
DOD	Department of Defense
DQOP	Data Quality Objectives Plan
EA	Environmental assessment
EE/CA	Engineering evaluation/cost analysis
EPA	U.S. Environmental Protection Agency
EM	Environmental Management
ES	Engineering-Science, Inc.
FAR	Federal Acquisition Rules
FFA	Federal Facility Agreement
FSP	Field Sampling Plan
FS	Feasibility Study
gpm	Gallons per minute
GR	Neutral gamma ray
G-W	Garber-Wellington
HHEM	Human Health Evaluation Manual
HKS	Harry Keith & Sons, Inc.
HSU	Hydrostratigraphic units
IDW	Investigation derived waste
IRP	Installation Restoration Program
IRPIMS	Installation Restoration Program Information Management System
IWTP	Industrial wastewater treatment plant

LDR	Load disposal restrictions
LSZ	Lower saturated zone
LTM	Long term monitoring
μg/kg	Micrograms per kilogram
μg/L	Micrograms per liter
μm	Micrometer
μS/cm	Micro Seimens per centimeter
MCLG	Maximum contaminant level goals
MCL	Maximum contaminant level
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
mph	Miles per hour
MSL	Mean sea level
MTV	Mobility, toxicity, or volume
MW	Monitoring well
NAAQS	National ambient air quality standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NGVD	National Geodetic Vertical Data
Ni	Nickel
NIPDWR	National Interim Primary Drinking Water Regulations
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NSPS	New source performance standards
OD	Outside diameter
ODEQ	Oklahoma Department of Environmental Quality
OSDH	Oklahoma State Department of Health
OSWER	Office of Solid Waste and Emergency Response
OW	Observation wells
OWRB	Oklahoma Water Resources Board
Pb	Lead
PCB	Polychlorinated biphenyl
PCE	Tetrachloroethene
PPE	Personal protective equipment
PRP	Principal responsible party
PVC	Polyvinyl chloride
QA/QC	Quality assurance/quality control
QAPP	Quality assurance project plan
R	Resistivity geophysical log
RA	Risk assessment
RI	Remedial investigation
ROD	Record of decision
RQD	Rock Quality Design
SARA	Superfund Amendments and Reauthorization Act
SCGW	Soldier Creek/IWTP Groundwater Operable Unit
SCS	Soil Conservation Service
SDWA	Safe Drinking Water Act

SMCL	Secondary maximum contaminant levels
SOW	Statement of work
SP	Spontaneous potential
SWTP	Sanitary Wastewater Treatment Plant
TBC	To be considered
TCE	Trichloroethene
TCL	Target compound list
TCLP	Toxicity characteristic leaching procedure
TDS	Total dissolved solids
TIC	Tentatively identified compound
TOC	Total organic carbon
TPH	Total petroleum hydrocarbons
USACE	U.S. Army Corps of Engineers
USAF	U.S. Air Force
USDA	U.S. Department of Agriculture
USDC	U.S. Department of Commerce
USGS	United States Geological Society
USZ	Upper saturated zone
UV	Ultraviolet
VOC	Volatile organic compound
WQC	Water quality criteria
VC	Vinyl chloride
Zn	Zinc
°C	Degrees Celsius
°F	Degrees Fahrenheit

SECTION 1

INTRODUCTION AND BACKGROUND

In 1980, the United States Air Force (USAF) began implementing the U.S. Department of Defense (DOD) Installation Restoration Program (IRP). The IRP is designed to identify and evaluate suspected problems associated with past hazardous waste management practices, and to control hazards to human health and the environment resulting from past operations. The IRP was initially divided into four sequential phases: phase I, initial assessment and records search; phase II, problem confirmation and quantification; phase III, technology base development; and phase IV, remedial actions. In 1986, the Superfund Amendment Reauthorization Act (SARA) to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) was passed. To be consistent with SARA, the USAF decided that all future work will follow U.S. Environmental Protection Agency (EPA) guidance for conducting remedial investigations and feasibility studies (RI/FS) (USAF, 1989).

The objectives of the RI efforts are:

- Define nature and extent of possible contamination
- Identify Applicable or relevant and appropriate requirements (ARAR's)
- Conduct a risk assessment
- Refine remedial action goals.

The data are used to support an FS and follow-up activities such as remedial design, if required, and subsequent remediation. The RI may require several stages to adequately define a site and produce data for the FS. The objective of the FS is to identify treatment technologies, screen technologies, and determine and compare remedial alternatives. The RI and FS are performed concurrently and interactively.

1.1 PROJECT OBJECTIVES

This work plan outlines a program for an RI/FS for the Soldier Creek/IWTP Groundwater Operable Unit (SCGW) of the Building 3001 and Soldier Creek NPL site. It includes project and site history, a description of the current understanding of the site environmental setting, a review of existing site data, identification of possible remedial alternatives, identification of data needs and quality objectives, and a discussion of the RI/FS tasks. The objective of this project is to acquire data to define the nature and extent of groundwater contamination, to evaluate the risks to human health, welfare and the environment, and to perform an FS if necessary for the selection of remedial alternatives. The RI/FS is designed to gather sufficient information to support decisions regarding the risks posed by contaminants at the site and potential remedial alternatives to address those risks.

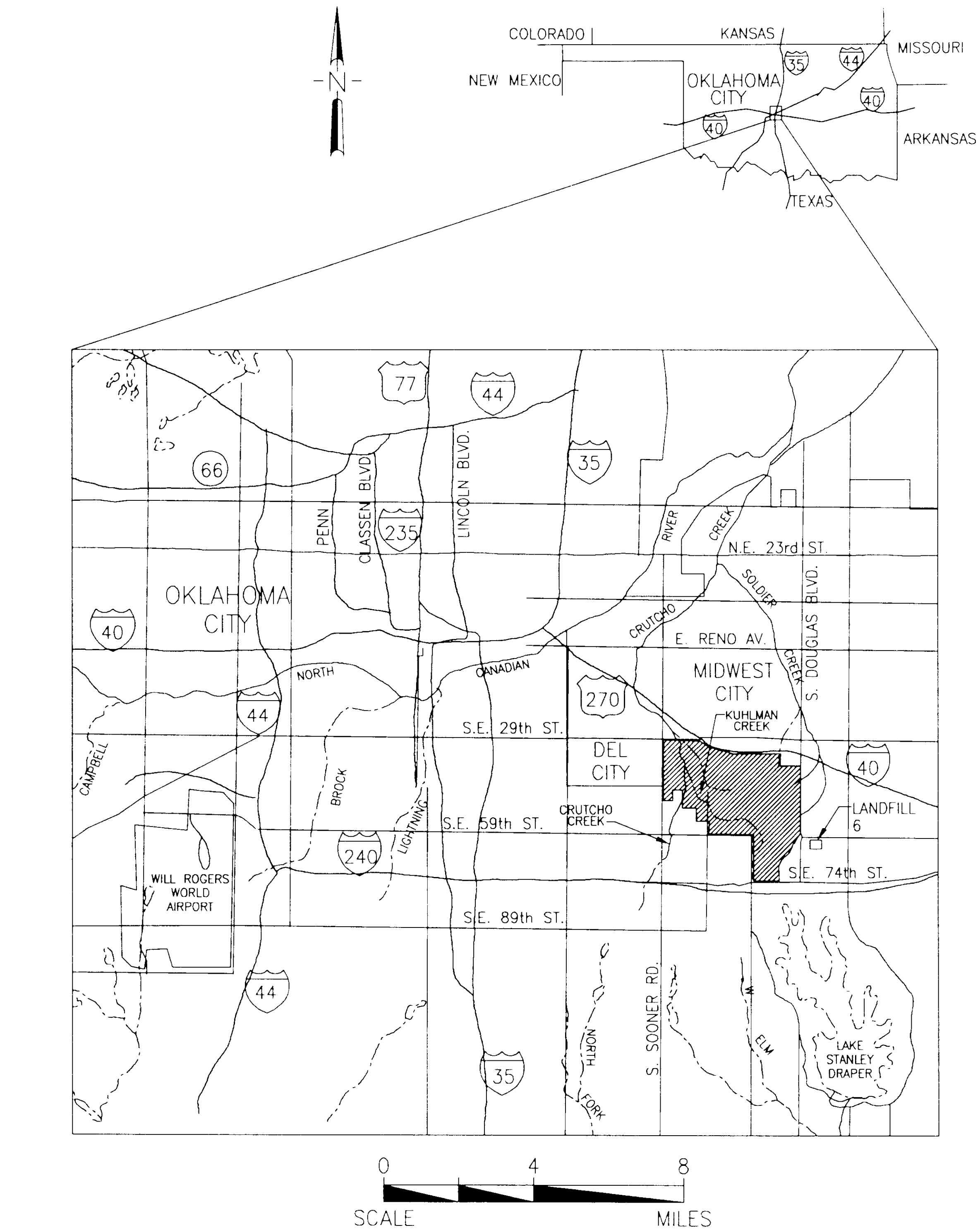
1.2 BASE LOCATION AND HISTORY

Tinker Air Force Base (AFB) is located in Oklahoma County in central Oklahoma, approximately 8 miles southeast of downtown Oklahoma City. Figure 1.1 is a location map of Tinker AFB. Figure 1.2 is the SCGW RI/FS site map. The base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 75th Street to the south. The base comprises 5,000 acres.

Tinker AFB was activated in March 1942 under the name of the Midwest Air Depot. During World War II, the depot was responsible for reconditioning, modifying and modernizing aircraft, vehicles and equipment. During this period, the civilian employment peaked at 14,925 employees.

At the conclusion of World War II, the Douglas Aircraft plant located east of the north-south runway was annexed to the base. Tinker AFB became involved in jet engine overhaul and later began modifying aircraft in a program to rebuild the nation's air power. Engine overhauling operations were performed in what is now known as Building 3001 located in the northeast quadrant of Tinker AFB. In 1948, Tinker AFB became a worldwide repair depot for several aircraft and a multitude of other weapons and engines. The level of activity has fluctuated during the history of the base, however the primary mission has not changed and Tinker AFB is still a major industrial complex for overhauling, modifying, and repairing military aircraft, aircraft engines, and accessory items.

The base has made several land acquisitions in addition to the Douglas Aircraft Plant. During 1951, the Air Force acquired a parcel of land located ½ mile east of the southeast corner of Tinker AFB. The area was named the Oklahoma City Air Force Station and was supported by Tinker AFB. In 1956, the area officially became a separate entity; however, support was still provided by Tinker AFB. The area was initially occupied by the 33rd Air Division and is presently occupied by the Engineering Installations Center, part of the Air Force Communications Command. In 1954, the base acquired a parcel of land south of the Southeast 59th Street boundary to extend the existing main runway. The land acquisition consisted of approximately 300 acres. During 1956, the base acquired additional land in the same area completing the parcel of land south of the Southeast 59th Street presently within Tinker AFB jurisdiction. In 1957, a 638 acre tract of land immediately west of the original air base was acquired to develop permanent military housing and community support facilities. In 1975, the base acquired an additional 187 acres of land situated contiguous to the west side of Air Depot Boulevard between Southeast 59th Street and Southeast 44th Street (ES, 1982).



LEGEND

HIGHWAY OR INTERSTATE

MAJOR ROAD

RIVER OR CREEK

OTHER BOUNDARIES

TINKER AFB

SOURCE: BLACK & VEATCH, 1993, MODIFIED

FIGURE 1.1
TINKER AFB
LOCATION MAP

TINKER AFB, OKLAHOMA

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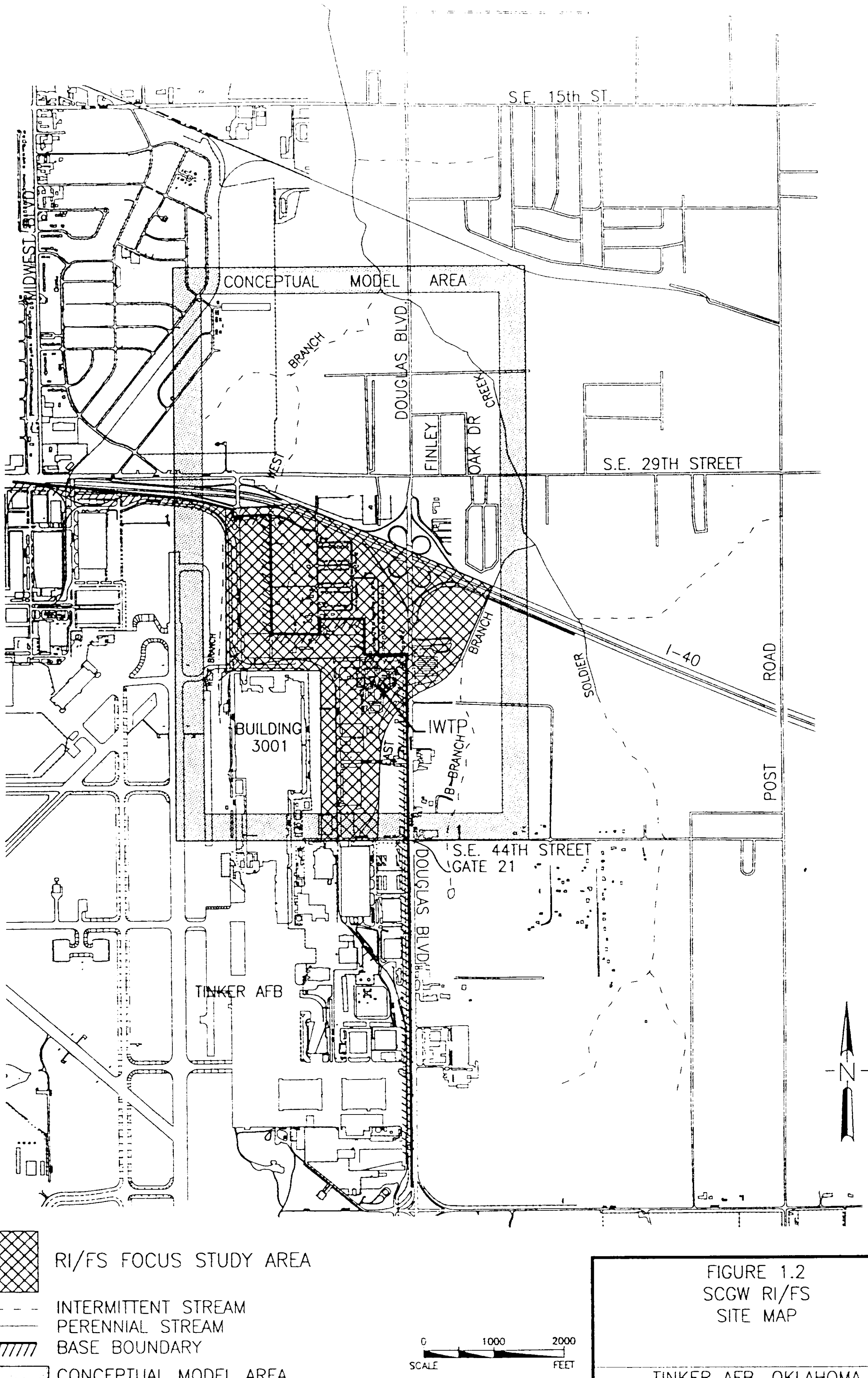

FIGURE 1.2
SCGW RI/FS
SITE MAP

TINKER AFB, OKLAHOMA

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1.3 IRP STATUS AND PROJECT TYPE

As part of the overall Air Force IRP, Tinker AFB began a preliminary assessment of previously used waste disposal sites in 1981 (ES, 1982). As a result of a basewide sampling program in 1983 which detected trichloroethene in the groundwater, extensive investigations were conducted in and around Building 3001. A summary of previous investigations is presented in Table 1.1. These investigations identified chromium as an additional chemical of concern in the groundwater. On July 22, 1987, the Building 3001 Site was added to the National Priorities List (NPL). On December 9, 1988, EPA Region VI, the Oklahoma State Department of Health (OSDH), and the United States Air Force, Tinker AFB signed the Federal Facility Agreement (FFA) under CERCLA Section 120 to "ensure that the environmental impacts associated with past and present activities at the (Building 3001 NPL site and associated operable units) are thoroughly investigated and appropriate remedial actions (are) taken as necessary to protect the public health, welfare, and the environment" (EPA, 1988b). An operable unit is a discrete action that comprises an incremental step toward comprehensively addressing site problems. The specific activities to be performed under the FFA include, but are not limited to, completion of RI/FS activities at the Soldier Creek Site (EPA, 1988b).

The Building 3001 Site and adjacent underground storage tank areas have undergone extensive investigations to determine the nature and extent of contamination in and around this complex. In addition, a risk assessment (USACE, 1988b) and an RI/FS (USACE, 1988a and 1988b) have been completed for the Building 3001 Site.

Investigation of possible sediment and surface water contamination of Soldier Creek began in 1984 (Radian, 1985). Based on the results of the investigations of Soldier Creek, a removal action was performed on on-base portions of East and West Soldier Creek in early 1986. Visibly contaminated sediments were removed and disposed of in an approved hazardous waste landfill.

The Soldier Creek/IWTP Groundwater Operable Unit (SCGW) is the focus of this investigation. The SCGW includes the off-base groundwater under and adjacent to Soldier Creek where contamination may have originated from the Soldier Creek/IWTP and Building 3001 NPL site.

1.4 WORK PLAN FORMAT

The format of this work plan is a combination of the work plan outline given in the Tinker AFB SOW and the RI/FS work plan outlined in the EPA guidance (EPA, 1989a). Section 1 is the introduction and background. Section 2 presents the initial site status; Section 3 describes the work plan rationale; a preliminary assessment of remedial alternatives is given in Section 4; Section 5 is the remedial investigation scope of work; Section 6 is the feasibility study scope of work; Section 7 presents the project schedule and organization; and Section 8 is the subcontracting plan.

Table 1.1 Summary of Previous Investigations
Tinker AFB, SCGW RI/FS
Remedial Investigation Report

Reference Document	Sampler	Dates	Sample Medium	Sample Analysis	Analyzed By
Installation Restoration Program; Phase II Confirmation/Quantification Stage 2; Final Report for Tinker AFB, Oklahoma (Radian, 1985)	Radian Corporation	6/84-7/84	Sediment	Metals, Fluoride, Cyanide, Polychlorinated Biphenyls (PCBs), Pesticides, Phenols, Nitrates, and Total Organic Carbon (TOC)	Radian Laboratories
An Evaluation of the Effects of Wastewater Discharge from Tinker AFB on Water Quality of Crutcho and Soldier Creeks (EPA, 1984)	EPA	10/84-11/84	Sediment Water	Metals, Volatile Organic Compounds (VOCs), Base/Neutral/Acid Extractable (BNAs); Water Quality Data	EPA Laboratory
Site Investigation Report (HKS, 1985)	Harry Keith & Sons, Inc.	10/85	Sediment	Metals, VOCs, BNAs, PCBs, Fluoride, Nitrate, Cyanide, Phenols	Environmental Laboratories, Inc
Building 3001 Remedial Investigations, Volumes I and II (USACE, 1988a and 1988b);	USACE Tulsa District	5/86-4/87	Water	VOCs, BNAs, Metals, TOC, pH, Specific Conductivity, Tentatively Identified Compounds (TICs);	USACE, Southwest Division Laboratory
Building 3001 Supplemental Quarterly Remedial Investigations	USACE Tulsa District	1/88-6/89	Water	VOCs, BNAs, Metals, TOC, pH, Specific Conductivity, TICs;	Oklahoma State Department of Health
Tinker AFB Groundwater Assessment Update	USACE Tulsa District	12/87-3/89	Water	VOCs, BNAs, Metals, TOC, pH, Specific Conductivity, TICs	Oklahoma State Department of Health

Table 1.1, continued

Reference Document	Sampler	Dates	Sample Medium	Sample Analysis	Analyzed By
"Sampling Results" (1) Groundwater Report	USACE Tulsa District	3/88,10/88	Water	VOCs, BNAs, Metals, TOC, pH, Specific Conductivity, TICs	Southwest Laboratory of Oklahoma
Final Storm Sewer Investigation For Soldier Creek (NUS, 1989)	NUS Corporation	10/89	Water	VOCs, Metals (Cd, Cr, Cu, Pb, Ni, Zn), Oils and Grease, Chemical Oxygen Demand, Cyanide, Phenols, Phosphorus, Chromium (VI)	NUS Corporation
Industrial Wastewater Treatment Plant Remedial Investigations Report (USACE, 1991a)	USACE Tulsa District	3/88-9/90	Water	VOCs, BNAs, Metals, TOC, pH, Specific Conductivity, TICs	USACE, Southwest Division Laboratory
Soldier Creek RI/FS (B&V, 1993)	B&V Waste Science and Technology	6/90 and 6/91	Water and Sediment	VOCs, BNAs, Metals, TOC, pH, Specific Conductivity, TICs	USACE, Southwest Division Laboratory
Off-base Groundwater Investigation (USACE, 1991b)	USACE Tulsa District	1/91-7/91	Water and Soil	VOCs, BNAs, Metals, TOC, pH, Specific Conductivity, TICs	USACE, Southwest Division Laboratory

In addition to this work plan, there are four complementary plans prepared for the SCGW RI/FS. They include:

- Field Sampling Plan (FSP) (ES, 1994a)
- Quality Assurance Project Plan (QAPP) (ES, 1994b)
- Health and Safety Plan (HSP) (ES, 1994c)
- Data Quality Objectives Plan (DQOP) (ES, 1994d).

SECTION 2

INITIAL SITE EVALUATION

2.1 SITE DESCRIPTION

2.1.1 Climate

Meteorological data are available from the weather station at Tinker AFB and also from the weather station at the Will Rogers World Airport, located about 12 miles west of Tinker AFB. The data from Tinker AFB is available for 1943 through 1993 and from the Will Rogers Airport for 1932 through 1993. Rainfall data for 1984 through 1993 was acquired for both weather stations.

Over the past 25 years, the wettest year at the Will Rogers Airport was 1986 (total precipitation 45.17 inches), and at Tinker AFB station the wettest year was 1985 (total precipitation 49.41 inches). The driest year at the Will Rogers Airport was 1976, with total precipitation of about 18 inches. The total precipitation at Tinker AFB for that year was about 20 inches. The average annual precipitation at Tinker AFB is 33.8 inches for the period between 1943 and 1993, with a low of 17.3 inches in 1954; however, the past several years have had above-normal precipitation. Average precipitation at the Will Rogers Airport from 1984 to 1992 was 40.17 inches and for Tinker AFB the average was 40.45 inches. (Battelle, 1994).

Overall, the monthly trends observed at Tinker AFB show the same pattern as the monthly trends at Will Rogers Airport. From 1981 to 1988, the highest average monthly precipitation occurred in May. The months of June, September, and April also had high average precipitation rates. The months with the lowest average monthly precipitation were January, February, and December (National Climatic Data Center, 1985, 1988, and 1989).

Snowfall typically occurs in the months of November through March with only trace amounts falling in October and April. The average yearly snowfall was 9.4 inches with the majority falling in January and February.

The average annual temperature was 60.1 degrees Fahrenheit (°F). The warmest months of the year were June and July with mean temperatures of 81.6°F and 81.3°F, respectively. The coldest months were January and December with mean temperatures of 36.9°F and 39.8°F, respectively.

The annual mean wind speed was 12.4 miles per hour (mph) with the predominant direction from the south-southeast. During January and February the prevailing wind direction is from the north. During the months of November and December, the prevailing direction is from the south.

2.1.2 Topography

The topography of Oklahoma City and surrounding area varies from generally level to gently rolling in appearance. Local relief is primarily the result of dissection by erosional activity or stream channel development. At Oklahoma City, surface elevations are typically in the range of 1,070 to 1,400 feet mean sea level (MSL). At Tinker AFB, ground surface elevations vary from 1,190 feet MSL near the northwest corner where Crutcho Creek intersects the base boundary to approximately 1,320 feet MSL at Area D, located on 59th Street, east of the main installation (Figure 1.2).

2.1.3 Soils

The soils of Tinker AFB have been studied by the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) (1969) and by several geotechnical (foundation/construction) investigations. Surface soils of the installation area are predominantly of two basic types: residual and alluvial. The three major soil associations mapped by SCS within installation limits are Darrell-Stephenville, Renfrow-Vernon-Bethany, and Dale-Canadian-Port. The residual soils associations, Darrell-Stephenville and Renfrow-Vernon-Bethany, are the product of the weathering of underlying bedrock. The alluvial materials of the Dale-Canadian-Port association are stream-deposited silts and sands, whose occurrence is typically restricted to the floodplains of area streams (Tinker AFB, 1993).

2.1.4 Geology

Tinker AFB lies atop a sedimentary rock column several thousand feet thick composed of strata that range in age from Cambrian to Permian above a Precambrian-age igneous basement. Quaternary-age alluvium and terrace deposits can be found overlying bedrock in and near present day stream valleys. At Tinker AFB, Quaternary deposits consist of unconsolidated weathered bedrock, fill material, wind blown sand, and interfingering lenses of sand, silt, clay, and gravel of fluvial origin. The terrace deposits are exposed where stream valleys have downcut through older strata and have left them topographically above present-day deposits. Alluvial sediments range in thickness from less than 1 foot to nearly 20 feet. A map of the surface geology in the study area is presented in Figure 2.1, which shows the distribution of geologic rock units across the site.

Geologic units which outcrop at Tinker AFB consist of, in descending order, the Hennessey Group, the Garber Sandstone, and the Wellington Formation. These bedrock units were deposited during the Permian Age (230 to 280 million years ago) and are typical redbeds. They are composed of a conformable sequence of sandstones, siltstones, and shales. Individual beds are lenticular and vary in thickness over short distances. The interconnected, lenticular nature of sandstones within the sequence forms complex pathways for groundwater movement.

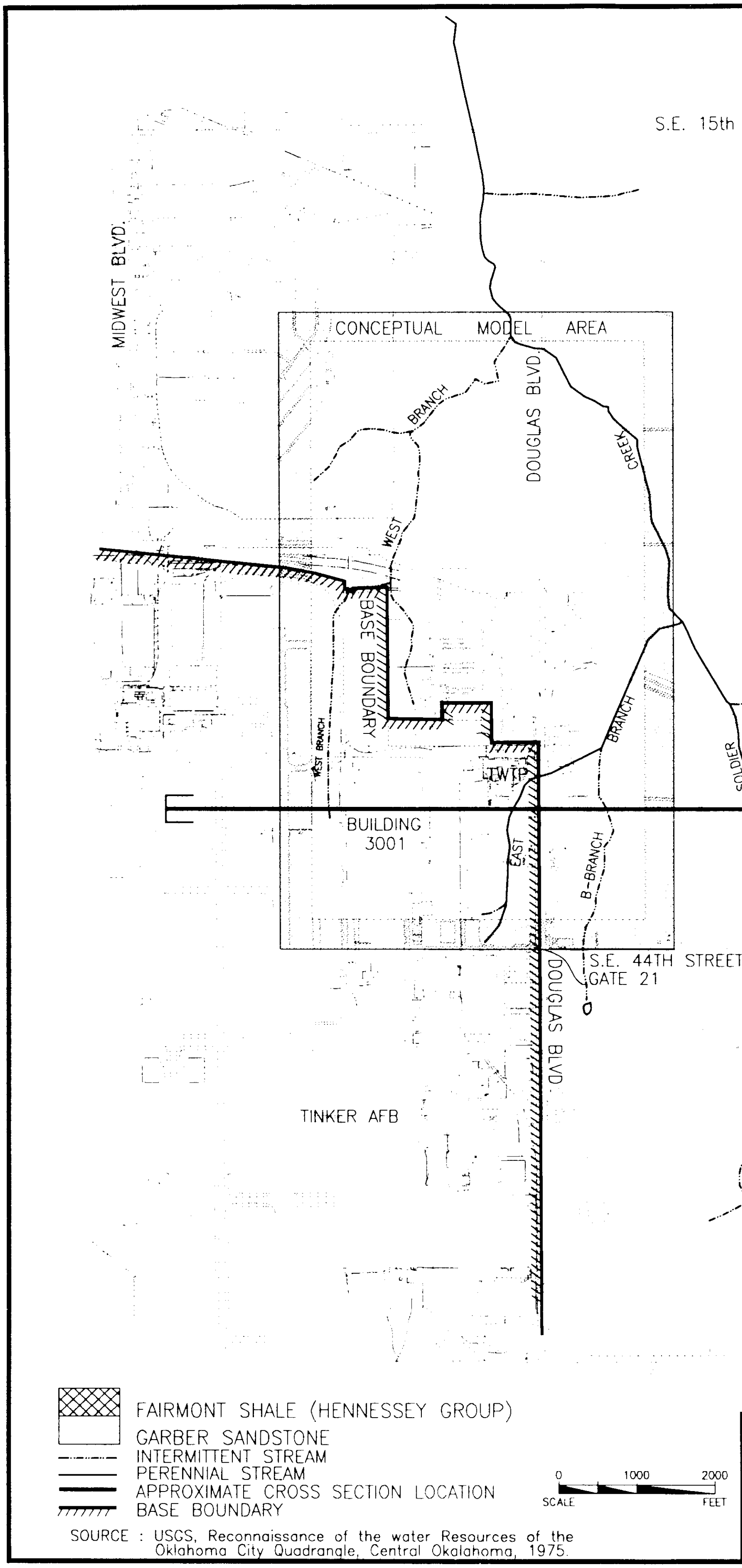

FIGURE 2.1
GEOLOGIC MAP

TINKER AFB, OKLAHOMA

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The surficial geology of the north section of the base is dominated by the Garber Sandstone, which outcrops across a broad area of Oklahoma County. Generally, the Garber outcrop is covered by a thin veneer of soil and/or alluvium up to 20 feet thick.

The Fairmont Shale is the lowest unit of the Hennessey Group in this area and represents deposition in a tidal flat environment cut by shallow, narrow channels. The Hennessey is comprised predominantly of red shales which contain thin beds of sandstone (less than 10 feet thick) and siltstone. In outcrop, "mudball" conglomerates, burrow surfaces, and desiccation cracks are recognized. The Hennessey outcrops over roughly the southern half of the base, thickening to approximately 70 feet in the southwest from their erosional edge (zero thickness) across the central part of Tinker AFB (Tinker AFB, 1993).

In contrast, the Garber Sandstone and Wellington Formation around Tinker AFB consist of an irregularly interbedded system of lenticular sandstones, siltstones, and shales deposited either in meandering streams in the upper reaches of a delta or in a braided stream environment. Outcrop units exhibit many small to medium channels with cut and fill geometries consistent with a stream setting. Sandstones are typically cross-bedded. Individual beds range in thickness from a few inches to about 50 feet and appear massive but thicker units are often formed from a series of "stacked" thinner beds. Sandstones are typically fine to very fine grained, friable, and poorly cemented. Shales are described as ranging from clayey to sandy, are generally discontinuous, and range in thickness from a few inches to about 40 feet (Tinker AFB, 1993). A generalized geologic cross section of the northeast quadrant is provided in Figure 2.2 (Battelle, 1993). The Garber Sandstone and Wellington Formation are divided into twelve alternate layers of sandstone and shale. Figure 2.2 indicates that the alternate sandstone layers are hydraulically interconnected below layer two and may be considered as one aquifer, the lower saturated zone (LSZ) as defined by Tinker AFB. The first layer is defined as the upper saturated zone (USZ). Figure 2.3 shows the potentiometric surface of the LSZ, and Figure 2.4 shows the water table surface the USZ.

Tinker AFB lies within a tectonically stable area; no major near-surface faults or fracture zones have been mapped. Most of the consolidated rock units of the Oklahoma City area are nearly flat-lying. A regional dip of 40 feet per mile in a generally westward direction is supported by stratigraphic correlation on geologic cross-sections at Tinker AFB. Bedrock units strike slightly west of north.

2.1.5 Groundwater

The most important source of potable groundwater in the Oklahoma City metropolitan area is the Central Oklahoma aquifer. This aquifer extends under much of central Oklahoma and includes water in the Garber Sandstone and Wellington Formation, the overlying alluvium and terrace deposits, and the underlying Chase, Council Grove and Admire Groups. The Garber Sandstone and the Wellington Formation portion of the Central Oklahoma aquifer is commonly referred to as the "Garber-Wellington (G-W) aquifer" and is considered to be a single aquifer because these units were deposited under similar conditions and

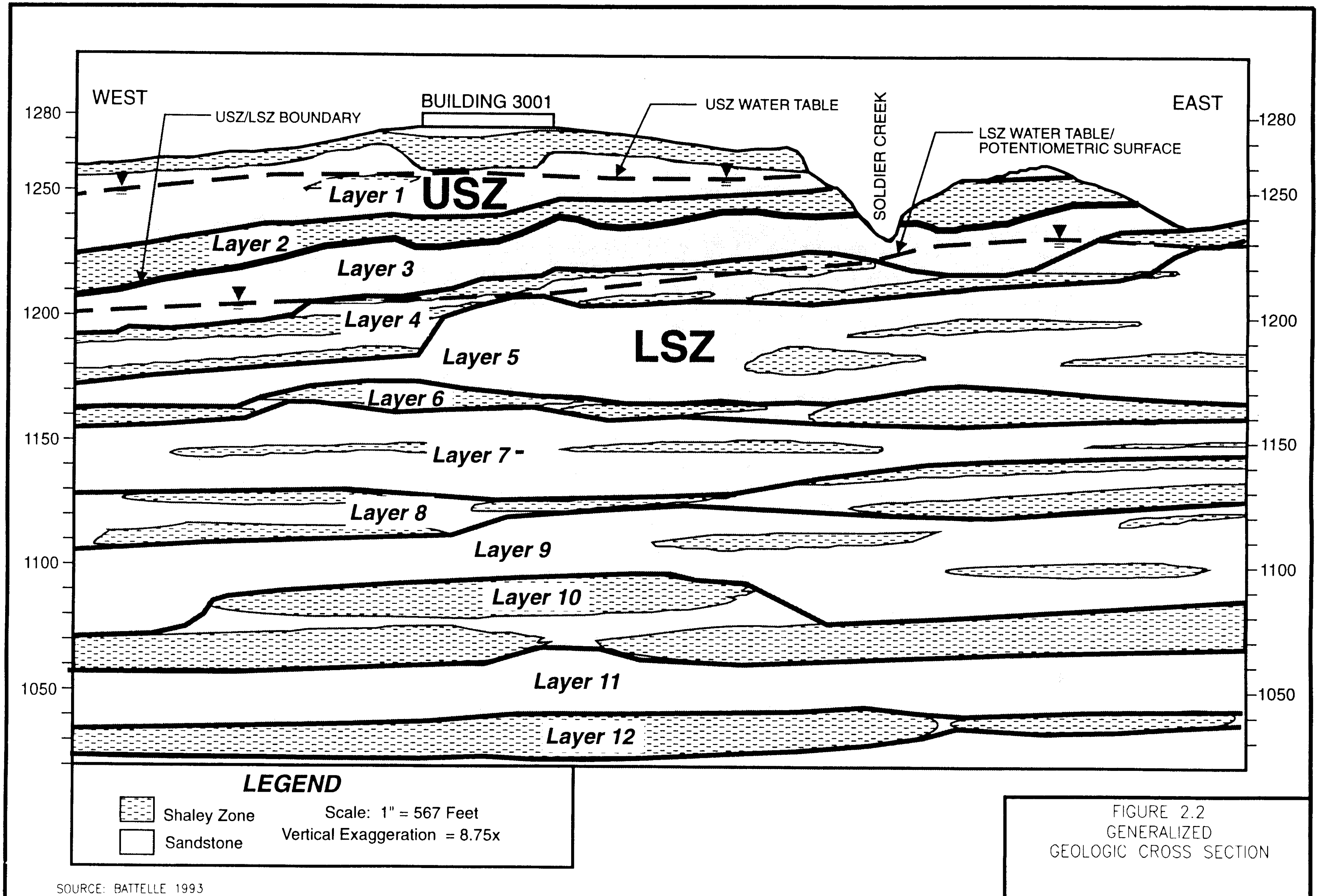

FIGURE 2.2
GENERALIZED
GEOLOGIC CROSS SECTION

TINKER AFB, OKLAHOMA

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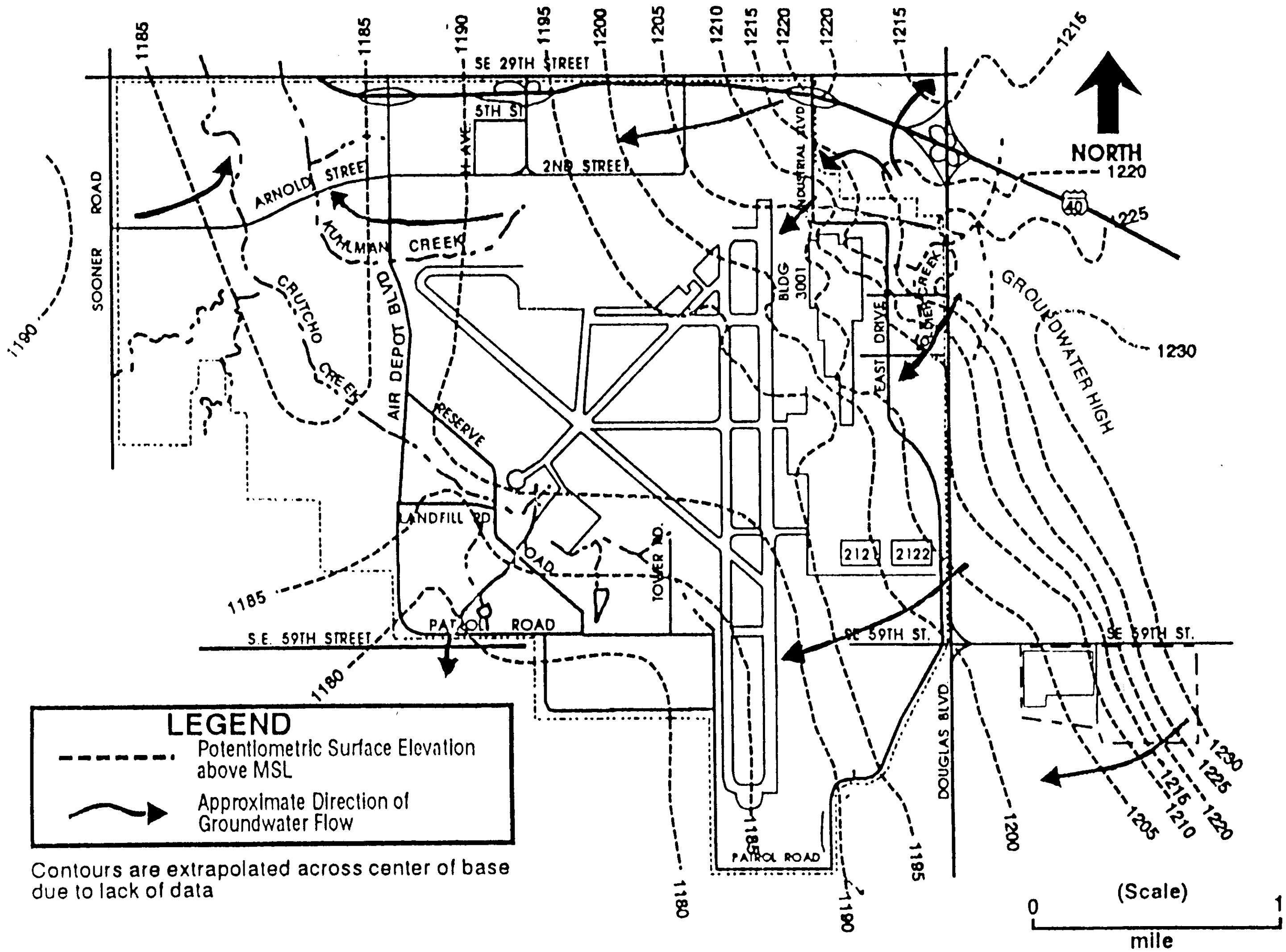
FIGURE 2.3

TINKER AFB

Potentiometric Surface of Lower Saturated Zone

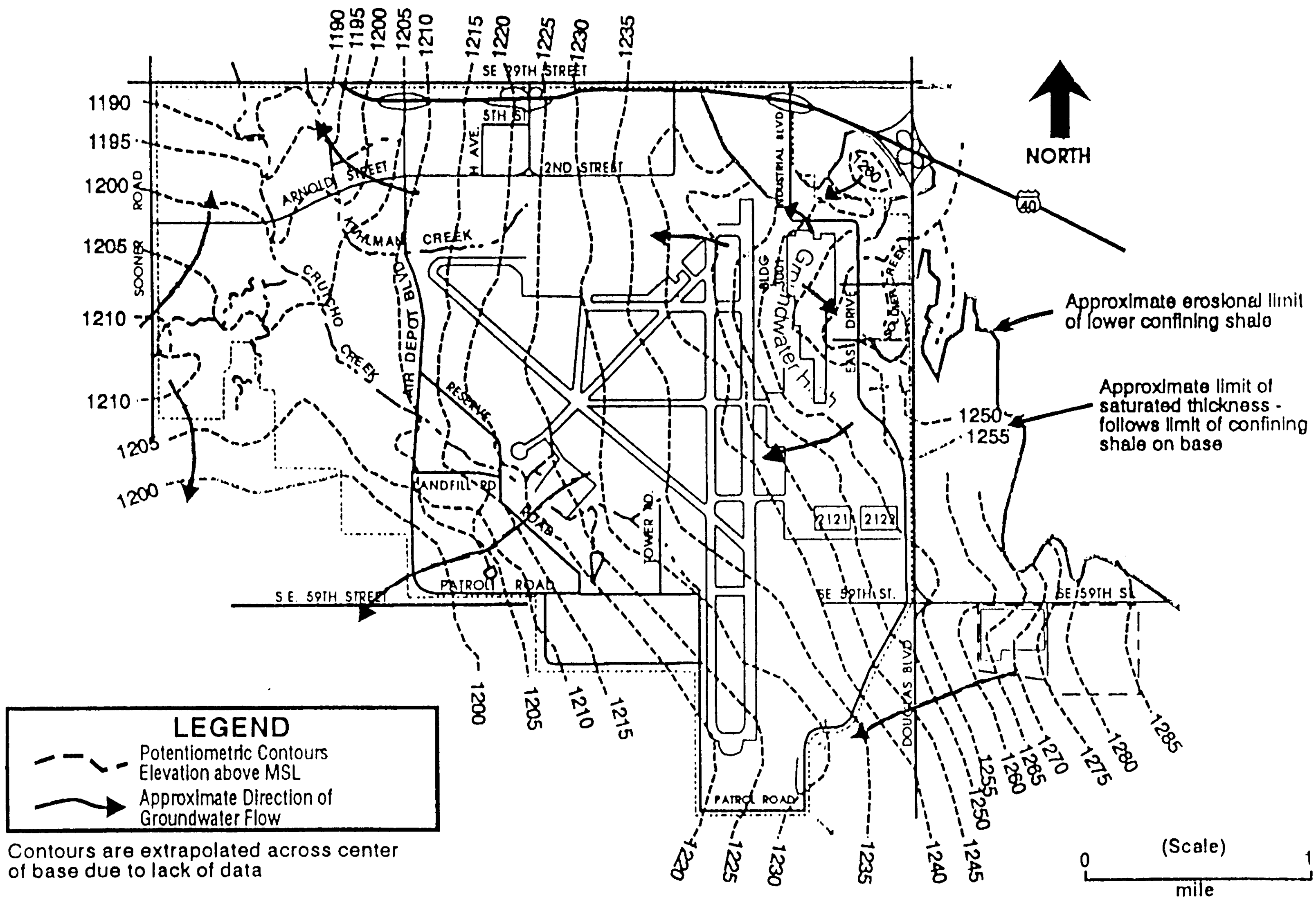


SOURCE: TINKER AFB, 1993

FIGURE 2.4

TINKER AFB

Water Table Surface of Upper Saturated Zone



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

SOURCE: TINKER AFB, 1993

because many of the best producing wells are completed in this zone. On a regional scale, the aquifer is confined above by the less permeable Hennessey Group and below by the Late Pennsylvanian Vanoss Group (Tinker AFB, 1993).

Tinker AFB lies within the limits of the Garber-Wellington (G-W) groundwater basin. At the present time, Tinker AFB derives most of its water supply from this aquifer and supplements the supply by purchasing from the Oklahoma City Water Department. The nearby communities of Midwest City and Del City derive water supplies from both surface sources and wells tapping the G-W aquifer. Industrial operations, individual homes, farm irrigation, and small communities not served by a municipal distribution system also depend on the G-W aquifer. Communities, such as Oklahoma City, presently depending upon surface supplies, also maintain a well system drilled into the Garber-Wellington as a standby source of water in the event of drought (Tinker AFB, 1993).

Recharge of the G-W aquifer is accomplished principally by percolation of surface waters crossing the area of outcrop and by rainfall infiltration in this same area. Because most of Tinker AFB is located in an aquifer outcrop area, the base is considered to be situated in a recharge zone.

Tinker AFB presently obtains its water supplies from a distribution system comprised of twenty-nine wells constructed along the east and west base boundaries and by purchase from the Oklahoma City Water Department. All base wells are completed into the G-W aquifer. Base wells range from 700 to 900 feet in total depth, with yields ranging from 205 to 250 gallons per minute. The wells incorporate multiple screens, deriving water supplies from sand zones that vary in thickness from 103 to 184 feet.

Groundwater flow at the base is very complex due to the highly variable geology. However, a conceptual model has been developed which divides the groundwater into vertical components, based roughly on depth. These water-bearing zones, from shallowest to deepest, are as follows: perched water table, top of regional, regional, and producing zone (USACE, 1988a).

The top of regional, regional, and producing zones are collectively called the LSZ by Tinker AFB (1993). The perched water zone is referred to as the USZ. Figure 2.2 and 2.4 indicate that the USZ does not exist east of the east branch of Soldier Creek. The USZ is generally unconfined, i.e., in water table condition. Table 2.1 shows the characteristics of each zone.

Table 2.1
Hydrogeologic Zones of Interest in the
Northeast Quadrant of Tinker AFB

Previous Investigations	SCGW RI/FS	Type of Aquifer	Depth Water Encountered
Perched water table	Upper saturated zone	Unconfined	15 - 30 feet
Top of regional	Lower saturated zone	Semiconfined to unconfined	50 - 80 feet
Regional	Lower saturated zone	Confined	110 - 175 feet
Producing zone	Producing zone	Confined	200 - 700 feet

2.1.6 Surface Water and Drainage

Drainage of Tinker AFB land areas is accomplished by overland flow of runoff to diversion structures and thence to streams, which flow intermittently. The northeast portion of the base is drained primarily by tributaries of Soldier Creek, a tributary of Crutcho Creek. The north and west sections of the base including the main instrument runway, drain to Crutcho Creek, a tributary of the North Canadian River. Two small unnamed intermittent streams crossing installation boundaries south of the main instrument runway generally do not receive significant quantities of base runoff due to site grading designed to preclude such drainage. These streams, when flowing, extend to Stanley Draper Lake, approximately ½ mile south of the base.

2.1.7 Land Use and Demography

Midwest City is north of Tinker AFB. The population of Midwest City in 1980 was 49,559. The projected population for the year 2000 is estimated to be between 57,100 and 64,600. Between 1970 and 1980, there was a large decrease in population between Midwest Boulevard and Douglas Boulevard and between Southeast 15th Street and Southeast 29th Street. This area is directly north of Tinker AFB. The decrease is attributed to the removal of the Glenwood Addition neighborhood located north of the base. As of 1980, the median age of the population in Midwest City was 28.5 years, an increase of 4.3 years from 1960. In 1980, 7.2 percent of the population was over 65 years of age, an increase of 4.1 percent from 1960. In 1980, 8.2 percent of the population was under the age of 5 years, a decrease of 5.5 percent from 1960.

The median income of Midwest City residents in 1979 was $17,537, which was greater than that for the residents of Oklahoma County and the state. In 1979, 22.8 percent of the households in Midwest City had an income of less than $10,000 per year, and 17.9 percent had income of greater than $30,000 per year. Public administration, which includes employment at Tinker AFB, had the largest amount of employment for an industrial group in Midwest City. Manufacturing, retail trade, and professional and related services also constituted a large percentage of the other industrial groups providing employment in Midwest City. Retail is the largest of the three categories of business (retail, service, and wholesale) in Midwest City.

Tinker AFB lies within an area representing transition from residential and industrial/commercial land use on the north and west to agricultural land use to the east and south. Soldier Creek and its branches, which flow northwest through the area, is bordered mainly by recreational and residential areas with some areas supporting commercial and industrial land use. Some industry such as a metal plating facility, and a dry cleaning facility are present within the drainage basin as well as commercial facilities such as gas stations, auto repair facilities, and a closed sanitary landfill. In addition, three schools, Soldier Creek Elementary, Steed Elementary, and Monroney Junior High exist within the drainage basin. There are ten public parks within the general vicinity of Tinker AFB, including the Joe E. Barns, Fred F. Meyers, Kiwanis, and Lions Parks. A public golf course is also located north of the base. Five trailer parks are located north and northeast of Tinker AFB (B&V, 1993).

The land use plan for the area immediately north of Tinker AFB, between Sooner Boulevard and Douglas Boulevard includes all levels of land use. The areas between Sooner Boulevard and Midwest Boulevard are zoned primarily for housing (single and multifamily units) and low to medium commercial use. The area between Midwest Boulevard and Douglas Boulevard is zoned primarily for heavy commercial and moderate to heavy industrial use (B&V, 1993).

2.2 HISTORY OF INVESTIGATION WORK

Several investigations pertaining to Soldier Creek have been conducted since 1984. A summary of the investigations is presented in Table 1.1. The descriptions in Sections 2.2.1 through 2.2.6 are taken from the Soldier Creek RI/FS Report (B&V, 1993).

2.2.1 Sediment Sampling - Radian Corporation 1984

The purpose of the IRP Phase II Confirmation/Quantification Stage 1 and Stage 2 investigations (Radian, 1985) was to determine if solvent storage and waste disposal practices resulted in environmental contamination. In addition, the investigation presented an estimate of the magnitude and extent of contamination, the identification of environmental consequences of migrating pollutants, and recommendations for additional investigations to identify the magnitude, extent and direction of movement of discovered contaminants. As part of this investigation, twenty-four sediment samples were collected along Crutcho Creek (including significant tributaries), Kuhlman Creek, East Soldier Creek, West Soldier Creek, Soldier Creek, a tributary of Elm Creek and two drainage ditches within Tinker AFB between June 20 and July 19, 1984. Seven of these sediment sampling stations were located within East Soldier Creek, West Soldier Creek, Soldier Creek, and two drainage ditches on Tinker AFB.

In general, sediment analytical results showed no evidence of widespread or elevated levels of industrial contaminants. Radian (1985) determined that no other follow-up action was deemed necessary for the area of study.

2.2.2 Sediment Sampling - Harry Keith & Sons, Inc. (HKS) 1985

The purpose of the HKS (1985) Site Investigation Report was to present analytical results from sediment sampling conducted to determine the magnitude of contamination found in East and West Soldier Creeks.

HKS observed that East Soldier Creek appeared to have a heavy buildup of a black oily sludge in and adjacent to the streambed, and all sampling locations exuded strong hydrocarbon odors.

2.2.3 Groundwater Sampling
U.S. Army Corps of Engineers (USACE), Tulsa District

Quarterly groundwater sampling and analyses has been conducted as a part of the overall groundwater assessment at Tinker AFB and as a part of the remedial investigation of the Building 3001 Site. The results of the sample analyses have been presented in several reports (USACE, 1988a, 1989a, and 1989b).

The Building 3001 Site remedial investigations indicated that the perched aquifer, i.e., USZ, was contaminated with organic solvents, trace metals, and fuel product (USACE, 1988a). The areas with highest concentrations of contaminants were located beneath Building 3001, the North Tank Area, and the Southwest Tank Area. Trichloroethene (TCE) and chromium were considered the primary contaminants in the USZ aquifer since their maximum concentrations were higher than the concentrations of other contaminants and they were consistently detected over a large portion of the site. Other significant contaminants included 1,2-dichloroethene (DCE), tetrachloroethene (PCE), acetone, toluene, benzene, and xylene. Significant inorganic contaminants detected include lead, nickel, and barium.

The supplement quarterly remedial investigations conducted at the base had indicated that the areal extent of TCE contamination had not changed significantly (USACE, 1989a). The areal extent of chromium contamination appeared to have increased slightly. All other contaminants had appeared to remain fairly stable with a general trend for lower concentration of metals (USACE, 1989a).

2.2.4 Surface Water Sampling – NUS Corporation (NUS) 1989

The purpose of the Storm Sewer Investigation for Soldier Creek performed by NUS Corporation (NUS, 1989) was to identify releases of potential contaminants from the storm sewers emanating from the Building 3001 complex and discharging to East and West Soldier Creeks on Tinker AFB.

The storm sewer investigation concluded that the integrity of the storm sewer system discharging to Soldier Creek was adequate and that the main reason for contamination in the creek was because of improper disposal operations (NUS, 1989). The study results indicated that there were four waste sources discharging into Soldier Creek. The four sources consisted of the following:

1. Process discharges, including non- or limited-contact process heating and cooling waters or evaporative cooling waters. This type of discharge constitutes the majority of the discharge volume.
2. Low volume accumulative wastes consisting of entrained or condensable oils and water-based wastes. These wastes are generated by the air compressor, vacuum pump, and fume handling systems, and are the primary sources of oil found in the Soldier Creek outfalls.
3. Waste materials, including spent cleaning solvents and lubricating oils. These wastes are maintenance related and were manually disposed of into catch basins and roof, floor, and process drains connected to the storm sewer system.
4. Cross contamination between waste systems as a result of improper connections.

Several buildings in the vicinity of and including Building 3001 were found to have operational problems that contributed to the contamination of Soldier Creek through the outfalls.

2.2.5 Industrial Wastewater Treatment Plant Groundwater Sampling - USACE Tulsa District, 1991

Groundwater sampling and analysis was conducted on monitoring wells in the vicinity of the industrial wastewater treatment plant (IWTP) between 1988 and 1990. The USZ (perched aquifer), and the LSZ (top of regional aquifer zone, and regional aquifer zone), wells at the IWTP were sampled at least once during the 3-year period. Semiannual sampling was conducted on the majority of the wells. The samples were analyzed for conductivity, pH, total organic carbon (TOC), volatile and semivolatile organics, and selected total and dissolved metals (arsenic, barium, cadmium, chromium, lead, mercury, nickel, selenium, silver, and zinc).

The results of the sampling and analysis are presented in the Industrial Wastewater Treatment Plant Remedial Investigation Report, (USACE, 1991a). The results indicated that the contamination in the top of regional aquifer zone of the LSZ was greater than that in the USZ. Groundwater elevations in all aquifer zones were found to remain fairly constant over the investigation; however, contaminant concentrations in the aquifer zones rapidly increased over the investigation period. Elevated concentrations of several contaminants including chromium, lead, vinyl chloride, 1,1-dichloroethane, 1,1-dichloroethene, trans-1,2-dichloroethene, 1,3-dichloropropane, 1,1,1-trichloroethane, TCE, PCE, chlorobenzene, methylene chloride, and 1,2-dichlorobenzene were detected in the groundwater.

2.2.6 Off-Base Groundwater Investigation Report - USACE Tulsa District, 1991

In 1991 Tinker AFB contracted the U.S. Army Corps of Engineers to install and test a network of off-base monitoring wells to determine if contamination found in private wells could be linked to on-base sources. Sixty-three monitoring wells in twenty-one clusters were constructed in phase I. Each cluster of three wells included one well each in the USZ (perched zone), and the LSZ's top of regional, and regional zones. During phase II one additional off-base cluster and one on-base well in the USZ (perched zone) were constructed. Groundwater samples from each well and a few soil samples were collected and analyzed.

The results of the off-base investigation indicated that some of the organic contaminants found in the off-base wells were not the same as these found in the on-base wells. Chlorinated organic hydrocarbons were the contaminants found primarily on-base. Aromatic hydrocarbons, i.e., benzene, toluene, xylenes, and ethyl benzene (BTEX) were the constituents that were primarily found in off-base wells.

2.2.7 Soldier Creek RI/FS - Black & Veatch, 1993

In June and July 1990 and June 1991 Black & Veatch (B&V) conducted a remedial investigation at the Soldier Creek NPL site. The purpose of the investigation was to evaluate the nature and extent of the threat posed by the presence, release, or potential release of hazardous substances.

During the RI/FS 230 sediment and 48 surface water samples were collected for chemical analysis. The surface water and sediment analytical results indicated the presence of volatile, semivolatile organics, and inorganics including metals at various locations along Soldier Creek.

2.2.8 Risk Assessment Report - Black & Veatch, 1993

A risk assessment was conducted for the Soldier Creek Site as part of the RI/FS investigation. The purpose of the risk assessment was to determine, by medium, the potential adverse effects of the Soldier Creek contamination to human health and the environment.

The results of the risk assessment showed noncarcinogenic risks exist in excess of the level of concern for off-base residents for exposure to the USZ (perched aquifer) and the upper LSZ (top of regional aquifer zone), on-base workers using the USZ (not currently a complete pathway), future off-base residents and on-base workers for exposure to the USZ and the LSZ. The risk assessment also concluded that a carcinogenic risk exists in the USZ and LSZ.

The report concluded that exposure to chemicals of concern in the surface water and sediments had a low potential carcinogenic risk in all scenarios. Exposure to chemicals of concern in the groundwater at the Soldier Creek Site had the potential for carcinogenic risk greater than one in one millionth (10^{-6}) for all scenarios. [The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (EPA, 1990) specifies that action must be taken when real risk is more than one in ten thousand (10^{-4}), and consider action when risk is between 10^{-4} to 10^{-6}.]

Another risk assessment is planned for the SCGW RI/FS, because new wells are being installed downgradient of the previous Soldier Creek Site RI/FS.

2.2.9 Current Tinker AFB Projects

Battelle is a subcontractor to ES on the SCGW RI/FS. Battelle's knowledge about the Tinker AFB's surface and groundwater setting and any related investigative activities make them an important part of the SCGW RI/FS. Currently Battelle has eight studies ongoing, in addition to this SCGW RI/FS. They include:

1. Groundwater Flow and Solute Transport Modeling for the Northeast Quadrant and Surrounding Area of Tinker Air Force Base, Oklahoma, Contract number F0406-89-D-0034; DO-5007.
2. Development of 3D Site Stratigraphy, SSP task number 92-501; DO-0552
3. Geostatistical Analysis of Geologic Heterogeneities, TCN-92-510; DO-0563
4. Evaluation of Existing Monitoring Wells, SSP task number 92-502; DO-0555
5. Monthly Water Level Measurements, SSP task number 92-474; DO-0548
6. Soldier Creek Investigations, SSP task number 92-475; DO-0518
7. Determination of Distribution Coefficients, SSP number 92-429; DO-0502

8. Work Plan and Data Compilation for the Base-wide Model at Tinker Air Force Base, SSP task number 93-359; DO-1019
9. Tinker AFB monitoring wells plug, abandonment and replacement activities
10. RCRA Facility Investigation at the IWTP and SWTP contract number F34650-93-D-0106, DO-5000.

Each of the above mentioned studies will aid the Soldier Creek/IWTP Groundwater RI/FS by providing raw data and a basic understanding of the hydrogeologic framework for much of the site. Studies 2 through 7 were initiated to support the groundwater flow and solute transport modeling activities for the northeast quadrant and surrounding areas of Tinker AFB (study #1) being developed for the Building 3001 NPL site. This area and the Soldier Creek/IWTP Groundwater RI/FS site overlap, and much of the information gained from the current studies is directly applicable to the RI/FS. Hydrogeologic information for Tinker AFB and surrounding areas and a modeling work plan were compiled for study 8, and therefore provides a brief introduction to the regional hydrogeologic setting for the RI/FS site. Task 3, 4, 5, 6, and 7 in this Work Plan will supplement these studies and will collect data within the SCGW study area to fill the data gaps discussed in Section 3.3. Task 9 activities include the abandonment and replacement of several monitoring wells. The new wells will provide more precise hydrologic and analytical information for input to the conceptual model. Task 10 field investigations have been completed by ES and will provide information regarding potential sources of contamination at the IWTP and SWTP. A brief summary for each of the current projects is presented in the following sections.

2.2.9.1 Groundwater Flow and Solute Transport Modeling

Tinker Air Force Base is currently developing a groundwater flow and solute transport model for the northeast quadrant. The model area includes Building 3001, the Industrial Waste Treatment Plant (IWTP), Soldier Creek, and adjacent off-base areas. Results from the groundwater flow model will consist of simulated head distributions, groundwater flow directions, velocities, and fluxes; estimated contaminant migration rates and concentrations in space and time, and simulation (and therefore evaluation) of existing and proposed extraction systems. The model will be revised in areas where new data is collected so that a better match between observed and simulated properties can be achieved.

Monitoring wells and soil borings completed during investigations within the northeast quadrant provided the framework for the initial conceptual model of the northeast quadrant and the development of a preliminary five-layer groundwater flow model. During development of the conceptual model, data deficiencies were identified that prevented accurate simulation of groundwater flow and solute transport. The deficiencies include the following: (a) identification of the hydrologic interactions between Soldier Creek and the underlying aquifers; (b) determination of potentiometric surface maps from accurate bimonthly water level measurements; (c) Tinker AFB production water well pumpage data for quantification of underlying groundwater withdrawals; (d) evaluation of existing monitoring wells and the installation of additional monitoring wells to obtain reliable data for determining groundwater flow directions and gradients and the extent of contamination; (e) geologic descriptions and laboratory analysis of continuous core samples collected from borings during initial remedial investigations lacked sufficient detail, particularly grain size analysis, to permit their intended use in developing a baseline geophysical log response for different soil and rock types encountered during drilling; and (f) determination of distribution coefficients for selected hazardous contaminants identified in the groundwater beneath the site.

Tinker AFB is currently conducting several investigations to collect the information required to address these data deficiencies and to update the conceptual model of the flow system beneath the northeast quadrant. These investigations include three-dimensional development of site stratigraphy, evaluating existing monitoring well locations and completions, monthly groundwater level measurements, Soldier Creek investigations, and laboratory studies to determine the distribution coefficients (K_ds) of several contaminants present in groundwater beneath the site.

2.2.9.2 Development of Three-Dimensional Site Stratigraphy

The purpose of developing three-dimensional (3D) site stratigraphy is to provide a better representation of the complex geology of the site. Once developed, the 3D stratigraphy will be used to generate the structural framework (layer tops and bottoms) of the groundwater flow and solute transport model for the northeast quadrant.

Eight detailed geologic cross-sections have been completed within the northeast quadrant. The eight cross sections are currently being updated with information from the new wells. In addition, four new cross sections are currently being generated to extend stratigraphic correlations to new well cluster locations. Six water bearing units comprised of sandstone have been identified from the stratigraphic correlations. Each sandstone unit is separated by relatively continuous shaley zones. These units make up the water bearing hydrostratigraphic units (HSU) that will be simulated in the groundwater flow and solute transport models.

2.2.9.3 Geostatistical Analysis of Geologic Heterogeneities

Tinker has undertaken an effort to determine the length over which stratigraphic correlations can be made and to determine the probability of sandstone and shale distributions in areas of limited data coverage using geostatistical methods. The results of this investigation indicate that stratigraphic correlations can be made over relatively long distances (on the order of 500 to 1,000 feet). At distances greater that 1,000 feet, lithologies cannot be predicted with a high level of confidence from the existing data distribution. The implications for modeling efforts are that model layers (sandstone and shale beds) and their associated hydraulic parameters can be extended a distance of approximately 500 feet beyond existing data points with a relatively high degree of confidence using geostatistical methods.

2.2.9.4 Evaluation of Existing Monitoring Wells

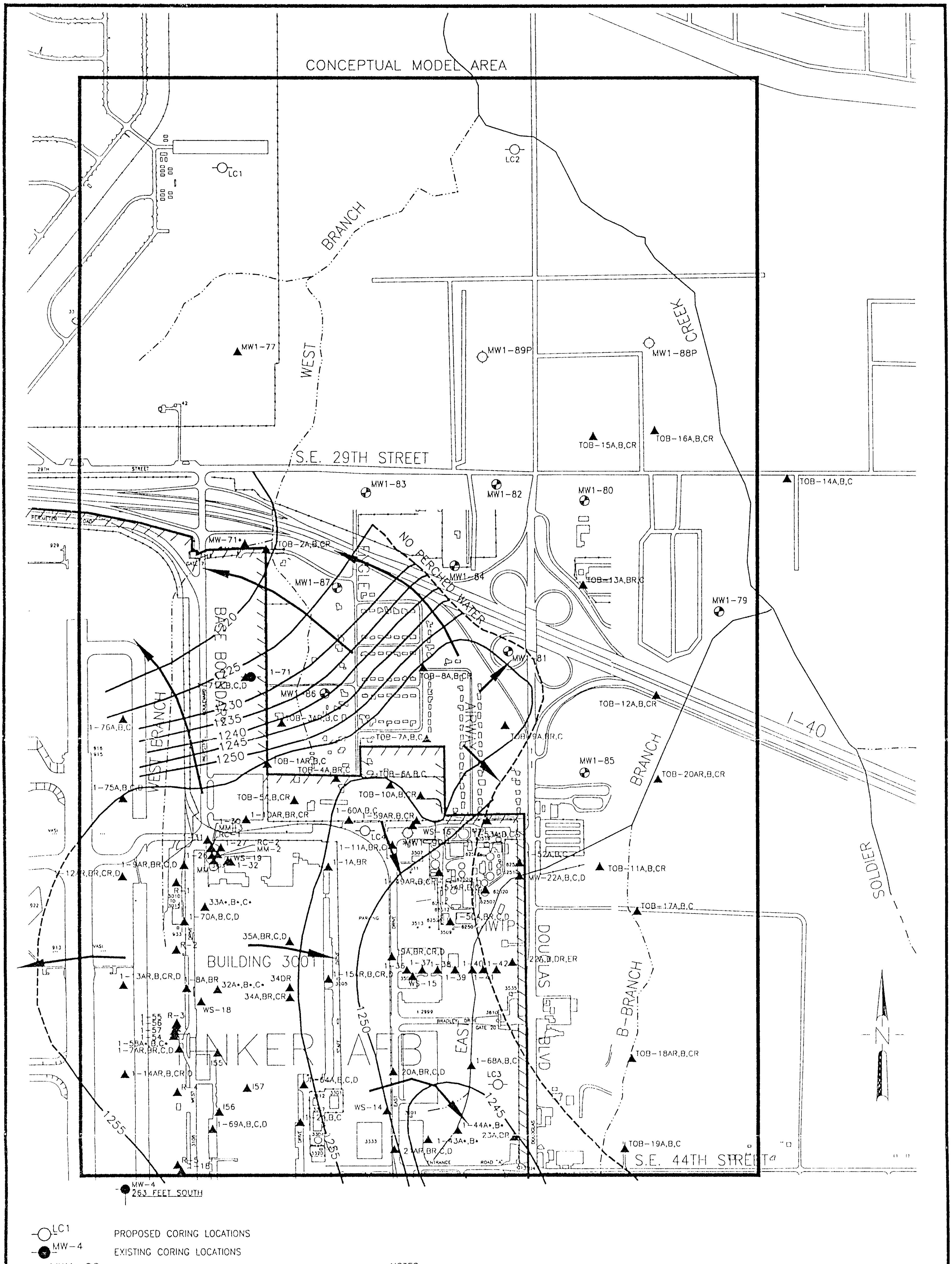
Examination of monitoring well construction information during development of the initial conceptual model for the northeast quadrant indicated that a number of wells had been screened within or across low conductivity shaley zones and others had been poorly constructed. In addition, new monitoring well locations were identified to better delineate the extent of contamination and to fill data gaps noted during preliminary development of the conceptual model.

Existing monitoring wells were evaluated using the well completion diagrams, geologic cross-sections, well hydrographs, and water table and potentiometric surface maps. Many monitoring wells were discovered to have excessively long filter packs that penetrated one or more shale beds. Wells which penetrate shale beds may allow downward migration of groundwater and contaminants giving a false impression of the dimensions of a contaminant plume. In addition, water levels taken from poorly constructed wells may be distorted which interfere with evaluating the direction and flow rates of the groundwater. The result of the evaluation was a list of wells to be plugged, abandoned, and replaced.

Monitoring wells determined to be poorly constructed in the northeast quadrant of Tinker AFB have been abandoned and replaced with new wells. In addition, new monitoring well clusters were installed to fill data gaps. Locations for new monitoring wells were determined from the extent of the plume as indicated by water quality samples collected from the existing wells, and from data gaps identified during construction of geologic cross-sections. Preliminary groundwater modeling efforts indicated the need for deep hydrogeologic data to define the bottom model boundary. As shown in Figures 2.5 and 2.6, sixteen new well clusters with three or four wells each have been installed at new locations to depths up to 245 feet below land surface to define the extent of contamination and to fill data gaps. One or two deeper monitoring wells were added to twelve existing clusters to gather similar information at critical locations where only shallow monitoring wells had existed.

2.2.9.5 Monthly Water Level Measurements

Tinker has undertaken a task to measure water levels on a monthly basis in monitoring wells installed within the northeast quadrant. The water levels are being measured over a 12 month period to provide information on seasonal fluctuations in water level elevations and groundwater flow directions and gradients. Eleven continuous water level recording devices have been installed to monitor short term responses to recharge events and pumping stresses. Hydrographs have been constructed from water level data collected from 1985 through July 1993. In addition, monthly water table maps and potentiometric surface maps have been constructed for four different water bearing hydrostratigraphic units (predominantly sandstone). Data used to generate the maps was collected from monitoring wells



-○ LC1 PROPOSED CORING LOCATIONS
-● MW-4 EXISTING CORING LOCATIONS
○ MW1-90 PROPOSED PIEZOMETER CLUSTER
◐ MW1-87 PROPOSED MONITORING WELL CLUSTER
▲ nnn R,• EXISTING MONITORING WELL CLUSTER
R=REPLACEMENT WELL
•=PLUGGED AND ABANDONED
→ APPROXIMATE GROUNDWATER FLOW DIRECTION
—1255— GROUNDWATER TABLE ELEVATION (FEET ABOVE MSL)
— · · — INTERMITTENT STREAM
——— PERENNIAL STREAM
/////// BASE BOUNDARY

SOURCE: BLACK AND VECH. 1993

NOTES:

1. GROUNDWATER ELEVATION CONTOURS ARE BASED ON WATER LEVELS MEASURED JULY 29 AND 30, 1991.
2. THE AREA AROUND WELLS TOB-3, TOB-2, AND 71 HAS BEEN CONTOURED AS A CONTINUOUS WATER SURFACE WITH THE PERCHED WATER ON-BASE, BUT MAY REPRESENT A SEPARATE PERCHED WATER SURFACE WITH NO PHYSICAL CONNECTION.
3. THE AREA AROUND WELLS 1-43 AND AND 1-44 HAS BEEN CONTOURED WITH THE OTHER PERCHED WELLS IN THE AREA BUT MAY REPRESENT A SLIGHTLY DEEPER STRATUM WITH A LOWER HEAD THAN THE SURROUNDING WELLS.

0 500 1000
SCALE FEET

FIGURE 2.5
WATER TABLE MAP FOR USZ CONCEPTUAL MODEL AREA

TINKER AFB, OKLAHOMA

AREAWEL2 5/12/94

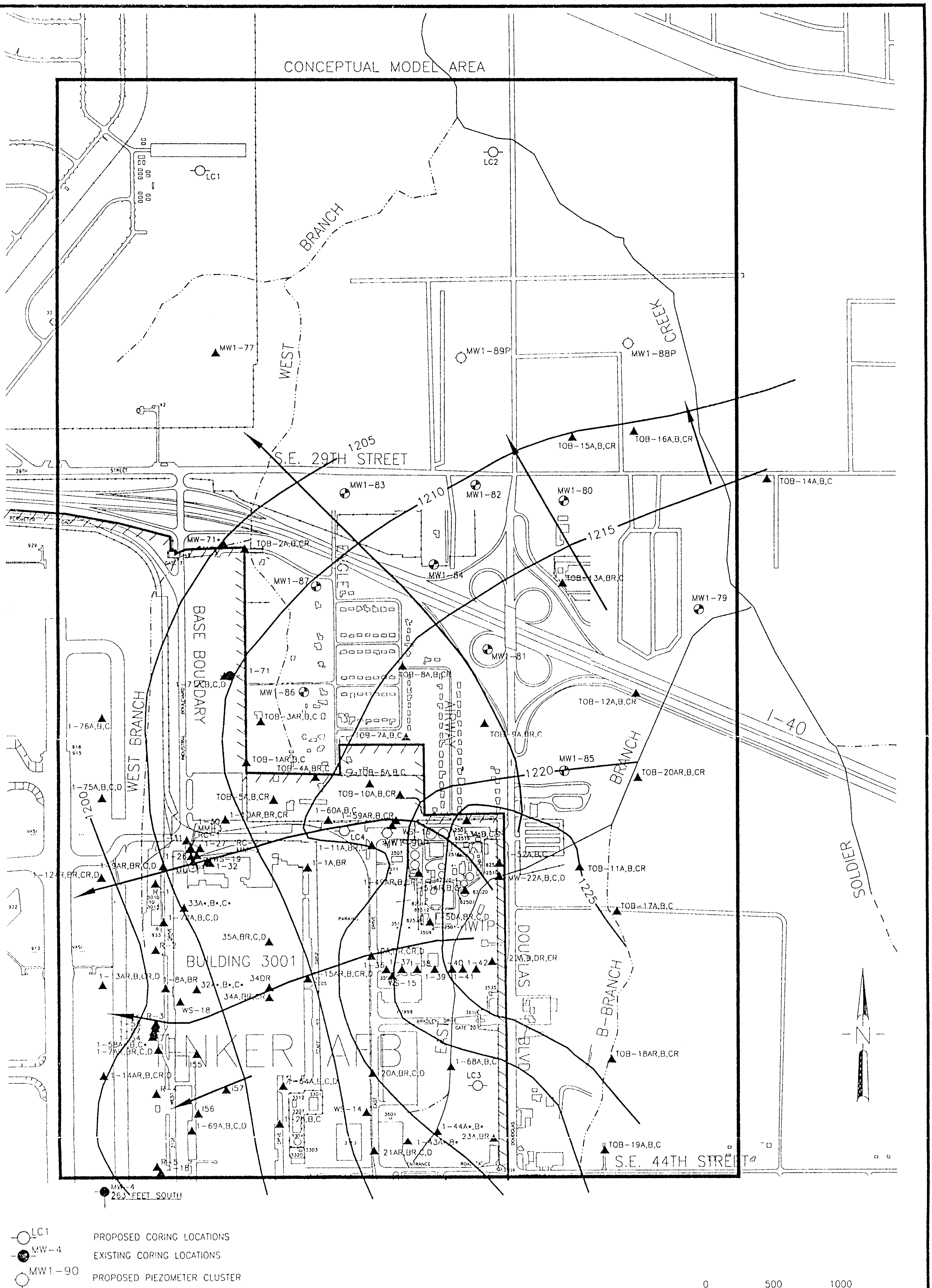


FIGURE 2.6
POTENTIOMETRIC MAP FOR LSZ
CONCEPTUAL MODEL AREA

TINKER AFB, OKLAHOMA

AREAWEL2 5/12/94

screened only within a single discrete hydrogeologic horizon. The horizons correspond to the layers (or HSUs) identified during the 3D stratigraphy task. The water level data will be used to establish steady state conditions and calibration targets to be simulated by the groundwater flow model. These conditions include groundwater level elevations, flow directions, and gradients. They may also be used to specify boundary conditions including no flow, specified flux, and specified head boundaries for the model.

2.2.9.6 Influent/Effluent Study of Soldier Creek

The objective of this study is to determine the direction and quantities of water moving between Soldier Creek and the underlying aquifers. This effort will indicate if sections of Soldier Creek are a source of recharge and/or discharge to the underlying aquifer and if seasonal reversals might affect this flow system. Data collection is currently in progress and is divided into stream discharge measurements and streambed permeability measurements. The stream areas under investigation are described and illustrated in Section 5.1.3.

Stream discharge is currently being measured at five gaging stations along the east and west branches of Soldier Creek. Stream stage measurements are being collected by continuous recorders at each station. Measurements began in late November of 1992. The quantity of water flowing past each gaging station is periodically calculated by measuring the velocity and cross-sectional area of the stream using techniques developed by the U.S. Geological Survey. These discharge measurements are made at different stream stages in order to establish a stream rating curve. The continuous stage measurements from the recorders are converted into continuous discharge measurements using the stage-to-discharge relation established by the rating curve. Data from this task will be used in the groundwater flow model to simulate stream segments which gain or lose significant quantities of water and also to perform streamflow recession analyses.

In situ streambed permeability measurements are currently being initiated to quantitatively examine the hydraulic properties of the streambed. The measurements involve mapping the spatial distribution of hydraulic properties in each reach of the stream over the entire northeast quadrant area. These properties include locations of pools, riffles, and runs, and the distribution of geologic materials (sand, gravel, clay, etc.) present in the streambed. Following the mapping, locations for permeability measurements will be selected and tested. The permeability measurements involve measuring the gradient across the streambed and measuring the flux (volume per unit time per unit area) across the same section of the streambed. This information will be used to calculate the hydraulic conductivity of the streambed.

2.2.9.7 Distribution of Coefficient (K_d) Measurements for Soils Near Building 3001 Tinker AFB

The objective of this study is to determine the distribution coefficients (K_d) of four selected volatile organics and four selected heavy metals identified as possible contaminants in the Building 3001 study area. The K_d values can be used to estimate the effectiveness of remedial efforts as well as provide data for predictive modeling and optimization of remedial cleanup. Efforts to determine K_d values for the hazardous contaminants identified in the groundwater beneath the northeast quadrant have been underway since August 1992. The contaminants examined included four industrial solvents (trichloroethylene [TCE], 1,1-dichloroethylene [1,1-DCE], 1,2-dichloroethylene [1,2-DCE], and tetrachloroethylene [PCE]) and four metals (chromium [Cr], lead [Pb], nickel [Ni], and barium [Ba]). The K_d values will be used to quantify sorption reactions (i.e., adsorption and ion exchange) between the contaminants and the granular porous geologic media. These and other geochemical interactions determine the relative rates at which the contaminants travel with respect to purely advective groundwater flow. This study will provide data for predictive solute transport modeling and optimization of remedial cleanup efforts at the northeast quadrant. Isotherm tests and two of three column tests for metals have been completed. Column studies on the solvents are in progress. Information gained from the isotherm and column studies will be used to determine the respective K_ds.

2.2.9.8 Work Plan and Data Compilation

Battelle compiled and evaluated geologic and hydrogeologic data for Tinker AFB and its immediate vicinity. Tinker AFB and other sources of information (USGS, ODEQ and OSDH) were consulted during the data collection process. A preliminary conceptual model was developed to aid in the data compilation and evaluation effort and in the generation of the base-wide work plan. To gain a better conceptual understanding of the geology for the base-wide model, two base-wide hydrogeologic cross-sections were prepared. The most significant observation from these cross-sections is that the Garber Sandstone and Wellington Formation of the Central Oklahoma Aquifer can be divided into three major water-bearing units. These units are referred to as the upper Garber-Wellington (G-W), the middle G-W, and the lower G-W.

A detailed modeling Work Plan was prepared to (1) refine the preliminary conceptual model, (2) prepare a numerical model representative of the physical system for the entire base, (3) calibrate and verify the model, and (4) prepare a final hydrogeologic modeling report. The Work Plan also presents potential applications of the base-wide model and two methods that can be used to construct local site-specific models for any area on base from the base-wide model.

2.2.9.9 Tinker AFB Monitoring Wells Plug, Abandonment, and Replacement Activities

Tinker AFB is currently plugging, abandoning, and replacing monitoring wells that are known to have screened zones that cross confining layers or have construction defects. At the time this work plan is being prepared, approximately 100 monitoring wells had been plugged and abandoned, and approximately 100 replacement wells had been installed at or near the same location. An additional 50 (approximate) wells are scheduled to be installed. As part of this program, a deeper zone is being screened at all the well clusters being replaced. Information from all of these well clusters will more accurately represent hydrologic and groundwater chemistry conditions at each location.

2.2.9.10 RCRA Facility Investigation at the IWTP and SWTP

Engineering-Science has performed a RCRA facility investigation at the IWTP and SWTP. The investigations were primarily limited to the surface soils and subsurface unsaturated zones beneath both sites. Some sediment sampling was performed on the east branch of Soldier Creek. Information gathered from these investigations will help to identify potential surface sources of contamination that could have migrated through the vadose zone and into the groundwater (ES, 1994e).

2.2.10 Tinker AFB Long Term Monitoring Projects

Long term monitoring (LTM) projects are described in reports prepared by CDM Federal Programs (CDM, 1993) and Roy F. Weston, Inc. (Weston, 1993). These reports describe areas of the base where quarterly groundwater sampling is performed. Data that is relative to this project will be used (where practical) in conjunction with the groundwater sampling conducted during the SCGW investigations. Sampling of new cluster wells will coincide as close as possible with the long-term monitoring to provide a complete picture of the contaminant plume(s) over a discrete time interval. Therefore, the plumes (or trends) established by the LTM could be projected into the new well area, if possible.

2.3 CONTAMINATION PROBLEM DEFINITION

Several contaminants have been detected in the groundwater at the site. The primary contaminants are TCE and chromium (Cr). Other organic contaminants found in the groundwater include chlorobenzene, 1,1-dichloroethene, 1,2-dichloroethene, PCE, 1,2-dichloropropane, and vinyl chloride (VC). All of these chlorinated hydrocarbons have been detected in the groundwater on-base. The on-base contamination has been attributed to past waste management practices at Tinker AFB (USACE, 1988a). Some of this on-base contamination may have migrated off-base. The extent of the possible off-base contamination that is directly related to the on-base contamination is unknown and is the focus of this investigation. The groundwater underneath the IWTP (Figure 2.5) is also the focus of this RI. Some potential sources located off-base may have contributed to contamination of the groundwater in the SCGW. A list of constituents of potential concern is presented in Table 2.2.

2.4 CONTAMINATION MIGRATION/ENVIRONMENTAL HEALTH EFFECTS

Previous investigations indicate that the groundwater contamination from the Building 3001 NPL site is generally flowing toward the southwest on-base but has one possible component migrating to the north in the USZ. Contaminants have been detected in some off-base private wells and a few of the base supply wells. The

Table 2.2
Tinker AFB SCGW RI/FS
Constituents of Potential Concern

Volatile organic compounds (SW-8260)*	Metals (SW-3005/SW-6010)*
Benzene	Antimony**
Chlorobenzene	Arsenic
Chloroform	Barium
1,1-Dichloroethane	Beryllium**
1,1-Dichloroethene	Cadmium
cis-1,2-Dichloroethene	Chromium (total)
trans-1,2-Dichloroethene	Chromium (VI)
1,2-Dichloropropane	Chromium (III)
Ethylbenzene	Copper
Methylene chloride	Lead (SW-3005/SW-7421)
Tetrachloroethene	Mercury (SW-7470, liquids; SW-7471, solids)
Toluene	Nickel
1,1,1-Trichloroethane	Selenium (SW-7740)
Trichloroethene	Silver
1,2,4-Trimethylbenzene	Thallium**
Vinyl chloride	Zinc
Xylenes (total)	
	Cyanide*** (SW-9010)
Semivolatile organic compounds (SW-8270)*	
Bis (2-ethylhexyl) phthalate	
1,2-Dichlorobenzene	
1,3-Dichlorobenzene	
1,4-Dichlorobenzene	
Di-n-octyl phthalate	
Naphthalene	
Other priority semivolatiles** (including pesticides and PCBs)	

* The compounds of concern are those contaminants that can be attributed to the Tinker AFB post waste disposal activities EPA solid waste methods.

** Priority pollutants not found in Tinker AFB wells but will be analyzed for groundwater for the newly installed monitoring wells and wells that have never been sampled before.

*** Cyanide is one of the 129 priority pollutants and will be analyzed for groundwater for new wells and wells that have never been sampled before. The other two priority pollutants that will not be analyzed are dioxin and asbestos.

primary route for human exposure to the groundwater contaminants is through ingestion of the water from these abandoned wells.

Some contamination has also been detected in surface water and sediment samples collected from Soldier Creek downstream of the base. A record of decision (ROD) was signed by EPA on 16 September 1993 for the sediments and surface water in Soldier Creek. As part of the ROD, Tinker AFB has implemented an ongoing program of the sediments and surface water sampling. Since a ROD is in place for the sediments and surface water in Soldier Creek, surface water and sediment risks will not be assessed in this SCGW RI.

2.5 INITIAL REMEDIAL MEASURES

As a result of the groundwater contamination found on-base and off-base, some private and public supply wells located north of the base and a few of the base supply wells were abandoned. City water has been provided to the well users in the area therefore allowing them to stop using the wells and prevent the ingestion of potentially contaminated groundwater.

2.6 INVESTIGATION STUDY AREA

The SCGW conceptual model and RI/FS focus study area is presented in Figure 1.2. The SCGW includes the groundwater under and adjacent to Soldier Creek where contamination may have originated from the Soldier Creek/Building 3001 National Priorities Listed (NPL) site. Also, the IWTP may have been a source of groundwater contamination.

The focus study area is delineated by the cross-hatch fill pattern in Figure 1.2. The purpose of this area is to (1) determine if and where Soldier Creek discharges to the groundwater; (2) focus the intrusive field investigation on the groundwater contamination north and east of building 3001 with the goal of identifying the potential existence of multiple contaminant sources and separating them, if possible; (3) delineate the extent of potential Tinker-related contamination within this area; (4) investigate the hypothesis that contamination in the USZ located within the focus study area is not capable of moving north of I-40 due to the areal limits of the USZ; (5) determine what is the fate of the groundwater contaminants within this area, i.e., do they discharge into Soldier Creek, discharge to the surface, or migrate vertically into the LSZ; (6) perform a risk assessment, if necessary, to evaluate the impact of potentially identified groundwater contaminants on human health and the environment.

The conceptual model area encompasses property that lies within the base boundary and off-base property that lies north of the base along Douglas Boulevard. The area is delineated by the outside edge of the stippled rectangle in Figure 1.2. The rationale for delineating this area is as follows: (1) The reaches of Soldier Creek inside the conceptual model area are the most likely to interact with the groundwater associated with the Soldier Creek/IWTP operable unit. (2) The conceptual model must account for the area surrounding the focus study area for the purpose of extrapolating geologic and hydrologic information across it. (3) If contamination is found, the source of the contamination must be delineated in terms of whether the IWTP, Building 3001, Soldier Creek, or some other area is responsible. Currently, existing data do not clearly determine where contamination located north of the IWTP originated.

SECTION 3

WORK PLAN RATIONALE

3.1 PROJECT OBJECTIVES

This work plan outlines a program for the SCGW RI/FS. It includes a project/site history, a description of the current understanding of the site environmental setting, a review of existing site data, identification of possible remedial alternatives, identification of data needs and quality objectives, and a discussion of the RI/FS tasks. The objective of this project is to acquire data to define the nature and extent of groundwater contamination, to evaluate the risks to human health, welfare and the environment, and if needed, to perform an FS for the selection of a cost-effective remedial alternatives. The RI/FS is designed to gather sufficient information to support decisions as to the risks posed by contaminants at the site and potential remedial alternatives to address those risks.

3.2 SCOPING DOCUMENTS

The documents used in preparation of this work plan are listed below.

- Statement of Work for the Remedial Investigation/Feasibility Study on the Soldier Creek/IWTP Groundwater Operable Unit of the Soldier Creek/Building 3001 National Priorities Listed Site, Tinker Air Force Base, August 25, 1993
- Statement of Work for A-E Environmental Services, Tinker Air Force Base, March 1993 (hereinafter referred to as basic SOW)
- Building 3001 Remedial Investigation Report, USACE Tulsa District. January 1993
- Off-Base Groundwater Investigation Report Northeast of Tinker AFB, USACE Tulsa District. October 1991
- Soldier Creek Remedial Investigation Report (B&V, 1993)
- Soldier Creek Risk Assessment Report (B&V, 1993)
- Battelle ongoing studies
- Other guidance documents listed in reference section.

3.3 DATA NEEDS AND GAPS

The data available regarding site and contaminant characteristics have allowed for the general identification of potential source areas, contaminant pathways, and receptors. The existing data are of insufficient quantity and quality to complete the understanding of the hydrogeology and the interaction of Soldier Creek with groundwater in the area northeast of Tinker AFB. Therefore, collection of additional data is necessary.

Data generated during the RI will be used for:

- Site characterization
- Health and safety
- Human health risk assessment
- Environmental assessment
- Evaluation of remedial alternatives
- Engineering design of remedial alternatives.

Table 3.1 lists data uses for activities performed during the SCGW RI/FS.

Contamination has been detected in the groundwater at the SCGW. Therefore, information regarding the nature and horizontal and vertical extent of any groundwater contamination is required so that the risk associated with contact and/or ingestion of the groundwater can be assessed.

Data required to support the RI/FS include:

- Data on the presence, nature, and magnitude of contaminants in groundwater
- Data concerning the potential migration of contaminants in the SCGW
- Data on the risk to human health and the environment resulting from exposure to contaminated groundwater
- Data on the physical constraints associated with groundwater extraction and/or treatment.

The work conducted at the Building 3001/Soldier Creek NPL site has already produced a significant amount of data on the geology, hydrology, and chemical contamination. However, there are some data gaps specific to the SCGW the RI/FS will address. A list of the data gaps are as follows:

- The relationship between Soldier Creek and the groundwater within the boundaries of the SCGW
- The hydrostratigraphy of the northeast quadrant and the groundwater flow and interaction of USZ and LSZ
- The extent of groundwater contamination from on-base

Table 3.1 RI/FS Data Uses
Tinker AFB, SCGW RI/FS

Activities	Data Use						
	Site Characterization (Including Health & Safety)	Risk/Env. Assessment	Evaluation of Alternatives	Engineering Design of Alternatives	Monitoring During Remedial Action	Principal Responsible Party (PRP) Determination	Northeast Off-base Groundwater Model
Groundwater Sampling	√	√	√				
Sediment Sampling	√	√	√				
Geophysical Logging	√						√
Soldier Creek Discharge Rates Determination (volumes/direction temporal nature)	√	√					√
Aquifer Pumping Tests	√	√	√				√
Deep Coring	√						√
Inspection of Private Wells	√	√				√	√
Soil Sampling	√					√	

Note: Check appropriate box(es)

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- The hydraulic relationship between the groundwater and Soldier Creek (i.e., whether Soldier Creek is discharging to the groundwater or receiving recharge)
- Geohydraulic characteristics of the USZ and LSZ (hydraulic conductivity, transmissivity, storativity, leakage)
- Hydraulic characteristics and hydrologic regime of Soldier Creek (flow rates and stream bed permeability)
- Possible impact of contamination to nearby private wells
- Characterization of the groundwater quality in the USZ and LSZ of the SCGW
- Physical and chemical parameter for feasibility study.

3.4 DATA QUALITY OBJECTIVE NEEDS

The data quality requirements were developed based on the anticipated use of the generated data, the appropriate analytical levels, contaminants of concern, the contaminant concentration levels of concern, and detection limit requirements. The Data Quality Objectives (DQOs) are for:

- Site characterization
- Risk assessment
- Off-base source identification
- Evaluation of remedial alternatives.

The analytical level for chemistry will be level III for most parameters using EPA methods. The data quality requirements and objectives are presented in the project DQOP.

3.5 WORK PLAN APPROACH - RI/FS TASKS

The SCGW RI/FS will be conducted with the following tasks.

- Task 1: Historical Review and Windshield Survey
- Task 2: Inspection of Private Wells
- Task 3: Soldier Creek Streamflow Survey
- Task 4: Lithologic Coring
- Task 5: Monitoring Well Installation and Sampling
- Task 6: Conceptual Model
- Task 7: Aquifer Pumping Tests
- Task 8: Soil Sampling
- Task 9: Sediment Sampling
- Task 10: Sample Analyses.

SECTION 4

REMEDIAL INVESTIGATION SCOPE OF WORK

4.1 PROJECT PLAN

4.1.1 Task 1: Historical Review and Site Reconnaissance Survey

The purpose of this task was to determine if potential sources of groundwater contamination exist within the project area and to review other relevant information based on technical reports prepared to date. Information from projects that are ongoing was collected and reviewed. ES field staff supplemented this information with data gathered from a site reconnaissance survey of the area designed to locate previously identified sources and identify new potential sources.

The information collected during this task was used primarily for the preparation of this RI/FS work plan to identify the locations of needed monitoring wells, soil sampling points, and lithologic borings. The information derived from task one has also been used to identify potential sources of information (existing private wells), potential sources of contamination and to identify land use patterns. Figure 4.1 shows the potential sources of groundwater contamination within the project area.

4.1.2 Task 2: Inspection of Private Wells

The purpose of this task is to obtain geophysical information to assist in developing geological cross-section for this area. Sampling of private wells will indicate if groundwater contamination has occurred. Approximately twelve private wells have been identified during the historical review and will be geophysically logged with natural gamma ray (GR), and caliper (CAL) tools to acquire geological and well construction information. Television cameras will primarily record the condition of the existing casing. Once the logging has been completed for all of the wells, each well will then be sampled and analyzed for the chemical parameters listed under Task 10. A small submersible pump will be lowered into each well to purge the well prior to sampling. (For detailed procedures, see the field sampling plan [FSP].) If the pump cannot be used to purge the well, the well will be bailed.

During the historical review, information on the locations of private wells in the study area was obtained. The State of Oklahoma Department of Environmental Quality (ODEQ) has conducted an extensive survey of the private wells in the off-base area north and east of the study area. Information collected during this survey

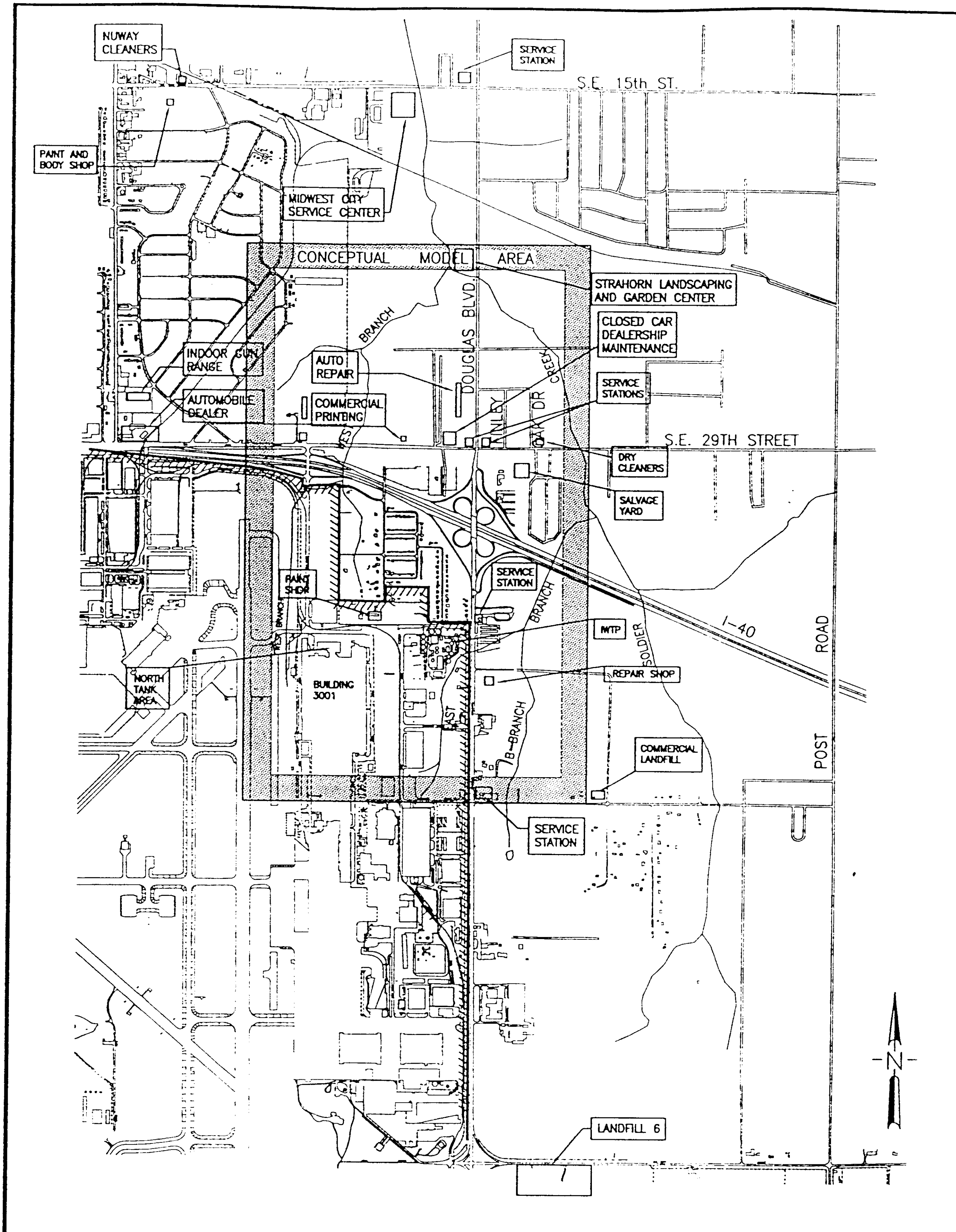

FIGURE 4.1
POTENTIAL SOURCES
OF GROUNDWATER
CONTAMINATION

TINKER AFB, OKLAHOMA

OFBASEPL 5/16/94

and chemical data on samples from some of these wells are maintained in a data base by the State of Oklahoma.

ES has obtained a copy of the data base and has used that information in selecting the wells which may be sampled as part of the RI/FS. A list of the proposed wells to be sampled and logged has been compiled. Field confirmation of the preliminary list of wells has been conducted to assure that the wells still exist and that they are readily accessible for sampling and geophysical logging. The following criteria will be used in the selection process:

- Preference for wells abandoned by the owner or no longer in use to avoid interrupting the owner's water supply
- Location with regard to existing and proposed monitoring wells
- Depth of intake or screened zone (USZ or LSZ)
- Access to the well head by the geophysical logging truck
- Preference for wells which do not have pumps currently installed.

It has been found that over twenty off-base private wells are scheduled for plugging and abandonment by Oklahoma County by the end of June 1994. The wells are located north and east of Tinker AFB boundaries and are approximately 100 feet deep or more. Tinker AFB is currently preparing to secure right-of-entry permits from the well owners. No wells that are currently being used as a water supply will be surveyed or sampled. The sampling of the private wells will follow the sampling procedures outlined in the companion FSP (ES, 1994a). Only one round of groundwater samples will be collected, because it is anticipated that the wells will be plugged and abandoned by the end of June 1994. Figure 4.2 shows the locations of the twelve domestic wells to be sampled.

Soil samples will also be collected at each well location where groundwater contamination is found as described in Task 8.

The location of all private wells inspected during this task will be surveyed by a subcontracted land surveyor. All surveying will follow the specifications outlined in the FSP.

4.1.3 Task 3: Soldier Creek Streamflow Survey

This task is a continuation of field work currently being conducted by Battelle at Tinker AFB. The current work involves measuring the discharge of Soldier Creek at six locations downstream from the base and measuring the hydraulic conductivity of the streambed. In Task 3, Battelle will acquire, install, and maintain two additional gaging stations. These two stations will be used to supplement the existing six gaging station network and fill data gaps for several important reaches of the stream.

The hydraulic conductivity of the streambed will be measured at six new locations to provide additional detail in areas that are not currently being measured. In conjunction with the streambed hydraulic conductivity measurements, the vertical hydraulic gradient across the streambed will be determined near each of the six

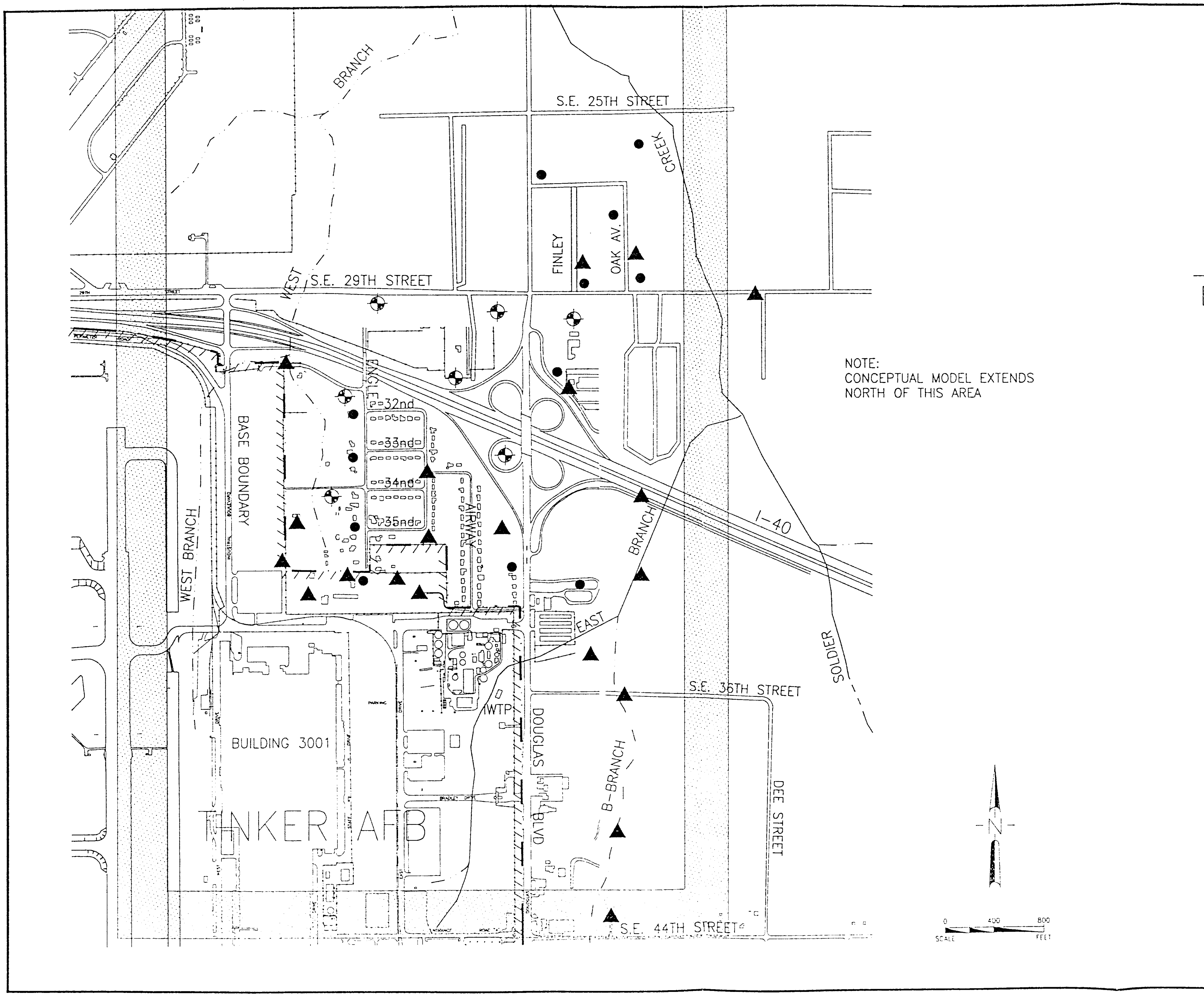

FIGURE 4.2
PROPOSED RESIDENTIAL W
SAMPLING LOCATIONS

TINKER AFB, OKAHOMA

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locations. These gradient measurements will be performed four times to observe if seasonal variations affect the direction or magnitude of water flowing across the streambed.

Information from all of these tasks will be integrated with other hydrogeologic data to further enhance the current understanding of the occurrence and movement of water within the area of the investigation. All of the stream discharge, vertical hydraulic conductivity, and hydrogeologic data will be used to determine how Soldier Creek interacts with the near-surface and underlying aquifer zones. Gaining and loosing stream segments will be identified and estimates of seasonal baseflow into and out of Soldier Creek will be determined.

4.1.3.1 Stream Discharge Measurements

Stream discharge measurements will involve measuring the stream discharge at the gaging stations to estimate the net water budget for each stream segment between the stations. Low flow conditions dominate the hydrologic regime of Soldier Creek, and thus emphasis will be placed on examining the gains and losses during this type of flow. These measurements will indicate overall gains and losses from each reach between stations. Automatic water level recorders will be installed at two locations in the Soldier Creek drainage basin near Tinker AFB. Figure 4.3 shows the locations of six recorders currently under operation, and the proposed locations of the two additional recorders. Four of the gaging stations are located on Soldier Creek below the Industrial Wastewater Treatment Plant (IWTP) and two of the stations are located on West Soldier Creek, below Gate 7. Entry right-of-way for each new location must be secured by Tinker AFB personnel.

All eight of the gaging stations will be equipped with digital water level recorders. Each gaging station will consist of a Stevens Model 420 Recorder, Submersible Depth Transmitter II, Stevens Data Card, a rechargeable battery, and a weather-resistant enclosure. The type of mounting hardware used at each site will depend on the layout and availability of secure mounting locations.

One or more perpendicular traverses across the creek will be selected at each gaging station for the purpose of establishing a stage-vs-discharge rating curve. Streamflow velocity will be measured. It may be necessary to use several different sections to envelope the flow at different stages of the stream. Changes in the stream channel through time may necessitate moving a recorder, and/or moving the section where the discharge is measured. Moving the recorder will necessitate re-establishing the rating curve.

Stream velocities will be measured with a Price Type AA flow meter "Pygmy" type flow meter or a portable flume. A stage-discharge rating curve will be established by plotting a series of point discharge measurements-vs-stream stage for each measurement. A computer program provided by Leupold and Stevens, the manufacturer of the water level recorders, will be used to calculate point discharge values from the water level and rating curve data. The program will also sum the daily, weekly and monthly discharge at each gaging station.

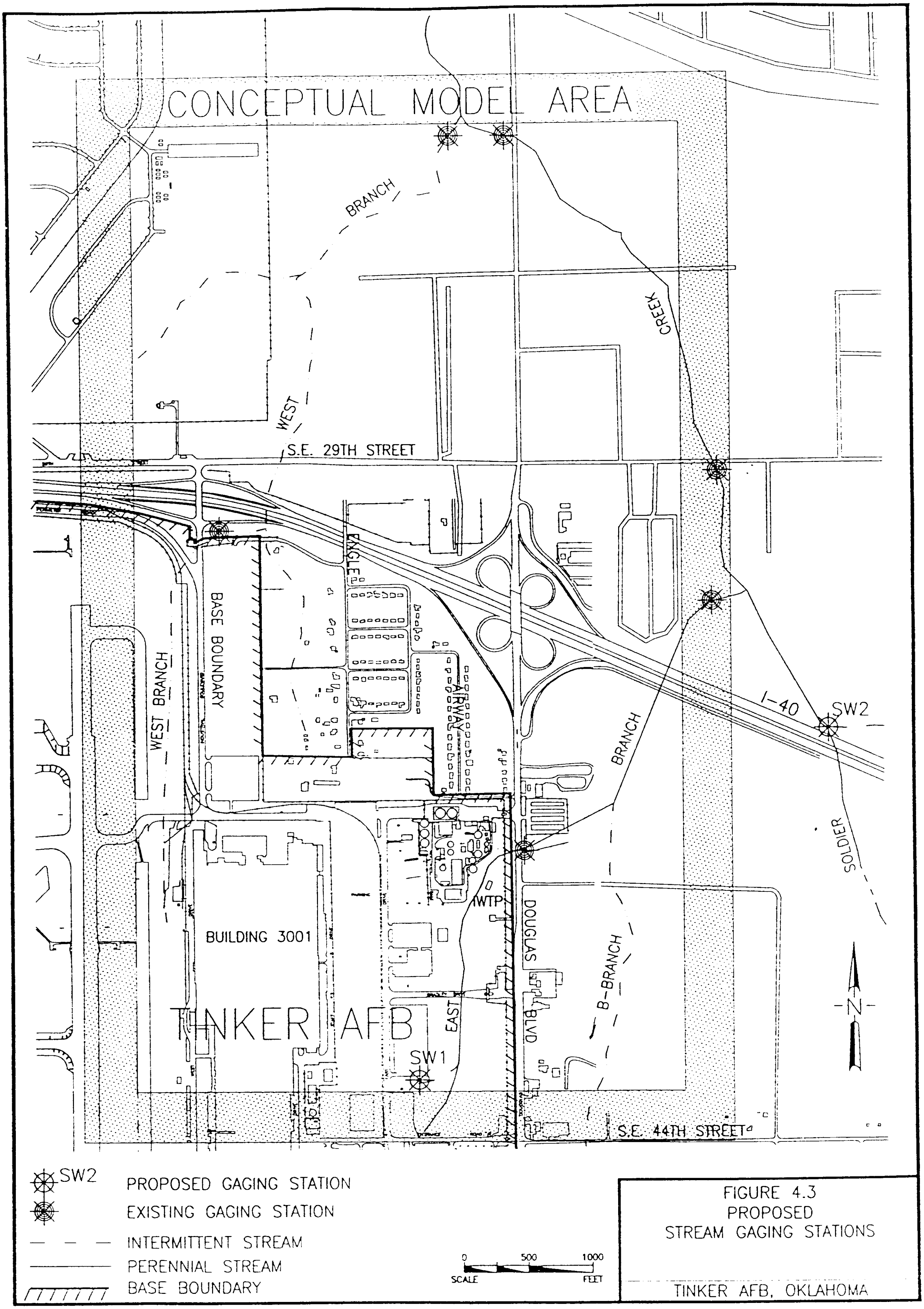

FIGURE 4.3
PROPOSED
STREAM GAGING STATIONS

TINKER AFB, OKLAHOMA

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4.1.3.2 Streambed Hydraulic Conductivity Measurements

This task will involve measuring the vertical hydraulic conductivity of the streambed. Results from this subtask will be integrated with similar data already collected for the groundwater flow modeling effort in the northeast quadrant of the base. This task will also identify areas of high conductivity within the unconsolidated stream sediments where preferential flow is occurring. The shale outcrops in the streambed will not interact with the stream to a sufficient degree that will allow measurement. An attempt will be made to measure the sandstone outcrops in the streambed. This will be accomplished by modifying the equipment and the method slightly to allow the permeameter to be inserted into the sandstone. This task will also indicate if the stream is gaining or loosing water at the measurement point under the seasonal hydraulic conditions present when the measurement is taken. The streambed permeability measurements were not designed to directly measure the stream-aquifer interaction. The method is designed to directly measure the vertical hydraulic conductivity of the near-surface streambed material. The interaction between the stream and the aquifer is determined by integrating all of the available hydraulic and geologic information. The vertical hydraulic conductivity of the streambed and the relative hydraulic gradient between the stream and the underlying alluvial material will determine the direction and quantity of water that will move between the stream and the aquifer. Standard measurement techniques can be employed to directly measure the hydraulic conductivity of the streambed and the hydraulic gradient across the sediments. All reaches of Soldier Creek within the SCGW conceptual hydrologic model area will be examined for potential measurement sites. The water depth, thickness of the alluvium, and access to the stream are all factors that must be considered when selecting measurement locations. Figure 4.4 shows the six stream segments. Streambed permeability will be tested for each of the six segments. These locations will coincide with the piezometers that will be measured every three months to observe seasonal effects on the hydraulic gradient across the streambed.

The method and equipment used to measure streambed hydraulic conductivity is described by Lee and Cherry (1978) and Payne (1992). This method uses a miniature piezometer to measure the hydraulic gradient across the streambed and a seepage meter to measure the flux. The miniature piezometer consists of $^3/_{16}$-inch-OD polyethylene tube with a perforated tip that is wrapped in surgical gauze. The seepage meter is a 8-inch segment cut from the end of a new 55-gallon drum.

The hydraulic conductivity measurements will be recorded on field computation sheets and input into a computer file. The data will be compiled on a spreadsheet at the end of the data collection and recalculated for comparison with the field results. Each installation of the permeameter is tested with three measurement replicates to insure reasonable repeatability of the results. The hydraulic conductivity values are also compared to published values to insure they are reasonable for the type of material being tested.

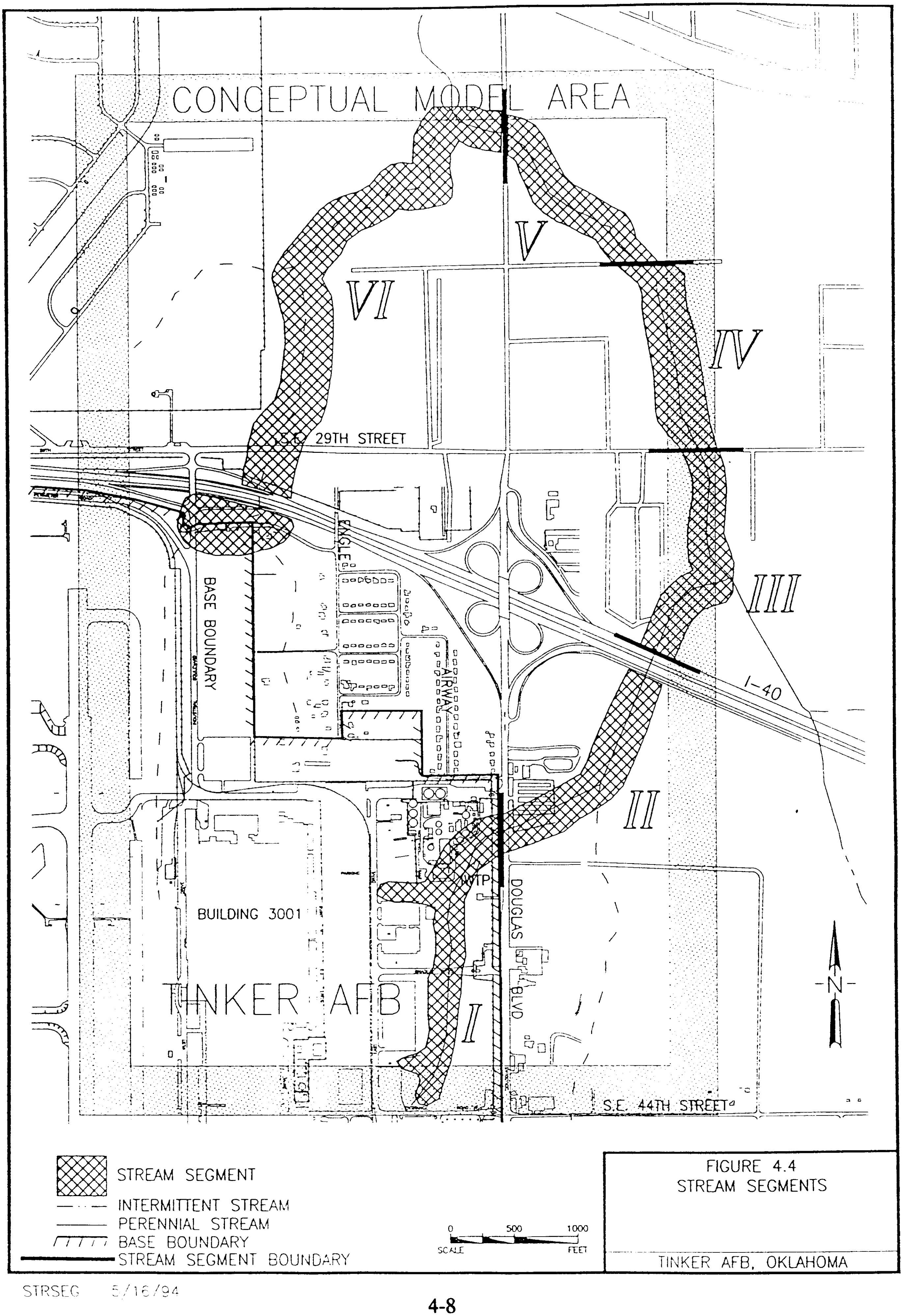

FIGURE 4.4
STREAM SEGMENTS

TINKER AFB, OKLAHOMA

STRSEG 5/16/94

Each individual piezometer must be driven sufficiently deep to permit measurement of the very low hydraulic gradients present in the bottom of Soldier Creek. The streambed in Soldier Creek is typically 2 to 5 feet deep, and the piezometer cannot be easily driven deeper than the top of the underlying consolidated zone. The vertical conductivity measurement method assumes that all of the water is moving strictly in a vertical direction. This is analogous to the assumption in the Theis equation that water flows in a horizontal, radial direction to a pumping well. Therefore, differences in the hydraulic conductivity with depth will be averaged over the depth interval of the piezometer. All water passing through the permeameter is assumed to pass through the same cross section at the depth of the adjacent piezometer. Several conditions can interfere with the permeability measurements. Sites with very low hydraulic gradients do not produce accurate, reproducible results. In areas where the stream current is extremely swift, the mechanical pulsing movement of the equipment can create a pumping action in the measurement device that can affect the magnitude and sometimes the apparent direction of flow. Sediment outgassing and chemical oxygen demand is also a problem, especially in areas where anaerobic conditions exist in the stream sediments. Gas pressure and chemical gradients can both affect the accuracy of the measurement. Vertical streambed hydraulic conductivity measurements that indicate interference by one or more of the above conditions will not be used in the interpretive analysis (Payne, 1992).

The second problem is a direct violation of the assumptions governing the method and can only be avoided by careful observation and experience in the field. The violation of the inherent assumptions with the method is that the stream and the underlying aquifer are not in hydraulic communication. This can only occur when unsaturated conditions exist below the stream or completely impermeable material forms a confining layer. (If a piezometer can be developed in the stream sediment and is capable of producing small quantities of water and returning to an equilibrium state, the material has sufficient permeability to be measured.) The first condition would be detected by continuous production of air from the piezometer during development, which has occurred at one location during previous measurements. The second condition is avoided by not setting permeameters at sites where the piezometer tip cannot be developed due to the presence of extremely fine sediments. If the piezometer cannot be developed, there is no reason to complete the test because the gradient measurement is absolutely necessary in order to calculate the conductivity.

4.1.3.3 Streambed Vertical Hydraulic Gradient Study

This task involves installing nested piezometers near each of the six permeability measurement locations. Four quarterly water level measurements will be collected from the piezometers using equipment similar to the miniature piezometers used in the hydraulic gradient measurements.

The piezometers will be installed in nested sets of three (conditions permitting). The piezometers will be installed to different depths in order to observe the hydraulic gradient across the streambed. In areas where consolidated material occurs at shallow depths, it may not be possible to install the piezometers at three different depths. If conditions permit, the piezometers will be protected with steel surface casings and reused for each of the four seasonal measurements.

It is likely that the piezometers may not be usable after 3 months of exposure in the streambed, especially during periods of high streamflow. In the event the piezometers are not usable, new piezometers will be installed in a nearby location. The exact location of the piezometer clusters will be determined during future reconnaissance surveys of the stream. The locations will be spatially distributed and placed with the intent to collect the most representative values for each stream segment. The results of this subtask will determine if seasonal changes affect the movement of water between the stream and the underlying material.

4.1.4 Task 4: Lithologic Coring

Four 200-foot continuous cores will be drilled prior to monitoring well installation. The cores will be drilled with a 4 7/8-inch OD Christianson Core Barrel sampler. The purpose of the continuous coring is to obtain samples of the geologic formations that can be compared to geophysical logs to substantiate log correlations. Information from previous coring activities lacks sufficient detail to provide adequate development of a baseline for comparing geophysical log response to changes in lithology. Detailed analyses (grain size, permeability, and porosity) of two existing 200-foot core samples collected near monitoring well clusters M-4 and 1-71 are planned as part of the Building 3001 NPL site investigation. The analyses will provide the basis for developing the baseline comparison between geophysical log response and changes in lithology. Coring activities for the Soldier Creek/IWTP RI/FS will be used to supplement the baseline and provide additional geologic data to refine the conceptual model of the site. Figure 4.5 shows the proposed location of each lithologic coring. A description of the location of each coring and the rationale is presented in Table 4.1.

Each of the cores will be logged at 0.5-foot intervals and at each change in lithology by an ES geologist/hydrogeologist in accordance with the procedures outlined in the FSP. The cores will be shipped to a laboratory to be slabbed, photographed, and logged with a natural gamma ray tool. Following the testing, the cores will be packaged and shipped to the University of Oklahoma Core Library. In the event that portions of the recovered cores are shown by the field monitoring equipment to be contaminated, those segments will not be shipped to the University of Oklahoma Core Library after testing. The geophysical testing laboratory will be provided with a container for temporary storage of the samples identified as being

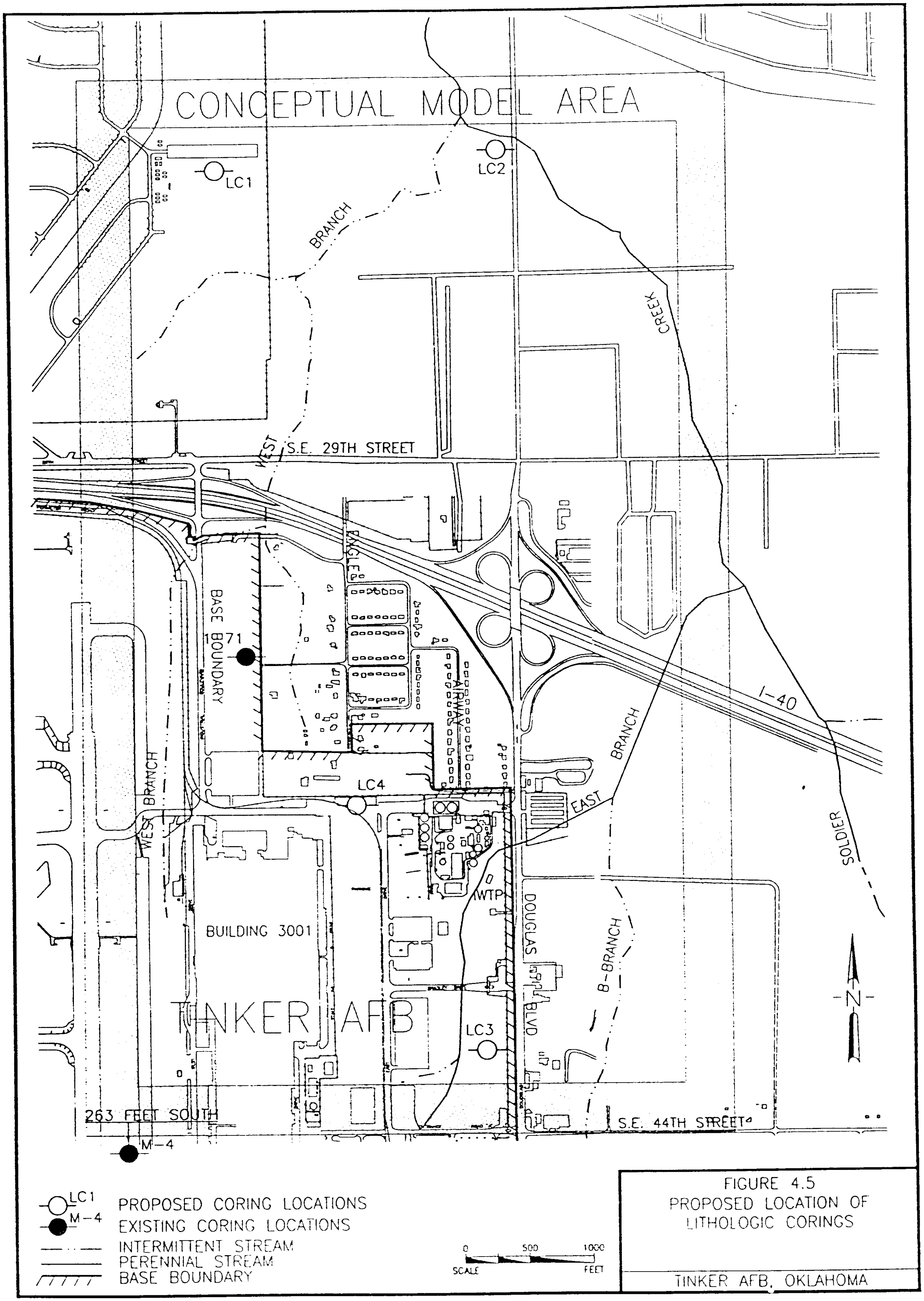

FIGURE 4.5
PROPOSED LOCATION OF
LITHOLOGIC CORINGS

TINKER AFB, OKLAHOMA

LITHCORE 5/12/94

Table 4.1 Proposed Corehole Locations

Corehole ID	Location	Rationale
LC1	Northwest corner of study area	Provide lithologic data for the northwestern corner of the investigation area.
LC2	North of base; just east of Douglas Blvd., near Soldier Creek	Provide lithologic data for north central area of investigation near confluence of West Branch Soldier Creek with Soldier Creek.
LC3	On base, just east of Douglas Blvd., between monitoring well clusters TOB-18 and 1-68.	Provide lithologic data for south-central area of investigation.
LC4	On base, approximately 175 feet west of monitoring well cluster 1-59 in area of proposed 7-day aquifer tests.	Provide additional lithologic data in the area of the proposed pump tests.

Notes: Lithologic data collected at existing coreholes 1-71 and M-4 will be used to supplement the other 4 corehole locations.

1-71 is located on base near the western boundary of the focused study area.

M-4 is located just southwest of Building 3001.

Cores collected at 1-7C, 1-8C, and 1-11C no longer exist and contained very limited lab data. Any data that can be used will be used.

contaminated. After all the testing has been completed, this container of samples will be transported to Tinker AFB for eventual disposal in accordance with all applicable laws and regulations.

Twenty-four samples from the lithologic corings will be collected prior to the packaging of the cores for geotechnical analysis. The sampling procedures will follow those outlined in the FSP. The samples will be analyzed for Atterberg limits, particle size, soil moisture, total organic content, and permeability. In addition each core will be inspected to determine percent recovery and the rock quality design (RQD).

Upon completion, each borehole will be mudded and logged with borehole geophysical tools. Seven geophysical logs will be used: natural gamma ray (GR), caliper (CAL), spontaneous potential (SP), resistivity (R), micro-resistivity (MR), density (D), and neutron (N) logs. All logs will be digitally recorded. The logs will be presented as charts and electronic digital files. Following the borehole geophysical surveys, the borehole will be abandoned and plugged according to procedures defined in the FSP.

All drilling equipment and sampling equipment will be decontaminated prior to drilling each borehole following the procedures outlined in the FSP. Each borehole will be surveyed by a state licensed surveyor as outlined in the FSP.

4.1.5 Task 5: Monitoring Well Construction and Sampling

Nine monitoring well clusters and three piezometer clusters each having three wells per cluster will be drilled and constructed to fill data gaps and needs discussed in Section 3.3. Specifically, the purposes of these wells are (1) to delineate potential groundwater flow paths off-base from the IWTP toward the northeast; (2) to delineate the extent of groundwater contamination off-base that may have occurred from IWTP and Building 3001 sources on-base; (3) to provide data on the hydrogeologic characteristics of the RI/FS site; and (4) to investigate the impacts associated with Soldier Creek.

A significant amount of data on the hydrogeology and contaminant distribution has been gained from previous and ongoing investigations conducted at the Building 3001 NPL site. Depending on the areal extent of the USZ, existing monitoring well clusters generally have one well screened within the USZ and two or three wells with screens set at different levels within the LSZ. Where the USZ is not present, existing well clusters are typically screened at three different levels within the LSZ. As a general guideline, screened intervals for the new monitoring well and piezometer clusters will be set at depths of approximately 40, 90, and 150 feet. Within the areal extent of the USZ, new well clusters will have one screen set in the USZ and two screens set in the LSZ. Clusters installed outside the areal extent of the USZ will have screens set at three different levels within the LSZ. Actual screened intervals will be determined from geophysical logs and the extension of existing cross sections to the new well cluster locations to ensure that the new wells will be screened within consistent hydrostratigraphic units and that the current data gaps and needs will be addressed.

Tentative locations for the new monitoring wells and piezometers are shown in Figure 4.6, and a brief rationale for each cluster is presented in Table 4.2. The tentative locations were selected based on current knowledge of contaminant distribution and existing water table/potentiometric surface data for the USZ and LSZ. Upon completion of the domestic well survey, collection of water level measurements, and sampling of the recently installed monitoring wells as part of the well plugging, abandonment, and replacement, final monitoring well/piezometer locations will be selected.

Prior to the drilling and construction of each well cluster a 180-foot pilot boring will be drilled and geophysically logged with four tools: CAL, SP, single point R, and GR. Data collected from the geophysical logging will be used in consultation with the Tinker AFB hydrogeologist, to determine the screened internal depths for well construction. All twelve pilot holes will be drilled, logged, and plugged before well drilling begins as defined in the FSP. Three soil samples will be collected from each pilot hole for cation exchange capacity (CEC), total organic carbon (TOC), and pH analyses. Once the screened intervals for all twelve well clusters are determined, the wells will be drilled. Once the pilot hole has been geophysically logged, it will be abandoned by plugging with a cement/bentonite grout following the procedures outlined in the FSP. The plugged hole will be marked with a brass marker for future reference. Each drilling rig will be manned by a qualified geologist during drilling and monitoring well installation. The geologist will document drilling activities in the field log, prepare a lithologic log based on drill cuttings, ensure proper rig decontamination, coordinate investigation-derived waste disposal (IWD), ensure site restoration, etc. Each well will be drilled and constructed following the procedures outlined in the FSP (ES, 1994a). Prior to drilling at each cluster location, the rig and all drilling equipment will be decontaminated following the procedures outlined in the FSP (ES, 1994a).

Monitoring well installation and construction will follow guidelines in the *Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells* (EPA, 1989e). The monitoring wells will be constructed of 4-inch diameter PVC casing and wire-wrapped screen. The piezometers will be two inches in diameter and also constructed with PVC screen and casing materials. The filter pack will consist of 10-20 size sand. The screen length will be no more than 10 feet for confined and semi-confined zones and 15 feet for the water table (unconfined) zone. The screen opening is 0.010 inches based on Tinker AFB previous experience. The double casing method will be used for the twelve 90-foot wells and triple casing method will be used for the twelve 150-foot wells to prevent potential cross-contamination between strata. For wells deeper than 100 feet, schedule 80 PVC casing and screen will be used; for depth less than 100 feet, schedule 40 PVC will be used. PVC will be used since it is the best material for organics and heavy metals (EPA, 1992).

Once completed, the wells will be developed following the procedures outlined in the FSP (ES, 1994a). All purge and development water will be contained and transported for disposal at Tinker AFB. Purge and development water will be disposed in accordance with all appropriate laws and regulations as outlined in the

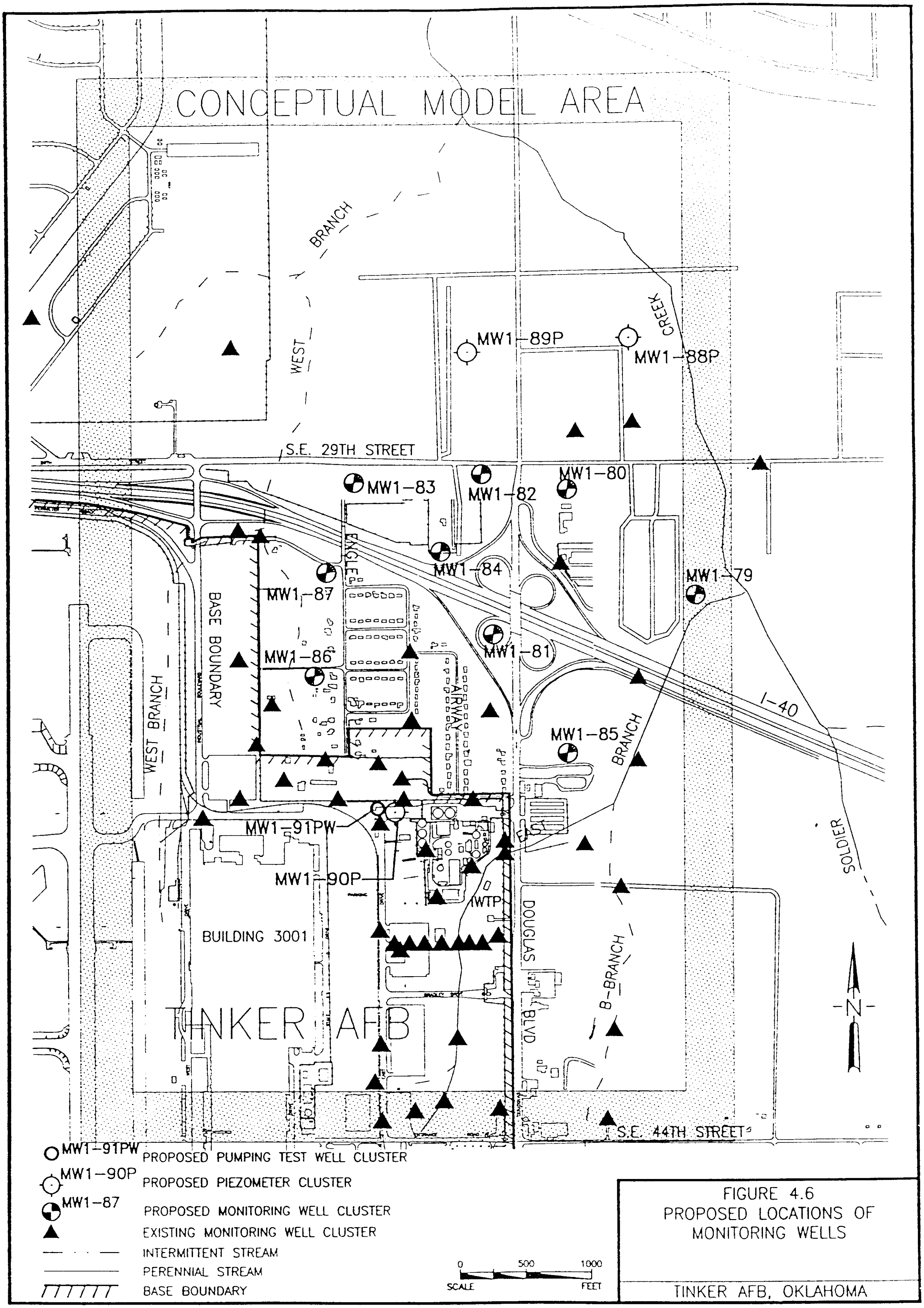

FIGURE 4.6
PROPOSED LOCATIONS OF MONITORING WELLS

AREAWELL 5/16/94

Table 4.2 Proposed SCGW Monitoring Well Locations

SCGW Well ID	Location	Rationale
MW1-79	Northeast of the base; east of the intersection of Douglas Blvd. and I-40 near Soldier Creek.	Further define interaction between Soldier Creek and groundwater; determine if Soldier Creek is a possible source of groundwater contamination.
MW1-80	Northeast of base; northeast of the intersection of Douglas Blvd., and I-40; South of 29th Street.	Located upgradient of potential contaminant sources (gas station, dry cleaner) along 29th St. Aid separation of Tinker source and off-base sources.
MW1-81	Northeast of base; at the intersection of Douglas Blvd., and I-40; inside south-east cloverleaf.	Provide hydrogeologic data to determine direction and rate of groundwater flow moving north-northeast from area of IWTP to off-base areas.
MW1-82	Northeast of base; northwest of the intersection of Douglas Blvd., and I-40; just South of 29th Street.	Located upgradient of potential contaminant sources (gas station, car dealer maintenance lot) along 29th St. Aid separation of Tinker sources and off-base sources.
MW1-83	Northeast of base; northwest of the intersection of Douglas Blvd., and I-40; South of 29th Street.	Provide hydrogeologic data to determine direction and rate of groundwater flow moving north-northeast from area of IWTP to off-base areas.
MW1-84	Northeast of base; just northwest of the intersection of Douglas Blvd., and I-40; South of 29th Street.	Provide hydrogeologic data to determine direction and rate of groundwater flow moving north-northeast from area of IWTP to off-base areas.
MW1-85	Northeast of base; southeast of the intersection of Douglas Blvd., and I-40; West of existing well cluster TOB-20B.	Provide hydrogeologic data to determine direction and rate of groundwater flow moving north-northeast from area of IWTP to off-base areas.
MW1-86	Northeast of base, North of TOB-4 and West of TOB-8 clusters.	Delineate groundwater flow path and extent of groundwater contamination North of TOB4 and West of TOB-8.

Table 4.2, continued

SCGW Well ID	Location	Rationale
MW1-87	Northeast of the base; west of the intersection of Douglas Blvd. and I-40.	Provide hydrogeologic data to determine direction and rate of groundwater flow moving north-northeast from area of IWTP to off-base areas.
MW1-88P	Northeast of the base; northeast of the intersection of Douglas Blvd. and 29th Street.	Delineate groundwater flow paths and gradients in the northern portion of study area north of potential contaminant sources along 29th Street.
MW1-89P	Northeast of the base; northwest of the intersection of Douglas Blvd. and 29th Street.	Delineate groundwater flow paths and gradients in the northern portion of study area north of potential contaminant sources along 29th Street. Also aid further definition of intersection between Soldier Creek and groundwater.
MW1-90P	On base; northwest of IWTP; approximately 100 feet west of existing well cluster 1-59.	Provide observation (drawdown) data for the 7-day aquifer tests.

FSP (ES, 1994a). All equipment used for well development, i.e., bailers, pumps, will be properly decontaminated as outlined in the FSP (ES, 1994a) prior to use at each well.

Groundwater samples will be collected from each well and analyzed for the constituents listed in Task 10. Sample preparation, labeling, water level measurement, well purging, sampling, packaging, filling in chain-of-custody forms, decontaminating samplers, and shipping will follow the procedures outlined in the FSP (ES, 1994a). In addition, a list of on-base and off-base existing wells in the RI/FS focus area is currently being prepared for groundwater sampling concurrent (as close as possible) with the sampling of the newly installed off-base monitoring wells. These wells are currently being verified for location relevant to the focus area and construction integrity. Upon completion of this verification, a complete sampling program will be developed for a "snapshot" sampling event.

Those monitoring wells constructed on private property will require access agreements (right of entry) secured by Tinker AFB personnel sufficient for ES to complete the task. The thirty-six wells and piezometers will be surveyed by a state licensed surveyor as outlined in the FSP.

4.1.6 Task 6: Conceptual Model

The proposed hydrogeologic conceptual model is bounded on the north by the confluence between Main Soldier Creek and West Soldier Creek, on the south by Gate 21, on the east by a north-south line through the confluence between Main Soldier Creek and East Soldier Creek, and on the west by a north-south line parallel to the east edge of the main runway on the Tinker AFB air field (Figure 1.2). These boundaries might be adjusted based on the results of the RI/FS studies and data collected under Tasks 1 through 10.

The development of the SCGW conceptual model will be an extension and enhancement of the Northeast model and could be integrated with the base-wide model currently under development by Battelle, and with the conceptual model developed by Tinker AFB staff. Three full cross sections are currently being prepared for the base-wide model and tied into the cross sections developed by Tinker AFB. Eight additional full two-dimensional cross sections will be prepared for the northeast off-base area. The final number of cross sections will be dependent on the amount of available new data. The additional cross sections will provide a full understanding and a better definition of a conceptual model for the SCGW that can be used to make decisions on the RI/FS.

Specifically, the development of the conceptual model will involve the following work elements:

1. Combine all well and borehole information and analyses from existing private and commercial wells into a mappable database. This information will be incorporated in the database being prepared by the base-wide model. The base-wide model includes all available wells on base and in the immediate vicinity of Tinker AFB.

2. Combine all well and borehole information from the 4 coreholes (Task 4) and the 12 well clusters (Task 5) into the base-wide model.
3. Tie in the new data collected with cross sections developed for the base-wide model. Then, perform selected stratigraphic correlations along cross sections in the North area of the conceptual model. Also, depending on the new data, correct the current cross sections being prepared for the northeast model and the base-wide model, and construct fence diagrams.
4. Based on the data in items 1 through 3, evaluate/modify the stratigraphic geometric boundaries of the proposed conceptual model.
5. Generate structure maps for each of the layers from the cross sections prepared above. This involves inputting by-hand the picks for each of the layers, grouping lenses defined in the correlations, and performing a gridding operation to define the tops and bottoms for all the layers. Also, map out the shale lenses so rock/sediment properties can be assigned, accordingly. Having the shale lenses defined on these maps will help to understand the possible migration pathways for the contaminants.
6. Prepare new water level maps and water level difference maps for the three water bearing units based on the new data collected bimonthly by ES. Since no water level data are available off-base, current maps for the northeast model extrapolate the on-base water levels data off-base to the north.
7. Review of rainfall and barometric pressure records over the time duration for which detailed well hydrographs exist. Further, systematically review water level and water quality records and geologic cross sections to delineate areas of hydraulic communication and migration pathways.
8. Prepare general maps of the areas where bedrock units outcrop or subcrop in the area. These maps will be generated based on the studies performed in items 1 through 4 and will aid in defining recharge/discharge areas.
9. Balance area inflows, including groundwater recharge, lateral and vertical boundary seepage or underflow and stream infiltration. Estimate the flux of groundwater throughout the conceptual model using one-dimensional analytical analyses.
10. Tie in all analyses to other studies conducted in the northeast quadrant and to studies being carried out for the base-wide model.
11. Produce a 3-D conceptual model.

In addition, the conceptual model will incorporate the conclusions from the Soldier Creek discharge task (Task 3) and will focus on the interaction that the stream may have had or is currently having with the shallow groundwater.

4.1.7 Task 7: Aquifer Pumping Tests

4.1.7.1 Pumping Test Design

Three long-term aquifer pumping tests will be performed in the area of investigation to determine aquifer parameters (horizontal permeability, storativity, transmissivity, confining layer leakage, and impact on East and West Soldier Creek) for the Tinker AFB groundwater conceptual model. The tests will be performed on a three-well cluster screened at approximate depths of 40 feet, 90 feet, and 150 feet, the same as the monitoring well clusters.

Several calculations were made to estimate the USZ's and LSZ's response to pumping. Based on these calculations, the optimum pumping rate, well design, observation well locations, and the pumping test well location were chosen. These calculations were made following procedures described in *Groundwater and Wells* (Driscoll, 1986). Table 4.3 shows the results of the calculations.

The Cooper and Jacob (1946) method, based on the Theis equation, was used to estimate the drawdown during the pumping test. The Cooper and Jacob method was developed for confined aquifers. Since the USZ and LSZ are unconfined in the area proposed for the test, the values obtained using this method can only be considered as a rough estimate. For designing the seven day tests, the confined equation yields a reasonable estimate for determining the optimum pumping rate and the resultant radius of influence. As discussed in Techniques of Water Resources Investigation of the USGS, Aquifer Test Design, Observation and Data Analysis, Book 3, Chapter B1, (Robert Stallman, 1971), once an aquifer is pumped long enough that the effects of delayed yield become negligible, the response approaches that of an artesian (confined) model.

The wells will be screened across the total thickness of the unit being tested. Each of the three aquifer tests will be conducted in the same manner. One piezometer cluster (MW1-90P) installed in Task 5, any other wells deemed appropriate in Task 2, and existing monitoring wells will be selected as observation wells (OW). The proposed location of the pumping test well cluster and an alternate location is shown on Figure 4.7. The piezometers and monitoring wells that will be used as observation wells for the pumping tests are also shown on Figure 4.7. The alternate location will be used if the proposed location is not accessible. Criteria for selecting the proposed and alternate pumping test locations are:

- The pumping well cluster will be located in or close to the focus RI/FS area, close to Tinker AFB plume
- Space (safe from trespassers) is needed for emplacement of generator and at least two 50,000-gallon (or larger) water tanks, and away from trespassers
- The location shall be close to IWTP or close to the base sewer to minimize the transport distance of discharge water
- The location will maximize the use of existing monitoring wells as observation wells to describe anisotropic hydraulic conductivity
- The location will be outside of the base water supply well influence.

Table 4.3
Pumping Test Design Parameters

Assumptions

Zones	Saturated[1] Thickness	Storativity[2]	Hydraulic[3] Conductivity	Transmissivity
USZ	18 feet	0.10	1.96 x 10 -3ft/min	380 gpd/ft
LSZ1	36 feet	0.10	1.47 x 10 -3ft/min	570 gpd/ft
LSZ2	45 feet	0.0001	5.9 x 10 -4ft/min	285 gpd/ft

Design

Zones	Optimum Pumping Rate	Radius[4] of Influence	Drawdown at[5] 1 foot from Pumping Well	Screen Length	Total Gallons Pumped
USZ	5 gpm	90 feet	13 feet	Bottom 15 feet of saturated zone	50,400
LSZ1	15 gpm	120 feet	26 feet	Bottom 30 feet of saturated zone	151,200
LSZ2	10 gpm	2,200 feet	50 feet	45 feet	100,800
				Total	302,400

1. USACE, 1991
2. Driscoll, 1986
3. USACE, 1988a
4. Radius of influence at the end of the 7 day test
5. Drawdown at the end of the 7 day test

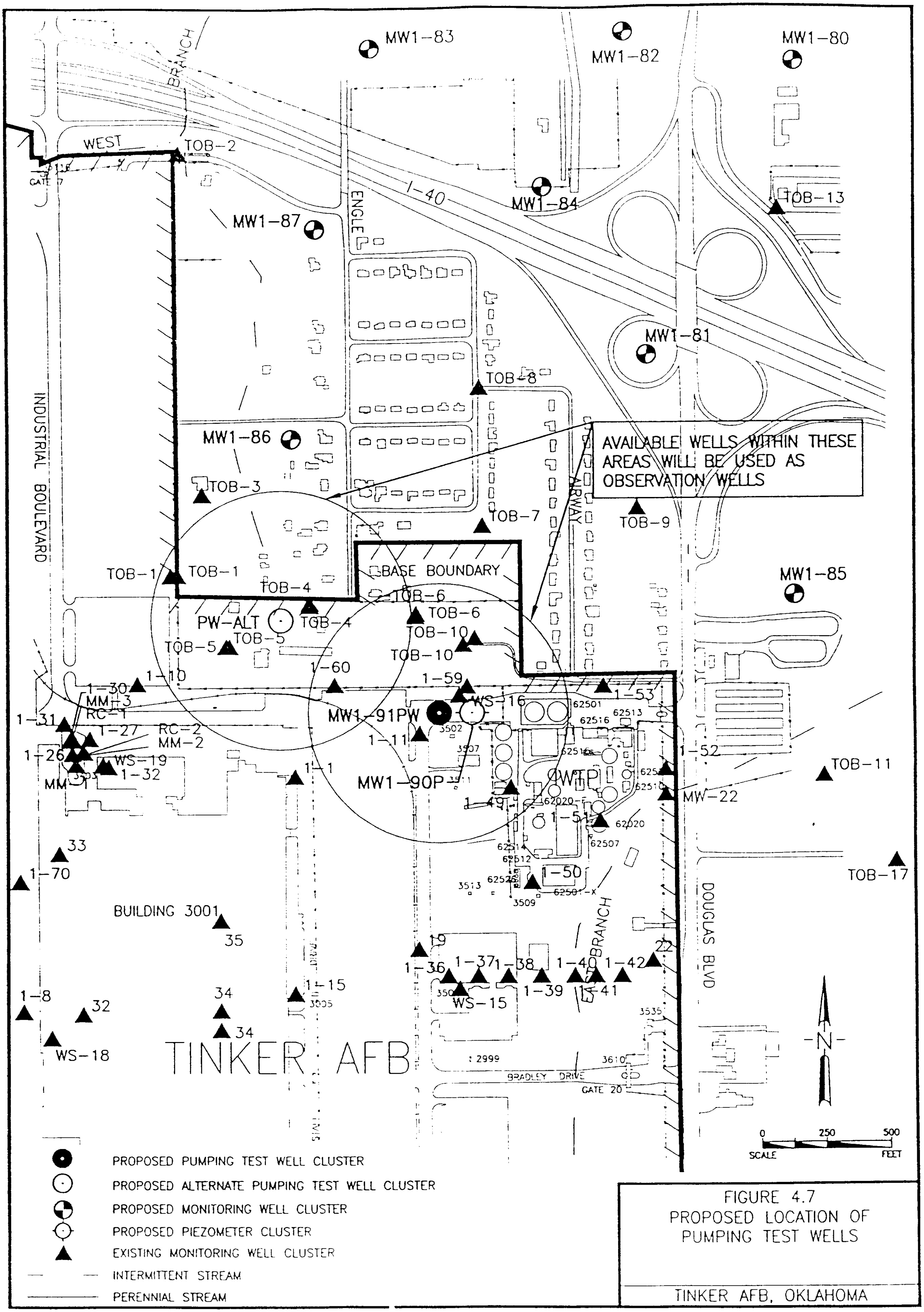

FIGURE 4.7
PROPOSED LOCATION OF PUMPING TEST WELLS

TINKER AFB, OKLAHOMA

PUMPTEST 5/16/94

As shown in Figure 4.7, piezometer cluster MW1-90P (located approximately 40 feet from the pumping well), MW1-11 and MW1-59 are all within the radius of influence for the primary confined and unconfined test. Several other wells (as shown on Figure 2.6) are within the radius of influence for the confined test. For the alternate test location, the piezometer cluster is again located 40 feet from the pumping well and TOB-4 and TOB-5 are also located within the zone of influence for confined and unconfined tests.

4.1.7.2 Pumping Test Execution

Each of the three pumping test wells will be constructed of 6-inch PVC casing and screen following the well construction procedures outlined in the FSP. The 6-inch diameter was selected to accommodate the pump and a pump shroud. To maximize the stress on the aquifer (i.e., maximum drawdown), the pump will be set near the bottom of the screened interval. A pump shroud will direct the ground-water flow into the pump over the pump motor. This will prevent the pump motor from overheating during the 7 day test.

Prior to each test, the water levels from the OWs that will be used for the test will be monitored approximately daily for a week to establish water level trends. Following the water level trend analysis a step drawdown test will be conducted to determine the optimum pumping rate for the test. The step drawdown test will take approximately 1 day to complete. Once the aquifer has recovered from the step drawdown test, the constant discharge test will commence. The total time anticipated for the water level trend and the step drawdown test is 3 days.

Each test will consist of 7 days of continuous pumping. Since one of the objectives of the pumping test is to determine leakage from overlying or underlying zones, a 7 day continuous test is needed. The 7 day test should allow sufficient time to observe any response in adjacent zones to pumping. Based on assumed pumping rates of 5, 10, and 15 gallons per minute and 16,400 gallons for step drawdown test, a total of 316,800 gallons of discharge water will be produced from each pumping well. At least two 50,000-gallon (or larger) tanks will be used to containerize the water from the constant discharge pumping test as well as the step drawdown test. Provisions will be made to transfer excess water to other holding tanks (to be located at the IWTP) as necessary. A direct reading flow meter with totalizer accurate to 1 gallon will be used to measure the pumping rate. The pumping rate will also be verified with a known volume container and stop watch.

During the test, the water levels in the pumping well and nearby monitoring wells will be measured for their response to the pumping. All three zones will be monitored to check for leakage. An eight channel data logger will be used to obtain continuous water levels during the test from the three pumping wells and three observation wells (one well screened in the zone being pumped and one well screened in each of the two other zones). The other observation wells farther from the pumping well will be measured manually with water level sounders. In addition to the eight channel data logger and pressure transducers, two well sentinel data loggers will be used to monitor observation wells that are within the radius of influence of the pumping test well but are either located too far from the pumping well or in locations where transducer cables can not be run, e.g., across major roads or freeways. ES will take selected manual measurements of the water level using an electric sounder to back up the data logger.

Once the pump is turned off at the end of the seventh day, the recovery of the water level from the test will be monitored for 1 to 2 days or until the water level returns to 95 percent of the static level prior to pumping. Following the test, the discharge water will be sampled and analyzed for the constituents listed in Task 10. A 24- to 48-hour rush analysis will be requested to expedite disposal of the water. After the discharge water has been characterized, the water will be properly disposed of in accordance with all appropriate laws and regulations as outlined in the FSP (ES, 1993a).

The pump and ancillary piping, flow meters, and flow gauges will be provided and installed by a water well company. The discharge water will be transported to a permitted disposal unit. Once all three tests are complete, the tank frame will be returned to the vendor. The tank liner and underlying geotextile will have to be disposed in accordance with procedures described in Section 4.1.12.

Following completion of the pumping tests, the data will be analyzed to determine the hydraulic conductivity (horizontal only), specific yield, storativity, transmissivity, confining layer leakage and possible impact on Soldier Creek. The data will be analyzed using the Theis (1935) and Cooper and Jacob (1946) methods for the confined aquifers, the Hantush (1967) method to determine leakage, and the Neuman (1972) method for unconfined aquifers where appropriate. Time drawdown graphs will be plotted for each well monitored for each test. It is estimated that eight to ten wells will be monitored during each test. Residual drawdown (recovery) data will also be plotted and analyzed for each test. Water level data will be adjusted for trends due to either the long-term rise or fall or the diurnal effect. Barometric effects on the data from the confined aquifer tests will also be corrected before analysis.

4.1.8 Task 8: Soil Sampling

After the results of the groundwater analysis from the twelve private wells become available, soil samples will be collected in the vicinity of those private wells that show groundwater contamination. Data from the soil sampling activities will be compared with the groundwater sample data to determine if a potential surface source exists. Four soil samples will be collected from the vicinity of each private well logged and sampled in Task 2 that shows groundwater contamination. The samples will be collected at depths of 0, 1, 2.5, and 5 feet using a hand-operated soil sampling tool. The sampling will follow the procedures outlined in the FSP (ES, 1994a). All sampling equipment will be decontaminated prior to sample collection following the procedures outlined in the FSP (ES, 1994a). Each soil sample will be analyzed for the constituents listed in Task 10. A headspace survey will be performed on all soils recovered and only samples that have headspace readings above 50 ppm relative response, odor, or obvious discoloration will be sent to the laboratory for VOC analysis. Metals analysis will be mandated if metals are detected in the groundwater above background and drinking water standards.

4.1.9 Task 9: Sediment Sampling

The purpose of these samples is to determine whether or not contamination has entered the underlying aquifer. Contamination of the groundwater with Soldier Creek contaminants could be assumed if a downward vertical contaminant gradient can be identified in the undisturbed sediment and rock under the stream. Sediment samples will be collected from Soldier Creek to establish and evaluate possible groundwater contamination due to recharge from the creek. Up to twenty locations will be sampled with five samples from the groundwater influent location at depths of 0, 1, 2, 3, and 5 feet. The purpose of these samples is to determine if there is a vertical concentration gradient indicating that the contamination in the sediment is entering the groundwater. Those sections of Soldier Creek which are most likely to recharge the groundwater will be sampled. This requires that information from the Soldier Creek stream survey (Task 3) and the monitoring wells be evaluated prior to sampling. The sampling will follow the procedures outlined in the FSP. Each sediment sample will be analyzed for the constituents listed in Task 10 and for TOC, CEC, and pH. Each sediment sample location will be surveyed by a state licensed surveyor as outlined in the FSP.

4.1.10 Task 10: Sample Analyses

Sample analyses for the project will be accomplished via a subcontracted laboratory. ES will provide data validation and oversee laboratory production. The data quality objectives for the project are U.S. EPA level III that meet risk assessment requirements. Level III data are also used for site characterization, feasibility study, and PRP identification. Field parameters, EPA level I, will be used in site characterization. Details of the data quality objectives are presented in the DQOP (ES, 1994c). The quality assurance and quality control for the sample analyses is presented in the QAPP (ES, 1994b).

All soil, sediment, and groundwater samples will be analyzed for the constituents listed in Table 2.2. For newly installed monitoring wells and any well that has never been sampled before, groundwater samples will be analyzed for the 129 priority pollutants excluding asbestos and dioxins. All of these samples will be analyzed for volatile organic compounds (EPA method SW-8260), semivolatile organic compounds (EPA method SW-8270), inductively coupled plasma (ICP) metals (EPA method SW-6010) arsenic (EPA method SW-7060), mercury (EPA method SW-7470), lead (EPA method SW-7421), selenium (EPA method SW-7740), total cyanides (SW-9010). Detection limits for all of the metals analyses will be below maximum contaminant levels (MCLs). Soil and sediment samples will be analyzed using the same methods with the exception that method SW-7471 will be used for mercury, and SW-9010 will not be conducted. In addition, three soil samples collected from each of the thirteen pilot holes (Tasks 5 and 7) will be analyzed for TOC, CEC, and pH. The sediment samples of Task 9 will also be analyzed for TOC, CEC, and pH in addition to the compounds of concern listed in Table 2.2.

All samples will be entered into Installation Restoration Program Information Management System (IRPIMS) format for submission to the laboratory. The laboratory will also enter sample results into the IRPIMS.

Sampling of investigation-derived wastes (IDW) is described and discussed in Section 4.1.12. IDW data is not subject to IRPIMS database entry.

4.1.11 Identification of ARARs

Section 121 of the Superfund Amendments and Reauthorization Act (SARA) establishes clean-up criteria for Superfund sites. This section of the Statute sets forth the need for appropriate remedial actions, consistent with the NCP. Subsection (d) of Section 121 generally requires that remedial actions attain a level or standard of control at least equivalent to Applicable or Relevant and Appropriate Requirements (ARARs) promulgated under federal or state laws. "Applicable Requirements" are those clean-up or control standards and other substantive environmental protection requirements, criteria or limitations, promulgated under federal or state law which specifically address a hazardous substance, pollutant, contaminant, remedial action location, or other circumstances at a CERCLA site. "Relevant and Appropriate Requirements" refer to those clean-up or control standards, and other substantive environmental protection requirements, criteria or limitations, promulgated under federal or state law that, while not "applicable," address problems or situations sufficiently similar to those encountered at a CERCLA site that their use is well suited to the particular site. The USEPA has identified three categories of ARARs:

- Chemical specific
- Location specific (e.g., wetlands, historical or archeologic sites); and
- Action specific (e.g., performance and design standards).

In performing the RI, both location and chemical-specific ARARs will be considered. Action specific ARARs related to the performance of RI activities will also be considered.

Potential federal chemical-specific ARARs for this site include Safe Drinking Water Act (SDWA), Federal Ambient Water Quality Criteria (WQC) for the protection of human health and freshwater aquatic life, and state chemical-specific ARARs.

SDWA maximum contaminant level (MCL) apply to "public water systems," defined as systems for the provision of piped water for human consumption with at least fifteen service connections or serving at least twenty-five people (EPA, 1988a). MCLs are legally enforceable and are based on allowable lifetime exposure in drinking water for an adult, but are also required to reflect technical and economic feasibility of removing the contaminant from the water supply. SDWA MCL goals (MCLG's) are nonenforceable health goals for public water systems. Maximum contaminant level goals are set at levels that would result in no known or anticipated adverse health effects with an adequate margin of safety. Nonzero MCLGs are potentially relevant and appropriate standards for NPL site under the NCP (EPA, 1988a).

Federal WQC are nonenforceable guidelines used by states to set water quality standards for surface water. Federal WQC for specific pollutants should generally be identified as ARARs for surface water cleanup if particular circumstances exist at the site that WQC were specifically designed to protect, unless the state has promulgated Water Quality Standards for the specific pollutants and water body at the site. For example, WQC for the protection of human health can be considered relevant and appropriate to surface waters designated by the State as a public water supply or for recreation. WQC for the protection of aquatic life may be found relevant and appropriate when protection of aquatic life is a concern. WQC are considered ARARs for groundwater only if groundwater is a current or potential source of drinking water, they reflect current scientific information, and there are no Federal MCLs, nonzero MCLGs, or state ARARs. If groundwater discharges into surface water, the groundwater remediation should be designed so that the receiving surface water body can meet any ambient water quality standards that may be ARARs for that surface water body (EPA, 1988a and 1990).

There are some chemical-specific "to be considered" (TBC) criteria which may or may not be utilized during the RI/FS process based on best professional judgement, presence of media- and chemical-specific ARARs, and site conditions. These include Resource Conservation and Recovery Act (RCRA) Alternate Concentration Limits (ACL), Health Advisories, and Secondary Maximum Contaminant Levels (SMCLs). Health-based cleanup criteria will be developed during the project risk assessment and will be used in conjunction with ARARs as a TBC criteria.

Potential location specific ARARs for this site include critical habitat upon which endangered species or threatened species depend, wetlands, wilderness areas, areas affecting a stream or river, and areas affecting National Wild and Scenic or Recreation Rivers.

4.1.12 Management of IDW

The investigation derived waste (IDW) will include:

(1) Soil cuttings and drilling mud from soil boring and monitoring well installation

(2) Development water, purge water, and pumping test water removed from wells

(3) Water, solvents, or other fluids used to decontaminate field equipment and personal protective equipment (PPE)

(4) PPE and disposable sampling equipment (DE).

The purpose of this RI is to characterize the SCGW operable unit, while minimizing the IDW. The EPA (1991a) guidance on *Management of Investigation-Derived Wastes During Site Inspection* EPA/540/G-91/009 recommends that waste minimization should be addressed in the work plan.

4.1.12.1 The Area of Contamination

According to EPA guidance, offsite disposal of the four types of IDW listed above "always results in high costs regardless of the waste hazard, because there is no significant difference between the costs of disposal of hazardous and nonhazardous wastes." Therefore, within the realm of RCRA and CERCLA rules, EPA recommends leaving IDW in the originating area of contamination (AOC). If IDW is only moved within an AOC, it is unnecessary to determine whether it is subject to land disposal restrictions (LDRs).

EPA (1991) defines the AOC as a nondiscrete land area on or in which there is generally dispersed contamination. A waste source may be a waste pit, landfill, waste pile along with the contaminated soil, or the sediments in a contaminated stream. EPA recognizes "the best professional judgement" in delineating AOCs, e.g., a small area immediately adjacent to a borehole may be part of an AOC if the area is covered with surface soil similar to soil from borehole.

4.1.12.2 IDW Management Options

The onsite handling options given by EPA (1991) when IDW are RCRA nonhazardous are listed below. These are only options and not necessarily the course of action that will be taken during the RI/FS at Tinker AFB. Section 4.1.12.4 describes the manner in which IDW will be handled at Tinker AFB.

For soil cuttings:

- Spread around the well or boring,
- Put back into the boring,
- Put into a pit within an AOC, or
- Dispose of at the site's operating treatment or disposal unit (TDU).

For groundwater:

- Pour onto ground next to the well to allow infiltration or
- Dispose of at the site's TDU.

For decontamination fluids:

- Pour onto ground (from containers) to allow infiltration or
- Dispose of at the site's TDU.

For decontaminated PPE and DE:

- Double bag and deposit in the site or dumpster, or in any municipal landfill, or
- Dispose of at the site's TDU.

If IDW consists of RCRA hazardous soils that pose no immediate threat to human health and the environment, EPA (1991) recommends leaving the soils onsite within a delineated AOC unit. However, before deciding to leave RCRA-hazardous soils onsite, the site manager must consider the proximity of residents and workers in the surrounding area. The site manager must always use best professional judgement to make such decisions. Planning for leaving RCRA hazardous soil onsite involves:

1. Delineating the AOC unit.
2. Determining pit locations close to the borings within the AOC unit for waste burial.
3. Covering hazardous IDW in the pits with surficial soil
4. Not containerizing and testing wastes designated to be left onsite.

Another alternative for handling RCRA-hazardous soil is disposal in a TDU located on the same property as the AOC under investigation (EPA, 1991). If the TDU is outside the AOC, it must comply with the offsite policy. If any RCRA hazardous organic decontamination fluids are generated, they should be disposed of offsite in compliance with the offsite policy or in compliance with the conditionally exempt small quantity generator exemption. Small quantities (no more than 100 kg/month) of organic decontamination fluids may be containerized offsite prior to delivery to a hazardous waste facility (EPA, 1991, page 25).

4.1.12.3 RCRA Characteristic Wastes

A solid waste is a RCRA characteristic waste if it exhibits the characteristics of ignitability, corrosivity, reactivity or toxicity (toxicity characteristic leaching procedure, TCLP).

IDW exhibit ignitability if:

- They are a liquid, other than an aqueous solution containing less than 24 percent alcohol by volume, and have a flash point lower than 60°C (140°F).
- They are not a liquid and are capable, under standard temperature and pressure, of causing fire and, when ignited, create a hazard.
- They are an ignitable compressed gas.
- They are an oxidizer.

IDW exhibit corrosivity if:

- They are aqueous and have a pH less than or equal to 2 or greater than or equal to 12.5.
- They are a liquid and corrode steel at a rate greater than 6.35 mm (0.25 inch) per year at a test temperature of 55°C (130°F).

IDW exhibit reactivity if:

- They are normally unstable and readily undergo violent change without detonating.
- They react violently with water.
- They form potentially explosive mixtures with water.

- When mixed with water, they generate toxic gases, vapors or fumes that pose a danger to human health or the environment.
- They are a cyanide- or sulfide-bearing waste capable of (at the pH range of 2 to 12.5) generating toxic gases that can present a danger to human health or the environment.
- They are capable of detonation or explosive decomposition.
- They are a forbidden explosive.

IDW exhibits TCLP-toxicity when its leachate contains certain contaminants at levels exceeding their regulatory thresholds. TCLP adds 25 organic constituents to the previous RCRA list of EP toxicity chemicals and establishes regulatory levels for these chemicals. The TCLP is designed to determine the mobility of both organic and inorganic contaminants present in liquid, solid, and multiphasic wastes. A water containing less than 0.5 percent dry solid material, filtered through a 0.6 to 0.8-μm glass fiber filter, is defined as the TCLP extract. If this extract contains a regulated compound above its threshold level, then the water is hazardous by TCLP characteristic. If the filtered extract from the solid phase contains a regulated compound above its threshold level, then the solid material is RCRA-hazardous.

To identify RCRA characteristic waste, the site manager may rely on the knowledge of the properties of the substances from, for example, the Material Safety Data Sheets (MSDS) prepared by manufacturers, or on the results of tests described in 40 CFR 261.21 - 261.24. EPA (1991) recommends using knowledge of the properties of material instead of testing since most CERCLA wastes do not exhibit these RCRA characteristics. Therefore, the site manager should not test IDW, particularly if they are a soil of known RCRA characteristics, the AOC concept is applicable, and the wastes will be buried onsite.

Based on the off-base groundwater investigation report (USACE 1991) and the RI of Soldier Creek (B&V, 1993), neither soil, groundwater nor sediment of this SCGW RI could be classified as ignitable, corrosive, or reactive. Neither soil nor groundwater could be classified as TCLP-toxic.

The soil chemistry data reported in the off-base groundwater investigation (USACE, 1991) did not use TCLP extraction (EPA method SW-1311). However, it is not likely that the offsite soil cuttings are RCRA-hazardous waste since they are situated far from the contamination source on-base. The concentrations of soil metals are quite similar among all of the off-base wells.

The sediments of Soldier Creek collected by B&V (1993) were not extracted using TCLP. Therefore, these concentrations cannot be compared directly with TCLP levels. However, the entire reach of Soldier Creek can be considered to be an AOC.

4.1.12.4 IDW Disposal

IDW from drilling operations will be contained in transportable roller-type dumpsters. Wastes will be separated in roll-offs by well cluster group. Drums will only be used if cuttings are suspected to be hazardous based on field testing and observations, or if the amount of cuttings expected to be generated at a location (specifically core locations) is too small to warrant use of a roll-off. The soil cuttings (rolloffs and any other containers) will be removed so that the original site conditions can be restored. All rolloffs and drums containing wastes will be transported to Tinker AFB for temporary storage, tested, and disposed of in accordance with all applicable laws and regulations. A composite sample will be taken from each well cluster group in roll-offs to run TCLP toxicity test. Composite samples will also be collected from drums of the same boring or location. Each sample will be from a maximum of ten drums. Based on TCLP results, the cuttings may be delivered to a municipal (RCRA subtitle D) landfill or a hazardous (RCRA subtitle C) landfill.

To be conservative, the groundwater underneath Building 3001 will temporarily be considered a hazardous waste (e.g., TCE exceeding 500 $\mu g/L$). The pumping test might draw the TCE plume into the pumping wells. Therefore, the 7-day pumping test water will be stored in aboveground temporary tanks located on or close to the base. The pumping test water will be tested for volatile and semivolatile organics and metals before it is discharged to a permitted unit in accordance with all appropriate laws and regulations.

In the residential areas, the water will be drummed, returned to Tinker AFB, and transported to a permitted disposal unit in accordance with all appropriate laws and regulations.

Offsite disposal of any soil or sediments derived from sediment sampling and piezometer and gaging station installation will not be necessary, because Soldier Creek is an NPL site and the creek is an AOC. Sediment may be left in the creek.

The only level D PPE that will require disposal are gloves and coveralls. If level C is adopted, the used respirator filter cartridges will be double bagged with coveralls and gloves and disposed in a dumpster. Dumpster contents will be disposed of in a municipal landfill.

Throughout the project, an attempt will be made to minimize the amount of waste generated. For example, plastic sheeting will be used only when necessary to protect sampling equipment from dirty surfaces. Some wastes, such as cardboard boxes, will be recycled when possible.

4.2 FEASIBILITY STUDY TESTING (TREATABILITY/BENCH SCALE TEST)

No bench-scale or treatability studies are planned during this phase of work. The exact remedial technologies to be studied will not be known until the preliminary results of the RI are analyzed.

4.3 PUBLIC HEALTH/ECOLOGICAL EVALUATION

A quantitative baseline risk assessment (RA) will be conducted for the SCGW site. The baseline RA is an estimate of the potential risk to human health and the environment associated with exposure to site contaminants in the absence of remediation.

Baseline human health and ecological RAs will follow guidance given in the following documents:

- Risk Assessment Guidance for Superfund, volume I, Human Health Evaluation Manual (part A), EPA/540/1-89/002, December 1989
- Risk Assessment Guidance for Superfund, volume I, Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors, EPA OSWER Directive 9285.6-03, March 1991b
- Exposure Factors Handbook, EPA/600/8-89/043, July 1989
- Risk Assessment Guidance for Superfund, volume II, Environmental Evaluation Manual, interim final, EPA/540/1-89/001, March 1989
- USAF Handbook to support IRP statements of work including the General Guidance for Ecological Risk Assessment, Air Force Center for Environmental Excellence, May 1991
- Dermal Exposure Assessments: Principles and Applications, interim report, EPA/600/8-91/011B, January 1992.

Baseline RAs will be performed using data collected from the area which is the focus of the RI/FS investigation. Data collected prior to this delivery order will not be included in the RA task. Data collected from private wells will also not be included in the RA task. The only environmental media to be evaluated for human health and ecological RAs will be groundwater. Data from long-term monitoring (LTM) will be used to establish trends such as plume movement. Attempts will be made to conduct sampling under Task 5 concurrently with the LTM program; however, data from the LTM programs will not be used for the RA.

Soldier Creek surface water and sediments will not be evaluated for human health or ecological RAs during this investigation. A ROD on the sediments and surface water has been signed by EPA on 16 September 1993.

Twelve human exposure scenarios will be evaluated for pathway completeness based upon site conditions. Only those pathways determined to be complete will be quantified in the RAs. The twelve exposure scenarios include:

- (Resident) Ingestion, body contact, and inhalation of groundwater (well depth = 40 feet)
- (Resident) Ingestion, body contact, and inhalation of groundwater (well depth = 90 feet)
- (Resident) Ingestion, body contact, and inhalation of groundwater (well depth = 150 feet)
- (On-base worker) Ingestion of groundwater (well depth = 40 feet)
- (On-base worker) Ingestion of groundwater (well depth = 90 feet)
- (On-base worker) Ingestion of groundwater (well depth = 150 feet)

- (Resident) Inhalation of airborne (vapor phase) chemicals while showering (well depth = 40 feet)
- (Resident) Inhalation of airborne (vapor phase) chemicals while showering (well depth = 90 feet)
- (Resident) Inhalation of airborne (vapor phase) chemicals while showering (well depth = 150 feet)
- (Resident) Dermal contact with chemicals in water while showering (well depth = 40 feet)
- (Resident) Dermal contact with chemicals in water while showering (well depth = 90 feet)
- (Resident) Dermal contact with chemicals in water while showering (well depth = 150 feet).

No computer modeling will be included in the baseline RAs.

Carcinogenic and noncarcinogenic (chronic) risks will be evaluated in the baseline human health RAs. Noncarcinogenic (subchronic) risks will not be evaluated.

An acceptable risk of 1E-04 will be used as the acceptable upper bound carcinogenic risk value.

Only the wildlife toxicity (groundwater) ecological pathway will be evaluated for completeness based upon site conditions.

The risk assessment evaluation will consist of the following four steps:

- Chemicals of interest (COI) and data evaluation
- Exposure assessment
- Toxicity assessment and profiles for COI
- Risk characterization, posed by the site if no action taken.

4.3.1 Chemicals of Interest and Data Evaluation

Chemicals of interest will be chosen based on background concentrations, frequency of detection, and the availability of toxicity information. All of the available analytical data collected under this task will be reviewed in light of analytical methods used, quantitation limits, data qualifiers, and QA/QC samples.

4.3.2 Exposure Assessment

Exposure assessment will characterize exposure setting, identify exposure pathways, and quantify exposure. The objectives of the exposure assessment are to identify actual or potential routes of exposure (pathways), and to characterize the type and magnitude of exposure to the receptors. Exposure assessment is the determination of estimation (qualitative or quantitative) of the magnitude, frequency, duration, and rate of exposure.

4.3.3 Toxicity Assessment

Toxicity assessments and the resultant toxicity values will be used to evaluate carcinogenic and noncarcinogenic hazards associated with each chemical of concern and route of exposure. The objective of the toxicity assessment is to weigh available evidence regarding the potential for particular contaminants to cause adverse effects in exposed individuals and to provide, where possible, an estimate of the relationship between the extent of exposure to a contaminant and the increased likelihood and/or severity of adverse effects.

4.3.4 Risk Characterization

The final step conducted in the human health evaluation is the actual characterization of risk. For noncarcinogenic effects, projected intakes will be compared to reference doses and other appropriate toxicity values. For carcinogenic effects, probabilities of developing cancer over a lifetime exposure will be estimated from projected intakes and chemical specific dose response information. All risk assessments involve the use of assumptions, judgements, and imperfect data to varying degrees. Therefore, assumptions and uncertainties inherent in the risk assessment will be evaluated to place the risk estimates in proper perspective.

The objective of the environmental evaluation is to assess potential exposure to environmental receptors and will consist of the following three components:

- Identify any threatened or endangered species.
- Determine likely pathways for organisms to become exposed to contaminants from the site. Primarily through off-base groundwater discharging in Soldier Creek.
- Perform a risk assessment to evaluate the significance of contaminant levels to environmental receptors.

Existing data will be compared to criteria or guideline values, wildlife values, and livestock, and irrigation water criteria. The hazard quotient method will be used to sum potential exposures by media and receptor.

4.4 REMEDIAL INVESTIGATION REPORT

RI activities and results will be evaluated and presented in the RI report. This report will describe all steps and methodologies used in completing the field investigations, and will include all data collected. A determination of the nature and extent of contamination will be developed based on the data collected during RI activities. Figures will be included showing the water table surface of the USZ and the potentiometric surface of the LSZ. Groundwater elevations will be added to the wells. Isopleths maps of contaminants will be generated, if necessary. An analysis of the RI results relative to the identified potential remedial technologies of Section 4 will be included along with a determination of the adequacy of the RI data for support of the feasibility study. Additional data needs, if any, will be identified. Schedules will be recommended if necessary.

The proposed outline for the RI report is presented in Table 4.4. The RI will be delivered as internal draft, draft, draft final, and final submittals.

TABLE 4.4
PROPOSED RI REPORT OUTLINE

Executive Summary

1. Introduction
    - 1.1 Purpose of Report
    - 1.2 Report Organization
    - 1.3 Site Background
        - 1.2.1 Site Description
        - 1.2.2 Site History
        - 1.2.3 Previous Investigations

2. Study Area Investigation
    - 2.1 Field Activities, but not necessarily all of the following:
        - 2.1.1 Surface Features
        - 2.1.2 Contaminant Source Investigation
        - 2.1.3 Surface Water and Sediment Investigation
        - 2.1.4 Geological Investigation
        - 2.1.5 Soil and Vadose Zone Investigation
        - 2.1.6 Groundwater Investigation

3. Physical Characteristics of the Study Area
    - 3.1 Surface Features
    - 3.2 Meteorology
    - 3.3 Surface-Water Hydrology
    - 3.4 Geology
    - 3.5 Soils
    - 3.6 Hydrogeology
    - 3.7 Demography and Land Use
    - 3.8 Ecology

4. Nature and Extent of Contamination

5. Contaminant Fate and Transport
    - 5.1 Potential Routes of Migration
    - 5.2 Contaminant Persistence
    - 5.3 Contaminant Migration

Table 4.4, Cont.

6. Baseline Risk Assessment
    6.1 Human Health Evaluation
        6.1.1 Exposure Assessment
        6.1.2 Toxicity Assessment
        6.1.3 Risk Characterization
    6.2 Environmental Evaluation

7. Summary and Conclusions
    7.1 Summary
        7.1.1 Nature and Extent of Contamination
        7.1.2 Fate and Transport
        7.1.3 Risk Assessment
    7.2 Conclusions
        7.2.1 Data Limitations and Recommendations for Future Work
        7.2.2 Recommended Remedial Action Objectives

Appendices

A. Technical Memoranda on Field Activities
   Geophysical Logs
   Pumping Test Results
   Boring Logs
   Well Construction Diagrams
   Well Development Forms
   Results of Geotechnical Testing
   Photographs
   Results of Stream Flow Measurements
B. Analytical Data and QA/QC Evaluation Results
C. Risk Assessment Methods

SECTION 5

FEASIBILITY STUDY SCOPE OF WORK AND PRELIMINARY ASSESSMENT OF REMEDIAL ALTERNATIVES

The FS process consists of several interim reports culminating in the FS report. The FS is the mechanism to identify and evaluate options for remedial actions.

5.1 CURRENT SITUATION SUMMARY

The site characteristics will be summarized. The basis of the report will be the results of the RI. The contaminants of concern and the volume of contaminated groundwater will also be identified.

The site specific remedial response objectives for the FS will be presented in the report. The remedial action objectives will consist of the groundwater operable unit specific goals for protecting human health and the environment. The objectives will be specific to the site and based on results of the risk assessment and applicable, or relevant and appropriate requirements (ARARs).

The current situation report will be summarized as a technical memorandum. This summary will be incorporated into the final FS report.

5.2 REMEDIAL ALTERNATIVES BACKGROUND

Previous investigations of the Building 3001/Soldier Creek NPL site have identified two groups of contaminants of concern: volatile organics and heavy metals. In addition, previous investigations have identified volatile organics, semivolatile organics, and heavy metals in the sediments of Soldier Creek. A record of decision (ROD) for Soldier Creek surface water and sediments was signed by EPA and OSDH in September 1993.

To assess the potential remedial alternatives, remedial action objectives must be established. The objectives are to reduce the potential human health and environmental risk to an acceptable level and to comply with all ARARs.

General response actions for the remediation of contaminated groundwater include: no action, long-term monitoring, containment, above ground treatment, and *in situ* treatment. Treatment technologies for organic contaminants range from source removal, to containment (slurry walls, and interception trenches), to removal and treatment (carbon adsorption, stripping, bioremediation, oxidation, air sparging). Treatment technologies for inorganic contaminant include capping, source removal, precipitation, filtration, and solidification (for aquifer matrix/soils).

The remedial cleanup standards will be recommended by the findings of the risk assessment and ARARs. Preliminary standards for groundwater are the maximum contaminant levels (MCLs) promulgated under the Safe Drinking Water Act (SDWA) for public water supply systems. Other cleanup standards may be determined following the RI.

The performance criteria for the treatment technologies will be determined by ARARs, such as NPDES discharge limits, if discharge to surface water is considered for the treated groundwater. Treatment technologies will be chosen as part of a remedial alternative based, in part, on the ability to meet the required treatment levels.

Table 5.1 describes process options that may be applicable for the containment, extraction, treatment and disposal of the contaminated groundwater at this site. Based on this information, several alternatives are developed and are summarized in Table 5.2. The potentially feasible alternatives range from no-action to complete remediation. Table 5.2 also contains a list of data requirements for each alternative. As additional information is available for this site, these preliminary remedial alternatives may be modified.

5.3 REMEDIAL ALTERNATIVE DEVELOPMENT

Based on the results of the RI and the remedial action objectives, site specific remedial action alternatives will be developed to satisfy the remedial response objectives. The alternatives will be developed by combining appropriate remedial technologies to form alternatives.

5.3.1 Identification of Volume of Contaminated Media

The areas and volume of contaminated media will be estimated based upon the results of the RI. Interactions between media will be taken into account when calculating volume estimates. The volume estimates will consider the following:

- Acceptable exposure levels
- Potential exposure routes
- The nature and extent of contamination.

Volume versus concentration relationships will be defined and considered when developing remedial action alternatives.

5.3.2 Identification and Screening of Remediation Technologies

Categories of general response actions include no-action, reduce or eliminate mobility, toxicity, or volume (MTV) of contaminants, various levels of containment, and limited actions including long-term monitoring.

Potentially applicable treatment technologies will be identified at this stage. Broad categories of treatment such as chemical or thermal treatment will be

Table 5.1 Remedial Action Objectives, General Response Actions, Technology Types and Examples of Process Options for the Development and Screening of Alternatives

Environmental Media	Remedial Action Objectives	General Response Actions (For All Remedial Action Objectives)	Remedial Technology Types (for General Response Actions)	Process Options
Groundwater	For Human Health:	No Action/Institutional Controls:		
	Prevent ingestion of water having carcinogen(s) in excess of MCL(s) and a total excess cancer risk (for all contaminants) of greater than 10^{-4} to 10^{-6}.	No Action; use/access restrictions monitoring; alternate residential water supply	No action; fences; deed restrictions, groundwater classification change	None
	Prevent ingestion of water having non-carcinogen(s) in excess of MCL(s) or reference dose(s).	Containment:	Capping, vertical barriers, horizontal barriers, hydraulic containment	Clay cap, membranes, slurry walls, sheet pilings, liners, groundwater recirculation systems
	For Environmental Protection:	Removal, Treatment:	Removal: groundwater pumping, diversion, collection, drainages	Wells, subsurface drains or leachate collection drains.
	Prevent plants and wildlife from contacting water with toxic levels of contaminants.	Collection, treatment, discharge, *in situ* groundwater treatment, individual home treatment	Treatment: physical, chemical, *in situ*	Ion exchange, evap/dewater, adsorption, oxidation/reduction, precipitation, chemical oxidation, bioremediation
	Restore groundwater aquifer to acceptable concentrations of solvents and metals.		Disposal: Discharge to surface water, discharge to upgradient groundwater, discharge to IWTP	

Table 5.2 Potentially Feasible Remedial Response Actions

General Response Actions	Potentially Feasible Remedial Alternatives	Potentially Feasible Remedial Technologies	Factors Which Affect The Alternative	Field Data Needs
No action	No action	None	• Groundwater use • Public concerns • Contamination levels • Risk assessment • Regulatory requirements • ARARs compliance	• Contamination concentrations in groundwater
Limited action	Long term monitoring (LTM)	• No further action • Long-term monitoring of groundwater • Deed restrictions • Change creek classification	• Same as no action	• Same as no action • NCP requires five year review
Source containment	Hydraulic barriers	• Interception trenches • Recovery wells • Deed restrictions • Hydraulic curtain • Slurry wall	• Cost • Depth of contaminated groundwater • Flow direction • Same as no action • Areal extent of contamination	• Required depth of trench • Aquifer hydraulic conductivity, transmissivity, porosity • Groundwater flow direction • Source of contamination
Source removal	Groundwater collection and treatment	• Recovery wells • Dewatering • Air/steam stripping, volatiles • Carbon filtration, volatiles • UV/ozone, volatiles • Precipitation, metals • Ion exchange, metals • Restrict site access • Deed restrictions	• Aquifer characteristics: yield, transmissivity, depth • Chemical characteristics of groundwater • Same as no action	• Accurate estimate of aquifer hydraulic conductivity, transmissivity, porosity • Contaminants of concern in the groundwater under the RCRA site • Volume of waste material • Thickness, extent of soil units/aquifers • Particle size, porosity • Presence of faults, discontinuities • Type of porosity • Groundwater flow directions

Table 5.2, continued

General Response Actions	Potentially Feasible Remedial Alternatives	Potentially Feasible Remedial Technologies	Factors Which Affect The Alternative	Field Data Needs
In situ treatment	*In situ* treatment/LTM	• Vapor extraction • Biologic treatment • Steam/air stripping • Solvent extraction	• Cost • Permeability • Contaminant volatility • Further groundwater contamination	• Sediment composition • Porosity
Removal and treatment	Groundwater recovery; onsite treatment/long term monitoring	• Recovery wells • Thermal treatment • Bioreactors	• Cost • Permitting • Waste volume • Waste type • Public concerns • Regulatory requirements	• Contaminants of concern • Matrix characteristics of the sediments • BTU content • Cation exchange capacity
Removal and offsite disposal	Groundwater recovery; offsite disposal/long term monitoring	• Recovery wells • Transportation • Landscape restoration • Other offsite treatment • Thermal treatment	• Cost • Permitting • Waste volume • Waste type • Public concerns • Regulatory requirements	• Same as source removal and treatment

identified. Specific process options within the general treatment categories, such as precipitation or thermal desorption, will also be identified at this time.

The number of process options to be considered in forming alternatives will be reduced using three general screening criteria; i.e., effectiveness, implementability, and cost. These criteria will be applied only to the process options themselves and their respective target media, not the site as a whole. At this stage the focus of the evaluation will be on overall effectiveness of the process option.

The effectiveness evaluation will center on: (1) the ability of the process option to treat the estimated volume of contaminated media; (2) the potential effect of the process option on human health and the environment during construction and implementation; and (3) the reliability of the process with respect of the site conditions and contaminants.

The implementability assessment includes consideration of both technical and administrative feasibility. Emphasis is placed on availability of personnel and equipment, ability to obtain necessary permits, and availability of treatment, storage and disposal facilities.

Limited emphasis is placed on cost during the technology screening process. Engineering judgment will be used to evaluate the process options as to whether the overall costs are low, medium, or high.

5.3.3 Remedial Alternative Screening

Those technologies remaining after the screening will be assembled to establish site specific remedial action alternatives. General response actions will be combined with specific process technology to form a range of alternatives. A more detailed description of each alternative will be provided at this stage of screening to help differentiate between similar alternatives.

At a minimum the following alternatives will be considered:

- A no-action or site close out alternative
- An alternative which reduces or eliminates the mobility, toxicity, or volume of the waste
- An alternative which provides containment of the waste
- An alternative which consists of long-term monitoring.

The alternatives will be evaluated and screened as were the process options on the basis of effectiveness, implementability, and cost. Innovative technologies will be carried through the screening process if it appears the technologies may have significant advantages over traditional technologies, even if lacking detailed cost or performance data.

A technical memorandum will be submitted to Tinker AFB for review. The technical memorandum will document the above described identification and screening processes. All comments will be incorporated into the FS report.

5.4 REMEDIAL ALTERNATIVE ANALYSIS

The alternatives remaining after the screening process will undergo a detailed analysis. The analysis will provide adequate information for the final selection of an alternative. As part of the detailed analysis, the individual alternative descriptions will be refined with respect to areas/volume of media to be addressed. Performance requirements for the technologies will also be reviewed.

Nine evaluation criteria have been developed in the NCP (EPA, 1990) to serve as the basis for the detailed remedial alternative analysis. These criteria are:

1. Overall protection of human health and the environment
2. Compliance with ARARs
3. Long-term effectiveness and permanence
4. Reduction of mobility, toxicity, and volume
5. Short-term effectiveness
6. Implementability
7. Cost
8. State acceptance
9. Community acceptance.

A summary profile of each alternative compared with each of the evaluation criteria will be developed as part of the detailed analysis.

In addition to the individual detailed analysis, a comparative analysis among alternatives will be performed. The analysis is designed to assess the relative performance of each alternative with respect to each criterion. The comparative analysis will consist of a narrative discussion examining the strengths and weaknesses of each alternative relative to one another with respect to the criterion.

The results of the individual and comparative analysis may be presented in an alternatives array working paper. All comments on this working paper will be incorporated into the FS report.

5.5 FEASIBILITY STUDY REPORT

An FS report will be prepared summarizing all FS activities. The previously submitted working papers of Section 5.2 and 5.3 will be incorporated into the FS along with comments received from Tinker AFB.

The FS report will include an environmental assessment (EA) for each alternative remaining after the screening of remedial alternatives. The EA will correspond with the detailed analysis of alternatives and include information specific to the National Environmental Policy Act (NEPA) not otherwise considered in the nine evaluation criteria, specifically, elements listed on DD form 1391C, Certificate of Environmental Compliance and AF form 814 Preliminary Environmental Study.

The FS will be delivered as internal draft, draft, draft-final, and final submittals.

SECTION 6

SCHEDULE AND ORGANIZATION

6.1 SCHEDULE AND ORGANIZATION

The schedule for the SCGW RI/FS project is presented in Figure 6.1. The project start date was 26 August 1993. The contract end date is 16 September 1995, i.e., 750 days from the start date.

6.2 PROJECT ORGANIZATION/COORDINATION

Several organizations will be involved directly in the performance and review of this project. These organizations have specific project functions and relate to each other in various ways according to their project responsibilities. The purpose of this section is to provide an understanding of the overall project organization and the function and responsibility of various groups to aid in the exchange of information and to assure efficient project operation.

The key organizations and their responsibilities are listed below and shown graphically in Figure 6.2. Table 6.1 is a listing of the key contacts. Table 6.1 will be periodically updated and distributed to key project personnel.

The Tinker AFB EM remedial project manager is Mr. John Schroeder, P.E. The base contracting officer is Mr. Gordon Mohon. ES will inform Tinker AFB on any key personnel changes and acquire Tinker AFB approval on replacements before work assignment. The key professionals are the project manager, RI manager, FS manager, task managers and senior professionals that possess professional maturity and have the credentials and capability to be an expert witness.

Sam Moore, P.E., ES program manager, and John Osweiler, P.G., ES RI manager, are located at the ES Oklahoma City office. Mr. Osweiler will maintain the project continuity and coordinate and/or assist Battelle with field work for Task 3.

Project Manager

The project manager is responsible for the entire project team. The principal concern of the project manager is to ensure that the work is performed on time and within budget and that it meets the high standards of quality demanded by ES and Tinker AFB. The project manager will serve as the liaison for all communication

Figure 6.1
Proposed Schedule
Tinker AFB, SCGW RI/FS

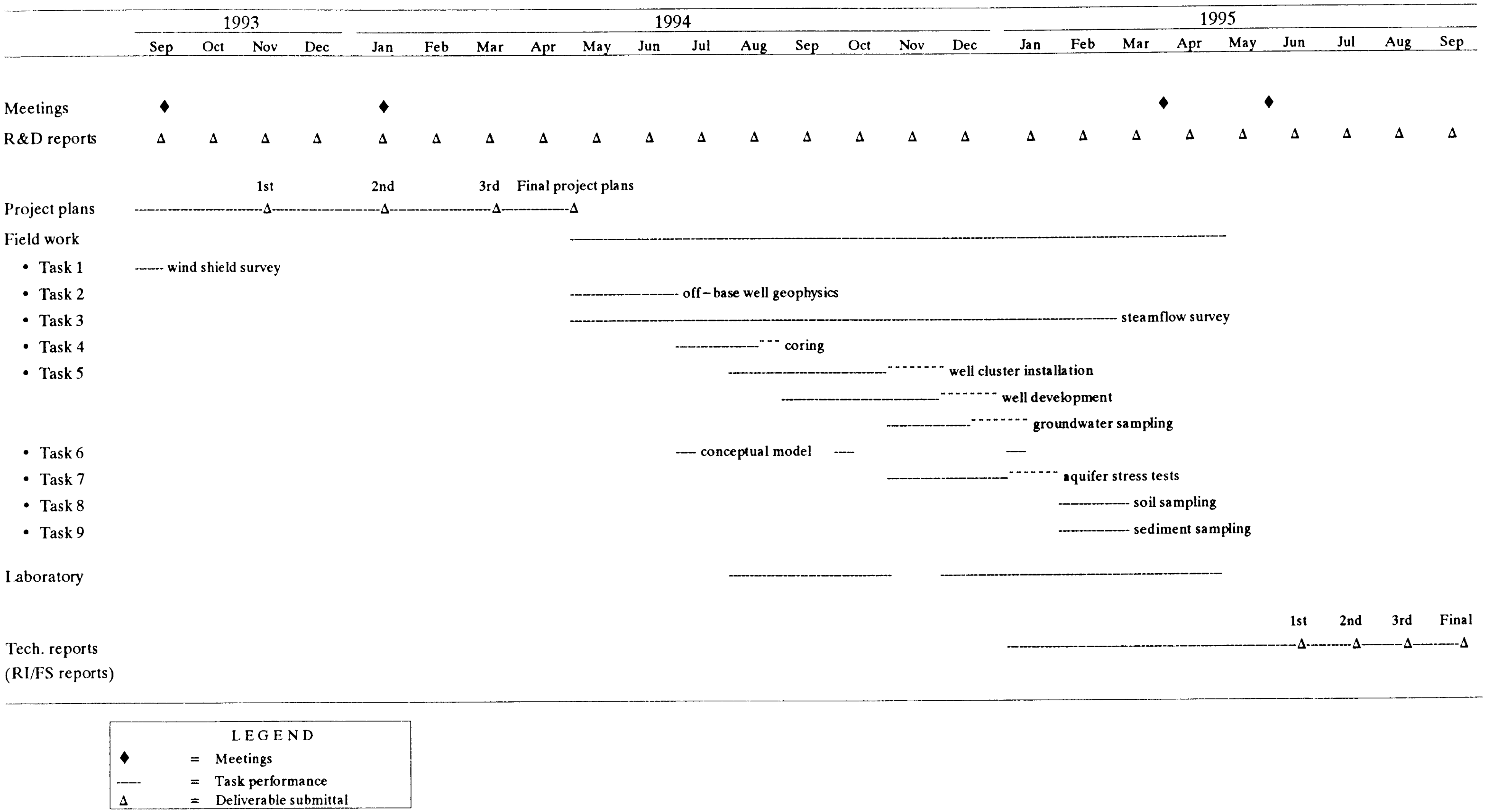

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Figure 6.2
Project Organization
Tinker AFB SCGW RI/FS

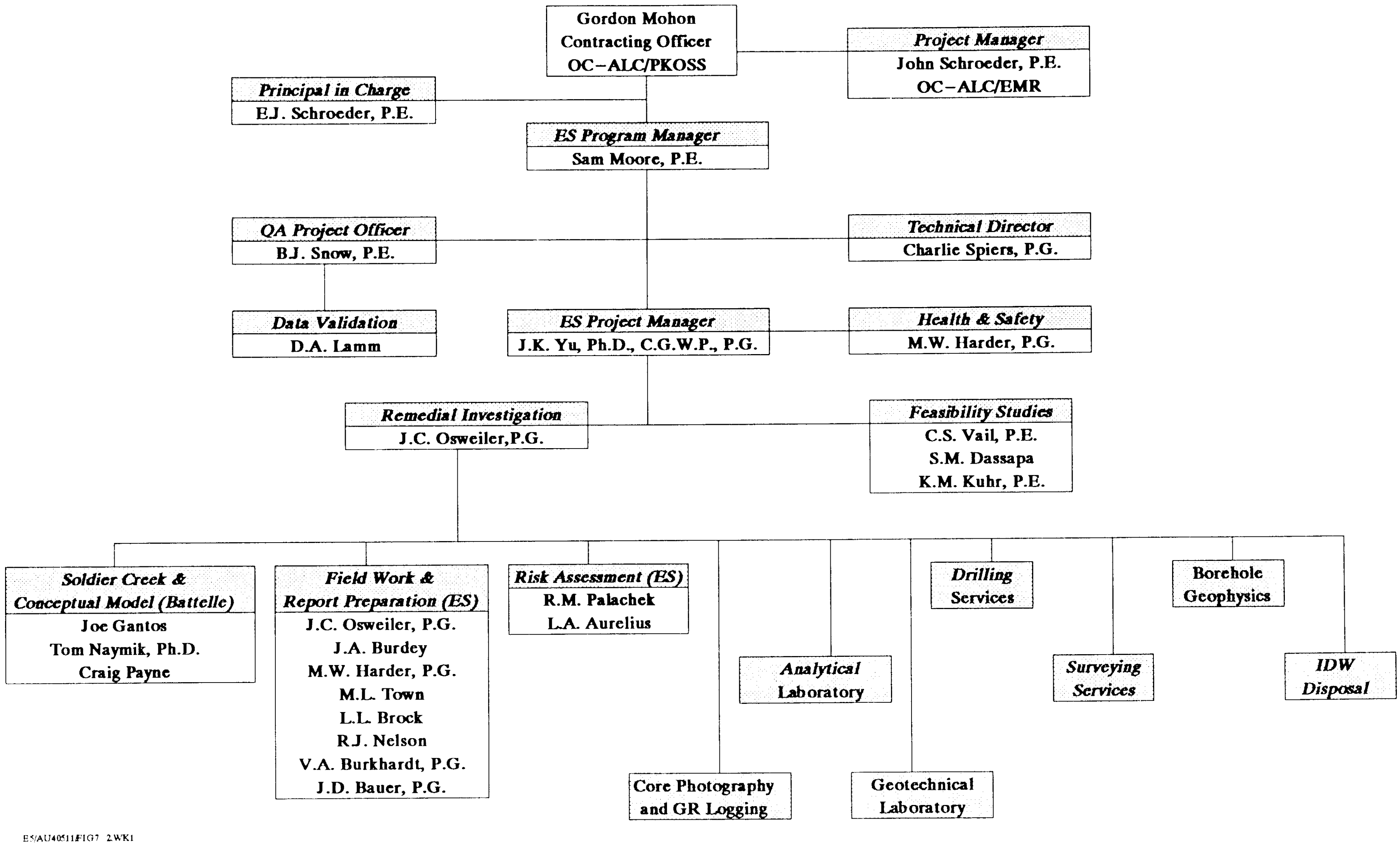

Table 6.1 Key Project Personnel
Tinker AFB SCGW RI/FS

Position	Personnel	Organization/ Address/ Telephone	Responsibilities
Tinker AFB Project Manager	John Schroeder, P.E.	OC-ALC/EMR 8745 Entrance Road A Tinker AFB, OK 73145-3303 (405) 736-2941	Primary contact Oversight of SCGW RI/FS activities.
Tinker AFB Contracting Officer	Gordon Mohon	OC-ALC/PKOSS 7858 5th Street, Suite 1 Tinker AFB, OK 73145-9106 (405) 739-3367	Contact for site access and information.
ES Technical Director	Charlie Spiers, P.G.	Engineering-Science, Inc. 57 Executive Park South, N.E. Suite 590 Atlanta, GA 30329-2265 (404) 235-2300	Technical review and oversight of investigation.
ES Project Manager	John Yu, Ph.D., C.G.W.P., P.G.	Engineering-Science, Inc. 8000 Centre Park Drive Suite 200 Austin, TX 78754 (512) 719-6000	Project administration and personnel coordination. Schedule and budget tracking.
ES RI Manager and Field Team Leader	John Osweiler, P.G.	Engineering-Science, Inc. 5600 Liberty Parkway Suite 700 Midwest City, OK 73110 (405) 732-9803	Maintain the RI project continuity and coordinate and assist with field work.
Tinker AFB Program Manager	Sam Moore, P.E.	Engineering-Science, Inc. 5600 Liberty Parkway Suite 700 Midwest City, OK 73110 (405) 732-9803	Program administrator

Table 6.1, continued

Position	Personnel	Organization/ Address/ Telephone	Responsibilities
ES Program Technical Director, Principal in Charge	Ernie Schroeder, P.E.	Engineering-Science, Inc. 8000 Centre Park Drive Suite 200 Austin, TX 78754 (512) 719-6000	ES nationwide IRP technical direction and contractual compliance oversight.
ES Corporate QA Officer	N.L. Presecan	Engineering-Science, Inc. 100 West Walnut Street Pasadena, CA 91124 (818) 440-6000	ES nationwide quality assurance.
ES Project QA Officer	Jay Snow, P.E.	Engineering-Science, Inc. 8000 Centre Park Drive Suite 200 Austin, TX 78754 (512) 719-6000	Ensure compliance with QA plan. Review and validation of laboratory data. Review of field records for completeness.
ES Project Health and Safety Officer	Marc Harder, P.G.	Engineering-Science, Inc. 8000 Centre Park Drive Suite 200 Austin, TX 78754 (512) 719-6000	Identification of health and safety protocols. Compliance with health and safety procedures.
Laboratory	To be determined	To be determined	Oversight of laboratory analytical activities.
Laboratory Project Manager	To be determined	To be determined	Coordinate sample analysis and laboratory report generation.
Laboratory QC Coordinator	To be determined	To be determined	Implement QC corrective actions and review data packages.

between ES and Tinker AFB. The project manager is John Yu, Ph.D., C.G.W.P., P.G.

Principal in Charge

The ES principal in charge is responsible for ensuring compliance with all contractual obligations of ES. The principal in charge will execute all agreements, subcontracts, and amendments to contracts and subcontracts. The principal in charge will also ensure that the contractual obligations of all subcontractors are met. The principal in charge is Ernest Schroeder, P.E.

Technical Director

The role of the technical director is to guide and review the technical aspects of the work through project completion to ensure that the highest standards are maintained. The technical director will direct the review of all project submittals, subcontracts, and deliverables. The technical director is Charlie Spiers, P.G.

Program Manager

The program manager (PgM) will ensure that all work is performed in accordance with the contract between Tinker AFB and ES. He will review all reports and ES invoices prior to submittal to Tinker AFB. He has primary responsibility for ensuring cost, schedule, and quality controls are maintained. The PgM is Sam Moore, P.E.

Quality Assurance Officer

The quality assurance officer will ensure that all documentation required by the quality assurance plan is correctly prepared and available in the project file. The quality assurance officer is Jay Snow, P.E.

Field Team Leader

The field team leader will be responsible for all field activities and will act as the main contact between the ES project manager and the Tinker AFB environmental project monitor. The field team leader will ensure that all field work is performed in accordance with State and Federal laws and regulations and the terms of all contractual agreements. The field team leader will complete daily progress reports and submit them to the project manager on a weekly basis. The field team leader will assist with the preparation of all documentation necessary for successful completion of the RI/FS.

The field team leader will ensure that all subcontractor work is performed in accordance with subcontract specifications and will track the progress of work. The field team leader will coordinate with the project manager to administer terms and conditions of the subcontract and assist the project manager in approving invoices. The field team leader will also work with subcontractors on the scheduling of field activities and assist in processing contract change requests. The field team leader will designate a temporary field team leader in his absence. The field team leader is John Osweiler, P.G.

Health and Safety Officer

The health and safety officer will ensure that all field activities are performed in accordance with the ES HSP and OSHA requirements. The health and safety officer will hold a brief health and safety meeting daily prior to the start of work. The site health and safety officer has the responsibility to stop work if it is being performed in an unsafe manner. The health and safety officer will designate a temporary health and safety officer in his or her absence. The site health and safety officer is Marc Harder, P.G.

Project Field Team

The project field team will consist of the field team leader, the site health and safety officer, and other individuals who assist the field team leader with the performance of field activities. The project field team will collect all soil and air samples, prepare all chain-of-custody records, prepare samples for delivery to the laboratory, and monitor all subcontract work.

6.3 PROJECT DELIVERABLES

For the RI/FS report, the internal draft is tentatively scheduled for June 1, 1995; the draft for July 16, 1995; the draft final for August 16, 1995; and the final for September 16, 1995.

SECTION 7

SUBCONTRACTING PLAN

The U.S. Air Force encourages the use of small and small disadvantaged businesses for subcontracted work. For the SCGW RI/FS project, ES will utilize as much as possible small and small disadvantaged businesses such as women, minority, and handicap-owned firms (8(A)firm). ES will follow the Federal Acquisition Rules (FAR), i.e., competitive bidding, in securing subcontractors. Tinker AFB OC-ALC/PKOSS will have to grant consent before ES can enter into a contract with subcontractors for this delivery order. Types of services which will be subcontracted are listed below:

- Soil boring and monitoring well drilling and construction
- General construction services
- Land surveying
- Laboratory chemical analysis
- Core preparation and analysis
- Borehole geophysics
- Geotechnical analysis
- Investigation derived waste disposal.

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