Multi-Phased Remedial Investigation (RI)
of Surface and Subsurface Contamination of Soldier Creek
at Tinker AFB, Oklahoma
U.S. Air Force Installation Restoration Program

FINAL

REMEDIAL INVESTIGATION WORKPLAN

MAY 1990

TINKER PROJECT NO: WWYK89-0196B
SITE ID NO: TINKER 0T03

Contract No.
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WASTE SCIENCE AND TECHNOLOGY CORP.

SOLDIER CREEK RI/FS (NPL Site)
Prepared for: Tinker Air Force Base through
U.S. Army Corps of Engineers
Tulsa District

FINAL

REMEDIAL INVESTIGATION WORKPLAN
TINKER AFB - SOLDIER CREEK RI/FS

Prepared for:
TINKER AIR FORCE BASE
through
TULSA DISTRICT CORPS OF ENGINEERS
CONTRACT NO. DACA56-89-C-0062

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PROJECT NO. 40054
MAY 4, 1990

Prepared under:
INSTALLATION RESTORATION PROGRAM
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SITE I.D. NO. TINKER OT03

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EXECUTIVE SUMMARY

This Remedial Investigation Workplan addresses the scope of the remedial investigation (RI) activities planned for implementation at the Soldier Creek site at Tinker Air Force Base (AFB). It describes the activities to be completed, the schedule, and the expected deliverables.

Tinker AFB is located southeast of Oklahoma City in central Oklahoma. The main portion of Soldier Creek is located to the east of Tinker AFB, however, two tributaries (West and East Soldier Creeks) originate on the base. The Soldier Creek site, a National Priorities List site, includes Soldier Creek, its tributaries, and any area underlying or adjacent to the water way which may be contaminated by the migration of hazardous substances, pollutants, or contaminants from Tinker AFB (EPA, 1988a). Tinker AFB is conducting a remedial investigation and feasibility study at the site under the U.S. Air Force's Installation Restoration Program.

The workplan's site description includes a summary of the previous investigations and analytical data pertinent to the understanding of existing environmental conditions at the site. Studies completed over the past several years provide limited information on surface water, groundwater, and sediment contamination. This existing data was reviewed and used to prepare a preliminary risk assessment for the Soldier Creek site.

A preliminary risk assessment was prepared during RI workplanning activities to identify the information that must be gathered during the field investigation in order to complete a baseline risk assessment. For the Soldier Creek site, the preliminary risk assessment identifies a subset of all contaminants detected during previous site investigations as the preliminary contaminants of concern for the site. Metals (including cadmium, chromium, copper, and lead); volatile organics (including trichloroethene and 1,2-dichlorobenzene); and cyanide were identified as preliminary contaminants of concern. The preliminary risk assessment identifies potential migration pathways (surface water/sediment, groundwater, and air), exposure routes (ingestion, dermal contact and inhalation), and potential receptors (on-base and off-base human, aquatic, and wildlife populations) for the site. This process identifies missing information such as lateral, vertical, and downstream extent of sediment contamination; contaminant concentrations in the sediment, surface and groundwater; and quantification of the potentially exposed populations which must be collected during the RI in order for a baseline risk assessment to be completed.

The workplan also preliminarily identifies the applicable or relevant and appropriate requirements (ARARs) for the Soldier Creek site. By law, any remedial action selected for a site must not only assure protection of human health and the environment, but must meet the ARARs. There are three types of ARARs: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs set protective levels for the media of interest (i.e. sediment, surface water, groundwater, and air) or set a discharge level if discharge is required as part of the remediation. Location-specific ARARs restrict concentrations with regard to locations such as wetlands, floodplains, and sensitive habitats. Action-specific ARARs are established by the remedial action itself and therefore define such items as performance levels or residual amounts. By establishing preliminary ARARs for the Soldier Creek site the workplan also identifies data gaps to be filled by the RI field investigation.

The preliminary identification of remedial action objectives and remedial alternatives focuses the RI data gathering efforts into those activities which will collect information needed to develop and evaluate mitigation measures for the site. The RI Workplan scopes the field work to gather the data necessary for site characterization and to provide the basis for the subsequent feasibility study, remedial design, and remedial action. When the remedial action objectives are satisfied, either sources of contamination are eliminated, contaminant transport is mitigated, or receptor exposure is prevented. The workplan restates the following remedial action objectives presented in the Data Quality Objectives Report: (1) prevent human and animal contact with or ingestion of contaminated sediments, surface, or groundwater; (2) prevent the release or transport of contaminants from any one of the three above-mentioned media to another; (3) prevent the degradation of surface and groundwater by on-base sources; and (4) prevent the inhalation of contaminants via use of contaminated groundwater.

Consideration is given to the remedial action alternatives most likely to be developed during the feasibility study because certain information will be required for their evaluation, design, and implementation. The RI Workplan identifies three sediment alternatives: (1) containment of contaminated sediments by in situ measures such as channel diversions, drainage controls, and retaining dikes; (2) containment and in situ treatment of dry drainage ways by stabilization or vitrification; and (3) removal (dredging or backhoe), surface controls, treatment (physical/chemical for the inorganics and biological, chemical, or physical/chemical for the organics), and disposal of treated sediments on-base or off-base. The one surface water alternative the workplan identifies involves collection of contaminated surface water, treatment, and discharge into Soldier Creek or a wastewater treatment facility. Contaminated groundwater may be contained by a physical barrier such as a slurry wall or a grout curtain or contained hydraulically by french drains or wellpoints. Hydraulic containment would require treatment of the extracted groundwater and discharge to the creek or to a wastewater treatment facility. A similar alternative would be to extract the contaminated groundwater but for the purpose of active restoration rather than containment. One final alternative would be to provide active restoration by in situ treatment methods such as permeable treatment beds or bio-reclamation.

The Soldier Creek RI has been subdivided into two phases to collect data and allocate resources more efficiently. The workplan describes the Phase I field investigation and sample/data analysis activities in detail. Since the Phase II activities depend to a large measure on the results and interpretation of the Phase I data, the Phase II investigation is described in general terms. The workplan mentions the acquisition of easements and permits required for access to private property. It also mentions support activities such as equipment procurement and mobilization, analytical laboratory subcontracting, and acquisition of sample bottles and shipping containers. The sediment, surface water, and groundwater sampling; the field survey; and the RI-derived waste handling activities are described in depth in the workplan. These activities may be summarized as follows:

- Approximately 84 sediment samples (not including blanks or duplicates) taken from two depths at 42 locations will be submitted for chemical analysis of acid, base/neutral extractables, metals and cyanide. An additional 84 samples taken from two depths at 42 locations will be submitted for volatile organic analysis and total organic carbon, and 16 samples will be submitted for physical parameter analysis (i.e. particle size, Atterberg limits, density, and permeability). One sediment background sample will be collected off-base and analyzed for the above-mentioned chemical parameters.

- Approximately 42 surface water samples (not including blanks or duplicates) will be analyzed for the same chemical parameters as the sediment samples. Sixteen samples will be analyzed for alkalinity, hardness, chemical oxygen demand, total suspended solids, biochemical oxygen demand, total organic carbon, oil and grease, and nitrates. One surface water background sample will be collected off-base and analyzed for the above-mentioned chemical parameters.

- At eight existing, off-base wells, groundwater levels will be measured and unfiltered samples will be collected and analyzed for the same chemical parameters as the surface water and sediment samples. Three filtered samples will be collected and analyzed for dissolved metals. No background groundwater sample will be collected as previous investigations conducted on Tinker AFB have established background groundwater chemical concentrations for the site vicinity.

- A field survey will be conducted which will establish the stream bed profile at each sampling location and at stations located every 100 feet along the length of the creek within the Phase I RI study area. The field survey team will also measure flow velocity at each sampling location and at stations located every 500 feet along the length of the creek within the study area.

The survey team will establish the location of outfalls and drains discharging to the creek within the study area and note surrounding area land use characteristics of potential importance to the project.

- RI-derived waste includes containerized excess sediment from sampling activities, decontamination solutions, and personal protective clothing. All RI-derived wastes will be containerized in 55 gallon drums with the drums staged at a designated location on-base. Following receipt of sample results, the disposal location of each type of RI-derived waste will be determined. Tinker AFB is the generator of RI-derived waste from this investigation and Tinker AFB personnel will sign manifests for its transport and disposal.

Samples will be tracked from the point of collection through review of analytical results. Data will be validated, reduced, and entered into a computerized database to facilitate data manipulation, evaluation, and reporting.

1.0 INTRODUCTION

This workplan defines the scope of work for the performance of remedial investigation activities for the Tinker Air Force Base-Soldier Creek Remedial Investigation (RI)/Feasibility Study (FS). A brief summary of the site location and history, a discussion of the authority for the work, and an explanation of the purpose and scope of the RI Workplan are included in this section.

1.1 SUMMARY OF SOLDIER CREEK SITE LOCATION AND HISTORY

Tinker Air Force Base (AFB) is located southeast of the Oklahoma City metropolitan area, bordering on Del City and Midwest City in central Oklahoma as illustrated on Figure 1-1. The main portion of Soldier Creek is located to the east of Tinker AFB, however, two tributaries (West and East Soldier Creeks) originate on the base. Soldier Creek flows to the north from its headwaters near Southeast 59th Street to its confluence with Crutcho Creek approximately six miles downstream. The Soldier Creek site includes Soldier Creek, its tributaries, and any area underlying or adjacent to the waterway which may be contaminated by the migration of hazardous substances, pollutants, or contaminants from Tinker AFB (EPA, 1988a).

For purposes of the Tinker AFB - Soldier Creek RI/FS project, West Soldier Creek is identified as the tributary which originates on the west side of Building 3001 and flows northward to its confluence with Soldier Creek approximately two miles downstream. East Soldier Creek is identified as the tributary which flows northward along the east side of Building 3001 and past the Industrial Waste Treatment Plant (IWTP), from its origin just to the north of Building 3705 to its confluence with Soldier Creek approximately one mile downstream. For the purposes of the Phase I RI, the study area primarily consists of the tributaries which directly receive

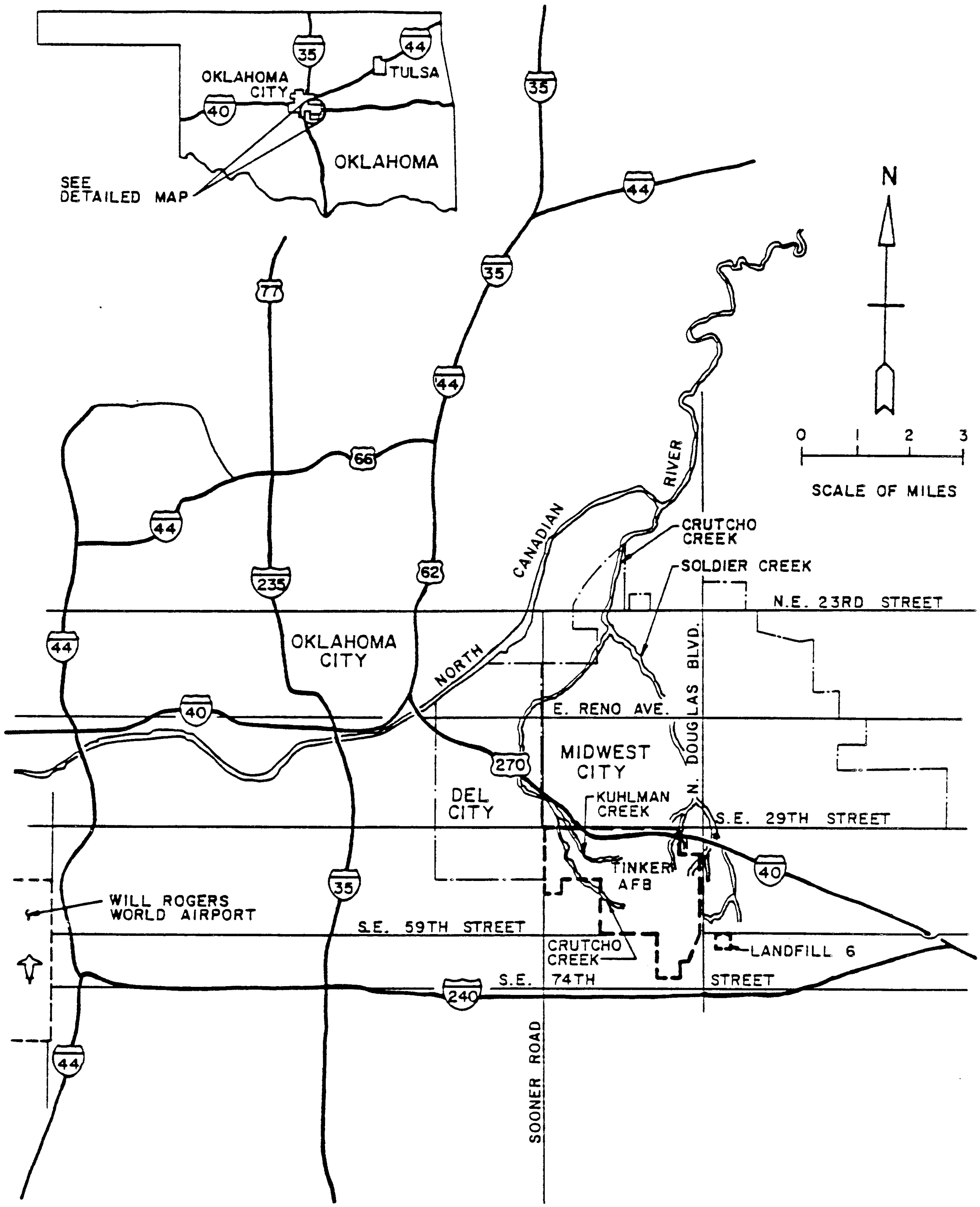


FIGURE 1-1
SITE VICINITY
TINKER AFB-SOLDIER CREEK RI/FS
RI WORKPLAN

discharges or runoff from Tinker AFB (West and East Soldier Creeks) and the main stem of Soldier Creek from its headwaters downstream to East Reno Avenue as illustrated on Figure 1-2.

Soldier Creek and its tributaries receive surface runoff from an area covering approximately 9,000 acres. Areas on Tinker AFB which contribute runoff or discharge to Soldier Creek and its tributaries include the eastern-most runway area, the Building 3001 complex, and the IWTP. The Building 3001 complex consists of an aircraft overhaul and modification complex to support the mission of the Oklahoma City Air Logistics Center. The IWTP, located in the northeastern portion of the base, receives industrial process discharge waters from the Building 3001 complex via a series of underground lines. Once received at the plant, these waters are treated and combined with treated sanitary wastewater prior to discharge to East Soldier Creek under a National Pollutant Discharge Elimination System (NPDES) permit.

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. The primary mission has not changed. Tinker AFB is still a major industrial complex for overhauling, modifying, and repairing military aircraft, aircraft engines, and accessory items.

As part of the overall Air Force Installation Restoration Program (IRP), Tinker AFB began an investigation of previously used waste disposal sites in 1981 (EPA, 1988a). A basewide sampling program was conducted in 1983. Analytical results from the sampling program indicated trichloroethene was present in the groundwater. Remedial investigations were conducted by Tulsa COE from 1986 to 1989 to determine the nature and extent of groundwater contamination in the Building 3001 complex area. These investigations determined that chromium, in addition to trichloroethene,

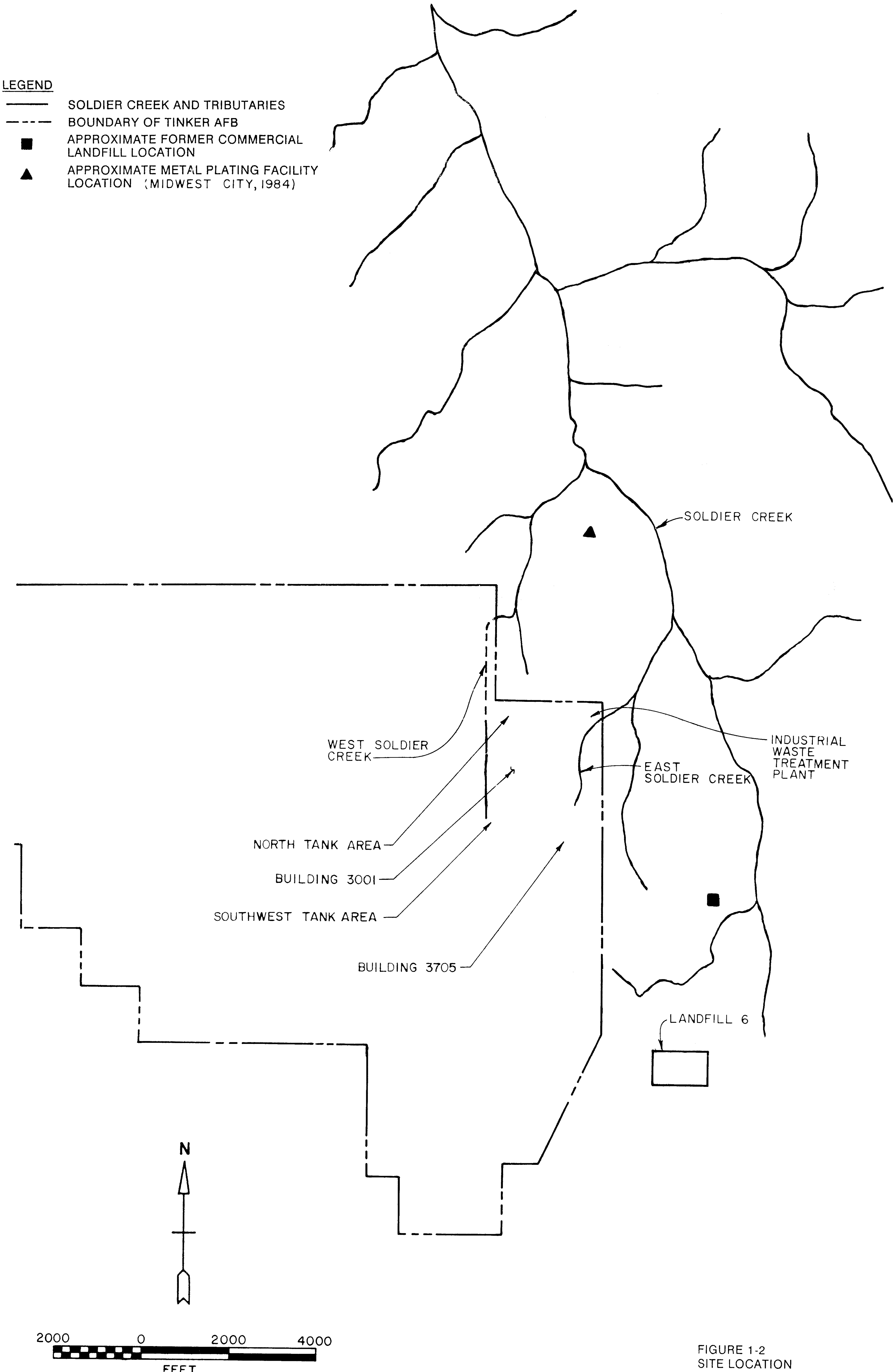


FIGURE 1-2
SITE LOCATION

were contaminants of concern in the groundwater. On July 22, 1987, the Building 3001 site and the Soldier Creek site were added to the National Priorities List (NPL).

1.2 AUTHORITY FOR THE WORK

The U.S. Environmental Protection Agency (EPA) Region VI, the Oklahoma State Department of Health (OSDH), and the U.S. Department of the Air Force, Tinker AFB signed a Federal Facility Agreement (Administrative Docket Number NPL-U3-2-27) under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) Section 120 and the Superfund Amendments and Reauthorization Act of 1986 (SARA) on December 9, 1988. The intent of this agreement is to ensure that the past and present activities at Building 3001 and Soldier Creek, NPL sites, are thoroughly investigated and appropriately remediated to protect the public health, welfare, and environment. The Federal Facility Agreement establishes procedures and schedules for developing, implementing, monitoring, documenting, and approving response actions at both the Building 3001 and Soldier Creek sites, in accordance with CERCLA and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), Superfund guidance and policy, Resource Conservation and Recovery Act (RCRA), and RCRA guidance and policy. The Federal Facility Agreement establishes requirements for the performance of the RI and the FS at the sites in accordance with CERCLA. The agreement establishes procedures for remedial actions and conducting a separate Focused RI/FS for each Operable Unit identified. It also establishes procedures for proposing a new Operable Unit at either site. This process allows for remedial actions to be implemented as Operable Units that have been (or will be) identified prior to the final remedial action for the site. The Federal Facility Agreement specifies that Tinker AFB will establish and maintain an administrative record that will include all documents that form the basis for the selection of a response action at both the Building 3001 and Soldier Creek sites (EPA, 1988a and Tulsa COE, 1989a).

The Building 3001 site has undergone extensive investigations to determine the nature and extent of contamination in and around this site (Tulsa COE, 1988a). In addition, a risk assessment (Tulsa COE, 1988b) and feasibility study (Tulsa COE, 1989a) have been completed for the Building 3001 site.

The U.S. Army Corps of Engineers, Tulsa District (Tulsa COE) is acting as an agent on behalf of Tinker AFB for the completion of RI/FS activities for the Soldier Creek site. This Remedial Investigation (RI) Workplan and accompanying Data Quality Objectives (DQO) Report, Quality Assurance Project Plan (QAPP), Sampling and Analysis Plan (SAP), and Health and Safety Plan (HSP) have been prepared by B&V Waste Science and Technology Corp. (BVWST) for the Tulsa COE under Contract Number DACA56-89-C-0062.

1.3 PURPOSE AND SCOPE OF THE RI WORKPLAN

This RI Workplan addresses the scope of the RI activities planned for implementation at the Soldier Creek site, and is intended to be a companion document to the DQO Report. Additional details regarding completion of RI field investigation activities are provided in the accompanying SAP and QAPP.

The RI Workplan presents the following information:

- Site Description
  - Site Location and Description
  - Site History
  - Previous Investigations and Reports
  - Environmental Conditions.
- Preliminary Risk Assessment
  - Preliminary Contaminants of Concern
  - Inherent Toxicity
  - Potential Migration Pathways
  - Potential Receptors and Routes of Exposure
  - Risk Assessment Data Gaps.
- Applicable or Relevant and Appropriate Requirements.

- Site Remedial Action Objectives and Preliminary Identification of Remedial Alternatives
  - Remedial Action Objectives
  - Preliminary Identification of Remedial Alternatives.

- Remedial Investigation Scope of Work
  - Phase I Field Investigation
  - Phase I Sample and Data Analysis
  - Phase II Field Investigation
  - Phase II Sample and Data Analysis
  - Assessment of Risks
  - Chemical-specific ARARs Development
  - Remedial Investigation Report
  - Miscellaneous Activities.

- Remedial Investigation Schedule.

2.0 SITE DESCRIPTION

2.1 SITE LOCATION AND DESCRIPTION

Tinker AFB is located in Oklahoma County to the southeast of the metropolitan area comprised of Oklahoma City, Del City, and Midwest City in central Oklahoma. The base is approximately bounded by Sooner Road to the west, Interstate 40 to the north, Douglas Boulevard to the east, and Southeast 74th Street to the South as illustrated on Figure 1-1. Soldier Creek is located mainly to the east of the base and flows to the north from its headwaters located just to the north of Southeast 59th Street, to its confluence with Crutcho Creek approximately six miles downstream. Two tributaries, referred to as East Soldier Creek and West Soldier Creek, are located on the northeastern portion of Tinker AFB as shown on Figure 1-2.

The Soldier Creek site includes Soldier Creek, its tributaries, and any areas underlying or adjacent to the waterway which may be contaminated by the migration of hazardous substances, pollutants, or contaminants from Tinker AFB (EPA, 1988). For the purposes of the Phase I Soldier Creek RI, the study area will primarily consist of the tributaries which receive discharges or runoff from Tinker AFB (West and East Soldier Creeks) and the main branch of Soldier Creek from its headwaters to where it flows beneath East Reno Avenue.

Soldier Creek and its tributaries receive surface runoff from an area consisting of approximately 9,000 acres. Areas on Tinker AFB which contribute runoff or discharge to Soldier Creek and its tributaries include the Building 3001 site and the IWTP, which comprises a total contributing area of approximately 300 acres. The Building 3001 site includes Building 3001 complex, two adjacent underground storage tank areas, and the surrounding areas encompassed by the lateral extent of contaminant plume (EPA, 1988a). The Building 3001 complex consists of an aircraft overhaul and modification complex to support the mission of the Oklahoma City Air Logistics Center. The primary activities at Building 3001 include the following:

- o Disassembly, degreasing, cleaning, and inspection of aircraft and engine parts and components.
- o Plating, painting, heat treating, and testing of metal parts and components.
- o Assembly and repairing of accessories including electrical, valve and governor, gear box, tubing and cable, fuel controls, nozzles, pumps, and bearings.
- o Assembly, testing, and packaging of aircraft and aircraft components.

The North Tank Area contains abandoned underground storage tanks for fuel oil, diesel fuel, and gasoline, and is located north of Building 3001. The Southwest Tank Area contains abandoned fuel and solvent tanks and active solvent tanks, and is located to the southwest of Building 3001 (Tulsa COE, 1988a).

The IWTP, located in the northeastern portion of the base (Figure 1-2), receives industrial process discharge waters from the Building 3001 complex via a series of underground lines. Once received at the plant, these waters are treated and combined with treated sanitary wastewater prior to discharge to East Soldier Creek under an NPDES permit with the Oklahoma Water Resources Board (NUS, 1989).

2.2 SITE HISTORY

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 airpower. 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 besides the Douglas Aircraft Plant. During 1951, the Air Force acquired a parcel of land located one half 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 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 (Engineering Science, 1982).

As part of the overall Air Force Installation Restoration Program (IRP), Tinker AFB began a preliminary assessment of previously used waste disposal sites in 1981 (EPA, 1988a). 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. These investigations identified chromium as an additional contaminant of concern in the groundwater. On July 22, 1987, the Building 3001 site and the

Soldier Creek site were added to the National Priorities List (NPL). On December 9, 1988, EPA Region VI, the OSDH, and the United States Air Force, Tinker AFB signed a Federal Facility Agreement under CERCLA Section 120 to "ensure that the environmental impacts associated with past and present activities at the [Building 3001 and Soldier Creek sites] are thoroughly investigated and appropriate remedial action [are] taken as necessary to protect the public health, welfare, and the environment" (EPA, 1988a). The specific activities to be performed under the Federal Facilities Agreement include, but are not limited to, completion of RI/FS activities at the Soldier Creek site (EPA, 1988a). The Building 3001 site has undergone extensive investigations to determine the nature and extent of contamination in and around the complex. In addition, a risk assessment (Tulsa COE, 1988b) and feasibility study (Tulsa COE, 1989a) have been completed for this site. The North Tank Area has been identified as a separate Operable Unit and the Southwest Tank Area is being remediated in accordance with underground storage tank regulations.

Investigation of possible sediment and surface water contamination of Soldier Creek began in 1984 (Radian, 1985a). Additional information on investigations conducted to determine the extent of contamination in Soldier Creek is presented in Section 2.3, Previous Investigations and Reports. Based on the results of the investigations of Soldier Creek, a removal action was performed on portions of East and West Soldier Creeks on Tinker AFB in early 1986. Visibly contaminated sediments were removed and disposed in an approved hazardous waste landfill. Post-removal sampling and visual inspection indicated that some contaminants may still be present in the sediments in Soldier Creek (Tulsa COE, 1988a). A storm sewer investigation for Soldier Creek was completed in October 1989 to determine which storm sewers could potentially transmit contaminants from Building 3001 to Soldier Creek (NUS, 1989).

2.3 PREVIOUS INVESTIGATIONS AND REPORTS

A variety of investigations pertaining to the Soldier Creek site have been conducted by a number of organizations since 1984. A summary of these previous investigations and pertinent reports is shown in Table 2-1. A description of each of these previous investigations is given in this Appendix including, if known, the purpose of each investigation, sampling locations, pertinent analytical data, sample methodology and conclusions. Each subsection is titled according to the organization that performed the sampling and the media sampled.

2.3.1 Radian Sediment Analytical Results

The purpose of the IRP Phase II Confirmation/Quantification Stage 2 investigation performed by the Radian Corporation (Radian, 1985a) was to determine if solvent storage and waste disposal practices resulted in environmental contamination at Tinker AFB. 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 on 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 and were identified by selected primary data users to be pertinent to the Soldier Creek RI. The locations of these sampling stations are shown on Figure 2-1 along with the metals (cadmium, chromium, lead, zinc) analytical results for each station. The metals analytical results were shown because of the relatively high concentrations in comparison to the other analyses results. Sediment sample analytical results for all analyzed parameters are shown in Table 2-2.

Sediment samples were collected using either a hand trowel or a section of 2-inch outside diameter polycarbonate tube. The tube was employed as a "plug" or coring device. Generally, the depth of sampling extended from

TABLE 2-1

SUMMARY OF PREVIOUS INVESTIGATIONS
TINKER AFB – SOLDIER CREEK RI/FS
RI WORK PLAN

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, 1985a)	Radian Corporation	6/84	Sediment	Metals, Fluoride, Cyanide, PCBs, Pesticides, Phenols, Nitrates, and Total Organic Carbon	Radian Laboratories
An Evaluation of the Effects of Wastewater Discharge from TAFB on Water Quality of Crutcho & Soldier Creeks (EPA, 1984)	EPA	7/85	Sediment Water	Metals, VOCs, BNAs Metals, VOCs, BNAs, Water Quality Data	EPA Laboratory
Site Investigation Report (HKS, 1985)	Harry Keith & Sons, Inc.	10/85	Sediment	Metals, VOCs, BNAs, PCBs, Pesticides Fluoride, Nitrate, Cyanide, Phenols	Environmental Laboratories Inc.
"Sample Results"(1) Report (HKS, 1986)	Harry Keith & Sons, Inc.	4/86 & 5/86	Sediment	Metals, BTX, VOCs	Environmental Control Laboratory
"Sample Results"(1) Report IWTP & STP Discharges (Tinker AFB, 1987a)	Tinker AFB	3/87 - 9/87	Water	VOCs	METLAB
"Sample Results"(1) Report (OSDH, 1987)	Oklahoma State Department of Health	6/87	Sediment Water	Metals Metals, VOCs	Oklahoma State Department of Health Laboratory
NPDES Analytical Results (Tinker AFB, 1987b)	Tinker AFB	9/86 - 7/87	Water	Water Quality Data (pH, TSS, Oil and Grease)	Analab of Texas
Building 3001 Remedial Investigations, Volumes I and II (Tulsa COE, 1988a and 1988d); Building 3001 Supplemental Quarterly Remedial Investigations, Draft (Tulsa COE, 1989b); Tinker AFB Groundwater Assessment Update (Tulsa COE, 1989c); and "Sampling Results"(1) Groundwater Report (Tulsa COE, 1988c)	Tulsa COE	3/88, 10/88	Water	VOCs, BNAs, Metals, TOC, pH, Specific Conductivity, TICs (2)	U.S. Corps of Engineers, Southwest Division Laboratory Oklahoma State Department of Health Oklahoma State Department of Health 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, COD, Cyanide, Total Phenols, Phosphorus, Chromium (Hex)	NUS Corporation

NOTES:
(1) "Sampling Results" – No reports were generated.
(2) TICs – Tentatively Identified Compounds.

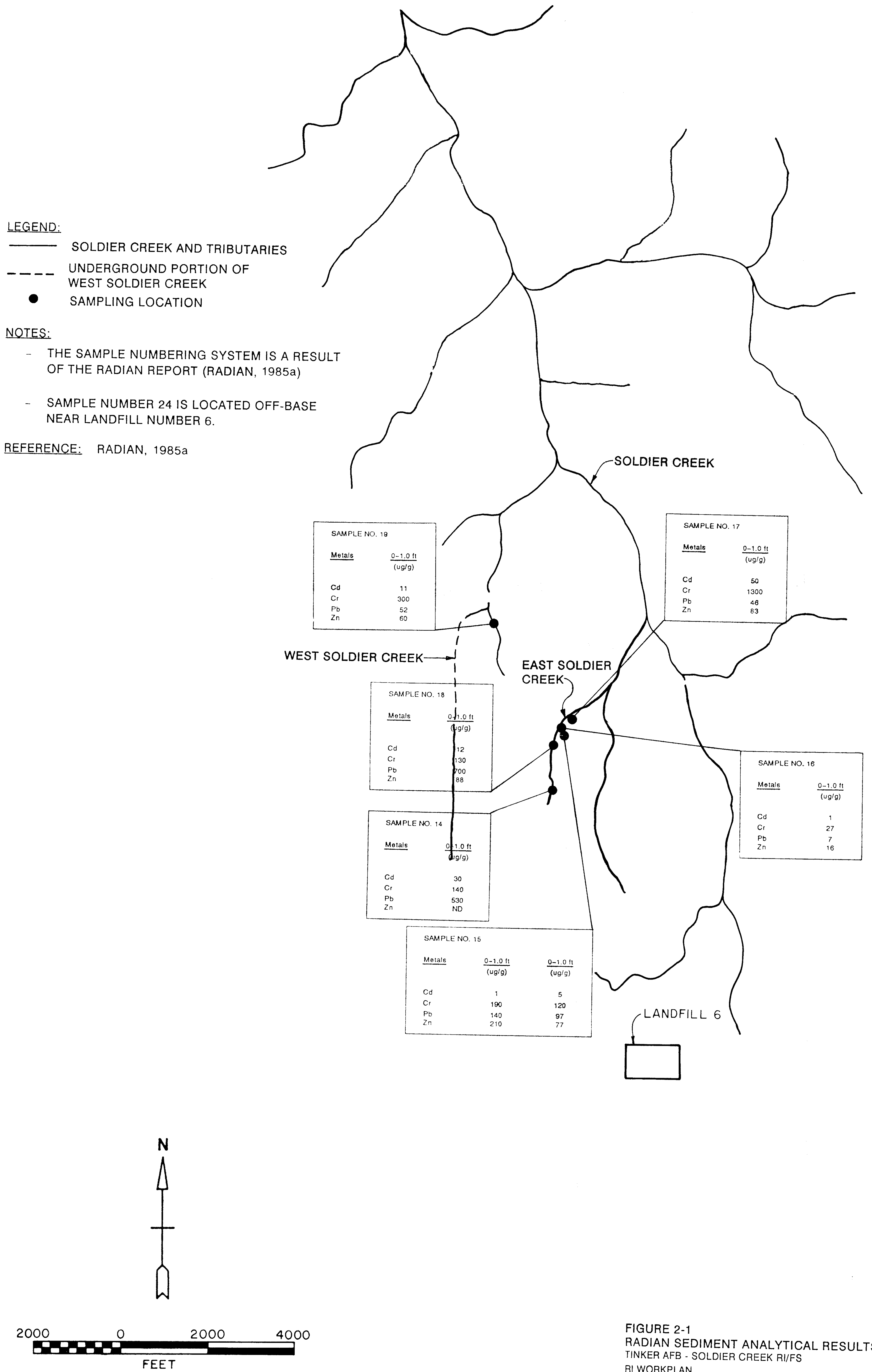


FIGURE 2-1
RADIAN SEDIMENT ANALYTICAL RESULTS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

TABLE 2-2

RADIAN SEDIMENT ANALYTICAL DATA
TINKER AFB – SOLDIER CREEK RI/FS
RI WORKPLAN

SAMPLE NO.	SAMPLE LOCATION	SAMPLER	DEPTH (FT)	DATE	UNITS	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Cu	Zn	Mn	Ni	Fl	NITRATE	PCBs	TOC
24	T-SED-28	RADIAN	0-1.0	7/19/84	ug/g	1	110	1	12	8	ND	ND	ND	5	8	250	6	3	3	ND	1
14	T-SED-15	RADIAN	0-1.0	6/20/84	ug/g	1	330	30	140	530	2	ND	3	52	ND	140	19	ND	ND	ND	4
15	T-SED-13	RADIAN	0-1.0	6/20/84	ug/g	2	220	1	190	140	1	1	2	230	210	250	43	ND	ND	ND	1
15	T-SED-18	RADIAN	0-1.0	6/29/84	ug/g	1	200	5	120	97	ND	ND	2	54	77	250	12	ND	1	1	1
16	T-SED-14	RADIAN	0-1.0	6/20/84	ug/g	1	320	1	27	7	ND	ND	2	4	16	530	6	ND	1	1	ND
18	T-SED-12	RADIAN	0-1.0	6/20/84	ug/g	ND	410	12	130	700	ND	ND	2	160	88	330	83	ND	1	1	ND
17	T-SED-11	RADIAN	0-1.0	6/20/84	ug/g	1	170	50	1300	46	ND	ND	2	45	83	790	230	ND	1	ND	1
19	T-SED-16	RADIAN	0-1.0	6/20/84	ug/g	1	220	11	300	52	ND	ND	2	69	60	170	170	ND	1	2	2

NOTE:
Cyanide, phenols, pesticides and herbicides analysis were determined with no chemical concentrations detected.
ND = Not Detected

6 to 12 inches below the channel bottom as conditions would allow. At several sampling locations, samples were collected as composites obtained from two or more discrete points in the area of the sampling station. Multiple point samples were collected for compositing at sample stations where stream conditions varied significantly with the station reach. Point samples were composited as the station sample to be representative of local stream conditions.

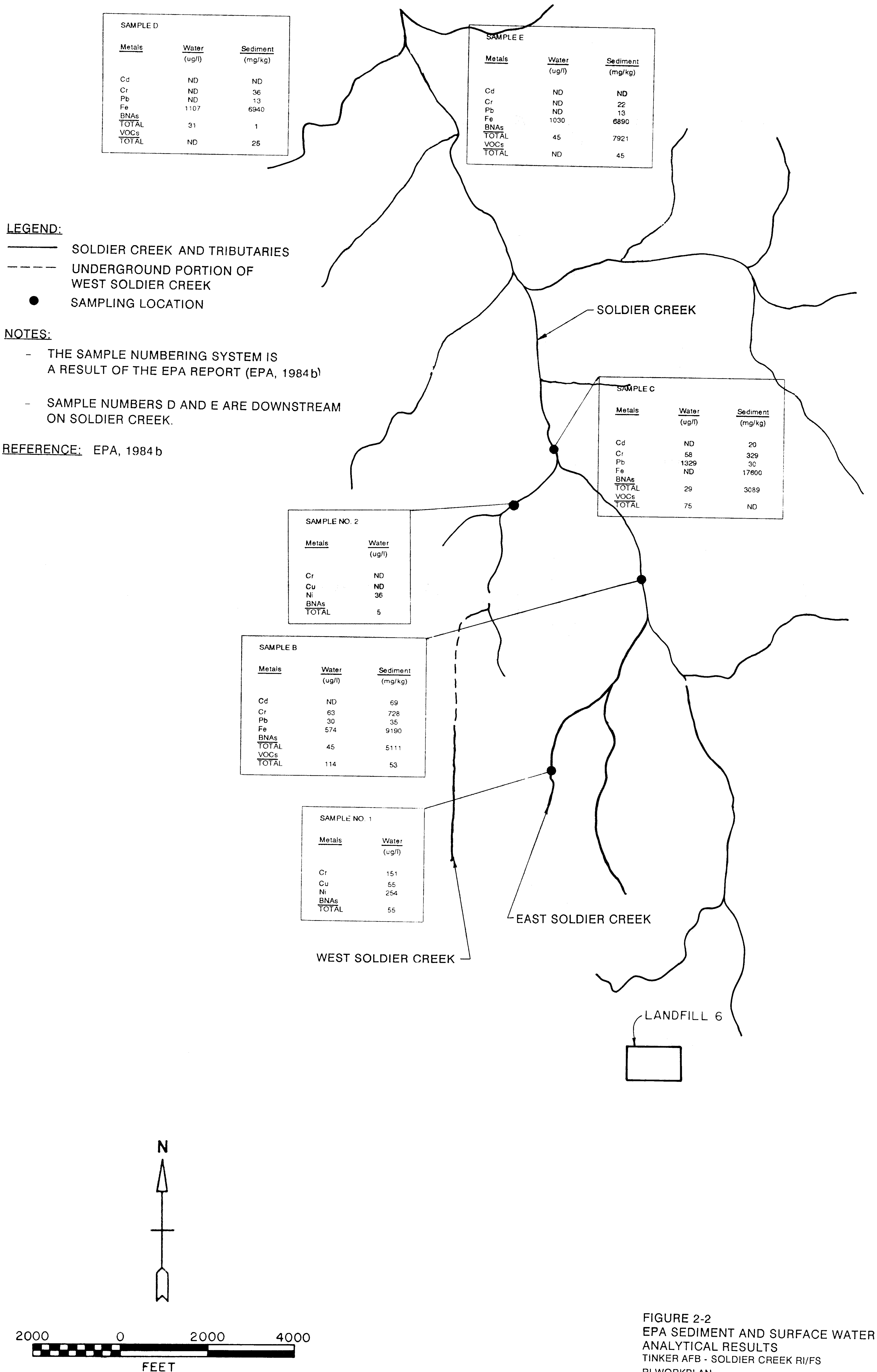
Immediately following the collection and compositing, each sediment sample was placed in a quart glass jar with a Teflon cap liner. Each sample was labeled and packed with ice in an insulated shipping container. Samples were shipped nightly to Radian Analytical Services using an overnight parcel service.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

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

2.3.2 <u>EPA Sediment and Surface Water Analytical Results</u>

The purpose of the report titled "An Evaluation of the Effects of Wastewater Discharge from TAFB on Water Quality of Crutcho and Soldier Creeks," (EPA, 1985a) was to present data and conclusions resulting from the Oklahoma Water Resources Board (OWRB) investigation of the potential toxics contamination of Crutcho and Soldier Creeks. EPA Region VI provided technical assistance to the OWRB by conducting chemical analyses and bioasssays on three effluent and five stream samples. Samples were collected by the OWRB and EPA on October 30 through November 1, 1984.

Six of the sediment sampling locations within Soldier Creek were identified by selected primary data users as pertinent to the Soldier Creek RI. The locations of these sampling stations are shown in Figure 2-2, along with the metals (cadmium, chromium, lead, iron), total acid, base/neutral



SAMPLE D

Metals	Water (ug/l)	Sediment (mg/kg)
Cd	ND	ND
Cr	ND	36
Pb	ND	13
Fe	1107	6940
BNAs TOTAL	31	1
VOCs TOTAL	ND	25

SAMPLE E

Metals	Water (ug/l)	Sediment (mg/kg)
Cd	ND	ND
Cr	ND	22
Pb	ND	13
Fe	1030	6890
BNAs TOTAL	45	7921
VOCs TOTAL	ND	45

SAMPLE C

Metals	Water (ug/l)	Sediment (mg/kg)
Cd	ND	20
Cr	58	329
Pb	1329	30
Fe	ND	17600
BNAs TOTAL	29	3089
VOCs TOTAL	75	ND

SAMPLE NO. 2

Metals	Water (ug/l)
Cr	ND
Cu	ND
Ni	36
BNAs TOTAL	5

SAMPLE B

Metals	Water (ug/l)	Sediment (mg/kg)
Cd	ND	69
Cr	63	728
Pb	30	35
Fe	574	9190
BNAs TOTAL	45	5111
VOCs TOTAL	114	53

SAMPLE NO. 1

Metals	Water (ug/l)
Cr	151
Cu	55
Ni	254
BNAs TOTAL	55

LEGEND:

- ——— SOLDIER CREEK AND TRIBUTARIES
- - - - - UNDERGROUND PORTION OF WEST SOLDIER CREEK
- ● SAMPLING LOCATION

NOTES:

- THE SAMPLE NUMBERING SYSTEM IS A RESULT OF THE EPA REPORT (EPA, 1984b)
- SAMPLE NUMBERS D AND E ARE DOWNSTREAM ON SOLDIER CREEK.

REFERENCE: EPA, 1984b

FIGURE 2-2
EPA SEDIMENT AND SURFACE WATER ANALYTICAL RESULTS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

extractables (BNAs), and total VOCs analytical data for each station. These data were shown to illustrate the metals concentrations and the possible "hot spots" for BNA and VOC contamination. The pertinent sampling analytical data for this investigation is shown in Table 2-3.

The precise sampling methodology for collection of the sediment and surface water samples is unknown. The effluent sample from outfall sampling point 1 was collected as a 24 hour composite. The effluent samples from the two other outfall sampling points were collected as single grab samples. Grab samples were collected at each stream sampling station.

In general, EPA concluded that water quality of Crutcho and Soldier Creeks was considered poor due to the concentrations of organic, metal and conventional contaminants detected in the water column. Pollution of Crutcho and Soldier Creeks was considered to be primarily due to discharges from Tinker AFB, especially outfall 1 from Building 3001. Oklahoma Water Quality Criteria (WQC) for chromium, copper, mercury, and cyanide were exceeded, and Oklahoma Water Quality Standards (WQS) for chromium, copper, TDS, sulfate and hardness were violated. State sediment quality goals for cadmium and chromium, and the water quality goal for cyanide, were exceeded. Overall, water quality was considered best at the Crutcho Creek station A, poorest at Soldier Creek stations B and C below industrial discharges, and intermediate at stations D and E, located further downstream on Crutcho Creek.

2.3.3 Harry Keith & Sons, Inc. (HKS) 1985 Sediment Analytical Results

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

Sixty-five sediment samples were collected at various locations within East and West Soldier Creeks. Data, including cadmium, chromium, lead, zinc, and total BNA concentrations, for each sampling location along West Soldier

TABLE 2-3

EPA SURFACE WATER AND SEDIMENT ANALYTICAL RESULTS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

SAMPLE NO.	SAMPLER	DATE	SURFACE WATER UNITS	Cd	Cr	Cu	Pb	Fe	Ni	BNAs TOTAL	VOCs TOTAL	SEDIMENT UNITS	Cd	Cr	Cu	Pb	Fe	BNAs TOTAL	VOCs TOTAL
1	EPA	10/84	ug/l	ND	151	ND	ND	ND	254	55	ND	mg/kg	ND	ND	ND	ND	ND	ND	ND
B	EPA	10/84	ug/l	ND	63	ND	30	574	ND	45	114	mg/kg	69	728	ND	35	9190	5111	53
2	EPA	10/84	ug/l	ND	0	ND	ND	ND	36	5	ND	mg/kg	ND	ND	ND	ND	ND	ND	ND
C	EPA	10/84	ug/l	ND	58	ND	1329	ND	ND	29	75	mg/kg	20	329	ND	30	17600	3089	ND
D	EPA	10/84	ug/l	ND	ND	ND	ND	1107	ND	31	ND	mg/kg	ND	36	ND	13	6940	1	26
E	EPA	10/84	ug/l	ND	ND	ND	ND	1030	ND	45	ND	mg/kg	ND	22	ND	13	6890	7921	45

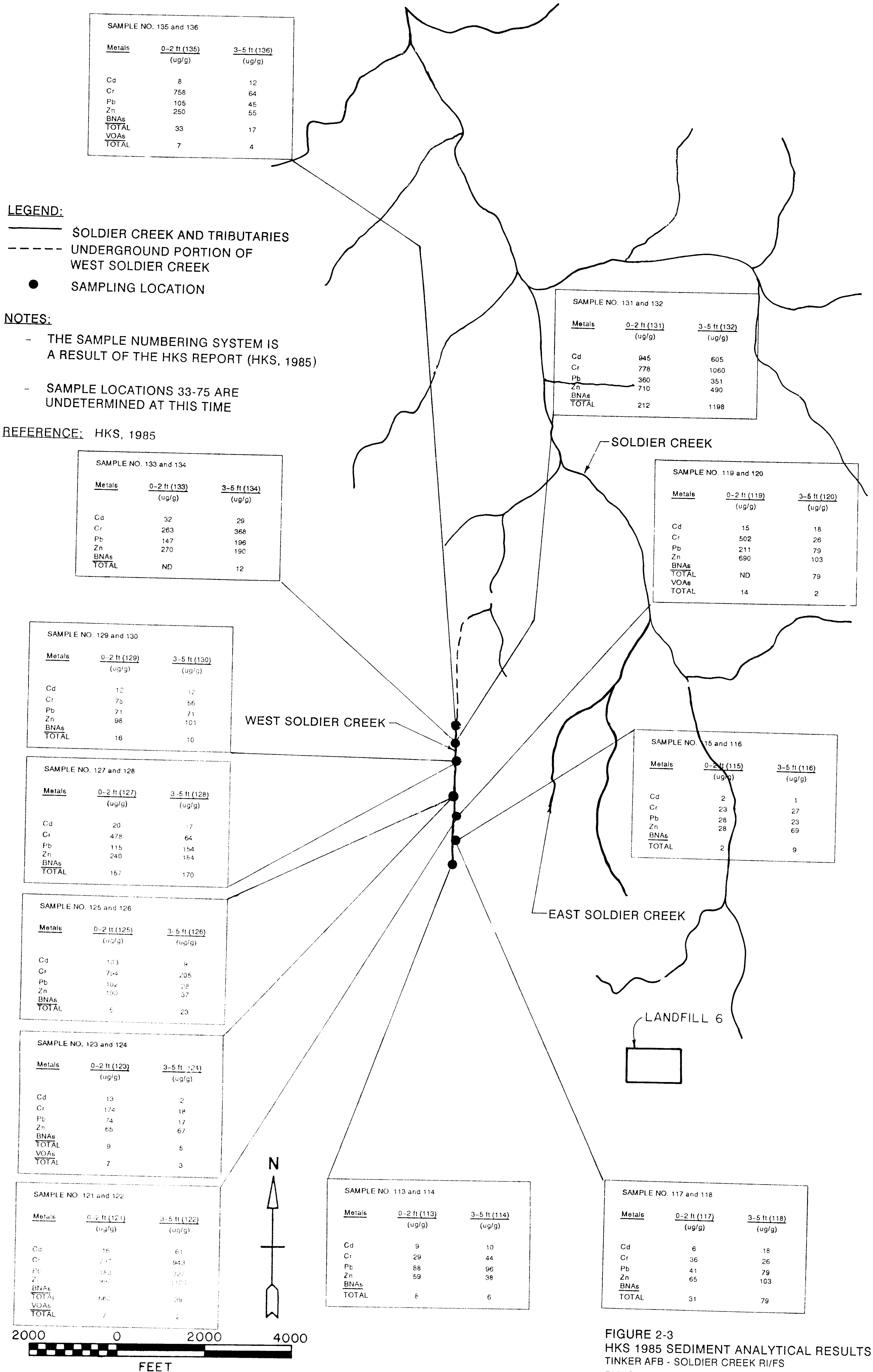
ND = Not Detected

Creek are shown on Figure 2-3. The locations of samples collected within East Soldier Creek are unknown at this time. Analytical data from this investigation for both East and West Soldier Creeks are shown in Table 2-4.

Sediment samples were collected using a hand trowel and scoop containing a plastic disposable sleeve that was changed at each sample point and depth. The samples were measured to the proper depth interval (0-2 and 3-5 inches) and placed into a "lab weight" plastic bag with an air tight seal. The sample bag was then placed into another plastic bag to ensure an air tight seal. An additional 400 grams of the same measured sample was placed into a glass jar with Teflon lid. Samples were transported for analysis immediately upon completion of the sample collection for all areas. Analysis was initiated approximately 12 hours after leaving the last sample location. All samples were rechecked for proper identification upon arrival at the laboratory.

HKS concluded that East Soldier Creek appeared to have a heavy buildup of black oily sludge in and adjacent to the stream bed. All sample sites and the adjacent areas exuded strong hydrocarbon odors. Many sample locations contained an approximately 2 inch thick layer of sediment that appeared clean and covered the black oily sludge underneath. The contamination observed, but not sampled, was at depths greater than 5 inches. Further, HKS stated that this deeper contamination may be more heavily concentrated, had an odor, and may have a different chemical character.

Conclusions presented in the HKS Site Investigation Report are described below. Many of the sample sites and the adjacent areas displayed evidence of high water conditions that could have washed away soluble and insoluble compounds which may have been present in the top layer of sediment. Even the normal water level conditions of a stream may carry a portion of the organic and inorganic contaminants downstream by the physical action of stream flow. Therefore, HKS expected extensive downstream effect of the contaminants that were found or had been present in the stream sediment.



SAMPLE NO. 135 and 136

Metals	0-2 ft (135) (ug/g)	3-5 ft (136) (ug/g)
Cd	8	12
Cr	758	64
Pb	105	45
Zn	250	55
BNAs TOTAL	33	17
VOAs TOTAL	7	4

SAMPLE NO. 131 and 132

Metals	0-2 ft (131) (ug/g)	3-5 ft (132) (ug/g)
Cd	945	605
Cr	778	1060
Pb	360	351
Zn	710	490
BNAs TOTAL	212	1198

SAMPLE NO. 133 and 134

Metals	0-2 ft (133) (ug/g)	3-5 ft (134) (ug/g)
Cd	32	29
Cr	263	368
Pb	147	196
Zn	270	190
BNAs TOTAL	ND	12

SAMPLE NO. 119 and 120

Metals	0-2 ft (119) (ug/g)	3-5 ft (120) (ug/g)
Cd	15	18
Cr	502	26
Pb	211	79
Zn	690	103
BNAs TOTAL	ND	79
VOAs TOTAL	14	2

SAMPLE NO. 129 and 130

Metals	0-2 ft (129) (ug/g)	3-5 ft (130) (ug/g)
Cd	12	12
Cr	75	56
Pb	71	71
Zn	98	101
BNAs TOTAL	16	10

SAMPLE NO. 115 and 116

Metals	0-2 ft (115) (ug/g)	3-5 ft (116) (ug/g)
Cd	2	1
Cr	23	27
Pb	28	23
Zn	28	69
BNAs TOTAL	2	9

SAMPLE NO. 127 and 128

Metals	0-2 ft (127) (ug/g)	3-5 ft (128) (ug/g)
Cd	20	17
Cr	478	64
Pb	115	154
Zn	240	164
BNAs TOTAL	157	170

SAMPLE NO. 125 and 126

Metals	0-2 ft (125) (ug/g)	3-5 ft (126) (ug/g)
Cd	103	9
Cr	794	205
Pb	102	28
Zn	190	37
BNAs TOTAL	5	23

SAMPLE NO. 123 and 124

Metals	0-2 ft (123) (ug/g)	3-5 ft (124) (ug/g)
Cd	13	2
Cr	174	18
Pb	74	17
Zn	65	67
BNAs TOTAL	9	5
VOAs TOTAL	7	3

SAMPLE NO. 121 and 122

Metals	0-2 ft (121) (ug/g)	3-5 ft (122) (ug/g)
Cd	16	61
Cr	[illegible]	943
Pb	183	327
Zn	[illegible]	[illegible]
BNAs TOTAL	662	39
VOAs TOTAL	7	2

SAMPLE NO. 113 and 114

Metals	0-2 ft (113) (ug/g)	3-5 ft (114) (ug/g)
Cd	9	10
Cr	29	44
Pb	88	96
Zn	59	38
BNAs TOTAL	8	6

SAMPLE NO. 117 and 118

Metals	0-2 ft (117) (ug/g)	3-5 ft (118) (ug/g)
Cd	6	18
Cr	36	26
Pb	41	79
Zn	65	103
BNAs TOTAL	31	79

FIGURE 2-3
HKS 1985 SEDIMENT ANALYTICAL RESULTS
TINKER AFB - SOLDIER CREEK RI/FS

TABLE 2-4

HKS 1985 SEDIMENT ANALYTICAL RESULTS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

SAMPLE NO.	SAMPLE LOCATION	DEPTH (FT.)	DATE	UNITS	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Cu	Zn	Mn	Ni	TOTAL BNAs	TOTAL VOCs
33	SOLD CREEK	0-2	10/05/85	mg/kg	1	210	386	108	118	ND	1	7	1010	218	275	43	ND	ND
34	SOLD CREEK	3-5	10/05/85	mg/kg	1	262	6	87	196	ND	1	6	110	98	435	29	19	ND
35	SOLD CREEK	*	10/05/85	mg/kg	1	185	12	164	139	ND	1	2	238	910	615	77	22	ND
36	SOLD CREEK	0-2	10/05/85	mg/kg	1	227	15	105	170	1	1	17	308	252	173	87	18	ND
37	SOLD CREEK	3-5	10/05/85	mg/kg	1	420	12	168	203	1	1	3	196	230	224	70	17	ND
38	SOLD CREEK	0-2	10/05/85	mg/kg	1	152	12	114	216	ND	1	14	288	202	507	69	65	ND
39	SOLD CREEK	3-5	10/05/85	mg/kg	1	168	8	149	251	1	1	8	135	144	336	51	31	ND
40	SOLD CREEK	0-2	10/05/85	mg/kg	1	101	13	256	226	1	1	22	318	388	401	90	ND	ND
41	SOLD CREEK	3-5	10/05/85	mg/kg	1	520	66	464	140	1	1	21	72	100	290	119	ND	ND
42	SOLD CREEK	0-2	10/05/85	mg/kg	1	102	18	262	189	1	1	26	476	230	189	131	ND	ND
43	SOLD CREEK	3-5	10/05/85	mg/kg	1	20	89	1310	435	2	1	26	51	520	447	306	140	ND
44	SOLD CREEK	0-2	10/05/85	mg/kg	1	103	2	35	19	ND	1	5	51	43	224	28	ND	ND
45	SOLD CREEK	3-5	10/05/85	mg/kg	1	242	1	12	13	ND	1	3	22	21	256	12	ND	ND
46	SOLD CREEK	0-2	10/05/85	mg/kg	1	272	42	712	121	ND	1	18	362	240	853	175	26	ND
47	SOLD CREEK	3-5	10/05/85	mg/kg	1	292	54	948	146	ND	1	26	520	525	844	197	154	ND
48	SOLD CREEK	0-2	10/05/85	mg/kg	1	216	48	424	94	ND	1	14	231	178	282	160	12	ND
49	SOLD CREEK	3-5	10/05/85	mg/kg	1	253	73	316	63	ND	1	10	220	62	161	53	3	ND
50	SOLD CREEK	0-2	10/05/85	mg/kg	1	212	17	402	49	ND	1	19	122	81	290	136	ND	ND
51	SOLD CREEK	3-5	10/05/85	mg/kg	1	101	43	1810	105	ND	1	24	91	115	180	158	11	ND
52	SOLD CREEK	0-2	10/05/85	mg/kg	1	78	2	12	11	ND	1	2	7	10	109	10	2	ND
53	SOLD CREEK	3-5	10/05/85	mg/kg	1	188	16	51	32	ND	1	6	24	34	273	28	159	1
54	SOLD CREEK	0-2	10/05/85	mg/kg	1	308	17	201	93	ND	1	15	195	145	269	112	1	ND
55	SOLD CREEK	3-5	10/05/85	mg/kg	1	403	35	485	73	1	1	12	93	580	451	127	6	ND
56	SOLD CREEK	0-2	10/05/85	mg/kg	1	161	76	259	27	ND	1	9	60	85	304	151	ND	ND
57	SOLD CREEK	3-5	10/05/85	mg/kg	1	88	185	184	77	ND	1	4	41	127	118	88	14	ND
58	SOLD CREEK	0-2	10/05/85	mg/kg	1	192	7	585	672	ND	1	16	106	388	358	86	ND	ND
59	SOLD CREEK	3-5	10/05/85	mg/kg	1	101	560	845	450	ND	1	6	83	401	700	43	ND	ND
60	SOLD CREEK	0-2	10/05/85	mg/kg	1	103	16	100	50	ND	1	8	21	28	398	81	ND	ND
61	SOLD CREEK	3-5	10/05/85	mg/kg	1	132	11	100	21	ND	1	5	16	26	320	42	ND	ND
62	SOLD CREEK	*	10/05/85	mg/kg	1	402	42	585	105	ND	1	9	134	154	72	178	ND	ND
63	SOLD CREEK	0-2	10/05/85	mg/kg	1	180	51	1010	79	ND	1	8	78	88	97	314	ND	ND
64	SOLD CREEK	3-5	10/05/85	mg/kg	1	440	38	783	102	1	1	6	206	274	70	330	14	ND
65	SOLD CREEK	0-2	10/05/85	mg/kg	1	93	1	45	10	ND	1	4	12	28	60	27	4	ND
66	SOLD CREEK	3-5	10/05/85	mg/kg	1	167	1	16	10	ND	1	2	7	17	435	16	2	ND
67	SOLD CREEK	0-2	10/05/85	mg/kg	1	293	1	232	161	ND	1	3	64	170	60	148	11	ND
68	SOLD CREEK	3-5	10/05/85	mg/kg	1	325	84	1720	246	ND	1	27	63	140	398	450	177	ND
69	SOLD CREEK	0-2	10/05/85	mg/kg	1	285	2	47	23	ND	1	8	16	38	435	38	ND	ND
70	SOLD CREEK	3-5	10/05/85	mg/kg	1	230	1	18	14	ND	1	1	8	16	502	14	ND	ND

TABLE 2-4

HKS 1985 SEDIMENT ANALYTICAL RESULTS
TINKER AFB – SOLDIER CREEK RI/FS
RI WORKPLAN

SAMPLE NO.	SAMPLE LOCATION	DEPTH (FT.)	DATE	UNITS	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Cu	Zn	Mn	Ni	TOTAL BNAs	TOTAL VOCs
71	SOLD CREEK	0-2	10/05/85	mg/kg	1	312	152	1760	625	ND	1	18	49	710	122	360	306	ND
72	SOLD CREEK	3-5	10/05/85	mg/kg	1	461	1220	6970	885	ND	1	57	476	1250	156	3850	538	ND
73	SOLD CREEK	*	10/05/85	mg/kg	1	245	2	22	171	2	1	2	16	53	420	10	ND	ND
74	SOLD CREEK	0-2	10/05/85	mg/kg	1	321	76	620	172	ND	1	17	295	310	158	350	ND	ND
75	SOLD CREEK	0-5	10/05/85	mg/kg	1	270	55	409	142	1	1	3	189	190	165	236	135	ND
113	DITCH	0-2	10/05/85	ug/g	1	394	9	29	88	ND	1	5	13	59	341	26	8	ND
114	DITCH	3-5	10/05/85	ug/g	1	388	10	44	96	ND	1	1	12	38	482	14	6	ND
115	DITCH	0-2	10/05/85	ug/g	1	305	2	23	28	ND	1	3	17	28	354	16	2	ND
116	DITCH	3-5	10/05/85	ug/g	1	242	1	27	23	ND	1	1	11	69	515	16	9	ND
117	DITCH	0-2	10/05/85	ug/g	1	230	6	36	41	ND	1	1	14	65	155	39	31	ND
118	DITCH	3-5	10/05/85	ug/g	1	302	18	26	79	ND	1	6	14	103	298	26	79	ND
119	DITCH	0-2	10/05/85	ug/g	1	380	15	502	211	ND	1	19	229	690	81	200	ND	14
120	DITCH	3-5	10/05/85	ug/g	1	350	25	359	155	ND	1	31	80	450	56	490	ND	2
121	DITCH	0-2	10/05/85	ug/g	1	270	16	737	183	1	1	55	169	990	546	330	662	7
122	DITCH	3-5	10/05/85	ug/g	1	420	61	943	327	1	1	79	189	1100	48	935	39	2
123	DITCH	0-2	10/05/85	ug/g	1	350	13	174	74	ND	1	8	22	65	143	482	9	7
124	DITCH	3-5	10/05/85	ug/g	1	508	2	18	17	ND	1	1	8	67	69	42	5	2
125	DITCH	0-2	10/05/85	ug/g	1	450	103	794	102	ND	1	4	64	190	100	3110	5	ND
126	DITCH	3-5	10/05/85	ug/g	1	310	9	205	28	ND	1	6	13	37	198	710	23	ND
127	DITCH	0-2	10/05/85	ug/g	1	180	20	478	115	1	1	55	95	240	61	97	157	ND
128	DITCH	3-5	10/05/85	ug/g	1	349	17	64	154	ND	1	21	59	184	91	187	170	ND
129	DITCH	0-2	10/05/85	ug/g	1	268	12	75	71	1	1	18	30	98	52	225	16	ND
130	DITCH	3-5	10/05/85	ug/g	1	315	12	56	71	1	1	12	28	101	58	155	10	ND
131	DITCH	0-2	10/05/85	ug/g	1	510	945	778	360	1	1	188	214	710	851	396	212	ND
132	DITCH	3-5	10/05/85	ug/g	1	310	105	1060	351	1	1	367	183	490	1160	324	1198	ND
133	DITCH	0-2	10/05/85	ug/g	1	310	32	263	147	ND	1	2	57	270	305	310	ND	ND
134	DITCH	3-5	10/05/85	ug/g	1	280	29	368	196	ND	1	3	44	190	398	170	12	ND
135	DITCH	0-2	10/05/85	ug/g	1	385	8	758	105	ND	1	2	54	250	780	820	33	7
136	DITCH	3-5	10/05/85	ug/g	1	103	12	64	45	ND	1	2	13	55	450	89	17	4

ND = Not Detected
* = Depth not available at this time

2.3.4 HKS 1986 Sediment Analytical Results

The purpose, sample methodology, specific sampling activities and conclusions of the 1986 HKS investigation (HKS, 1986) are unavailable at this time. The sampling locations, together with and pertinent metals (cadmium, chromium, lead) and VOC concentrations for each location, are shown on Figure 2-4. The sediment analytical results for this investigation are shown in Table 2-5.

2.3.5 Industrial Waste Treatment Plant (IWTP) and Sanitary Treatment Plant (STP) Discharge Surface Water Analytical Results

The purpose of this investigation (Tinker AFB, 1987a) was to sample the IWTP and STP water discharge and determine surface water concentrations of specific contaminants of interest. Tinker AFB personnel collected the surface water samples. The sample methodology, specific sampling activities and conclusions of the 1987 surface water analytical results are unavailable at this time. The sampling locations together with the volatile organic analysis results are shown on Figure 2-5.

2.3.6 OSDH Sediment and Surface Water Analytical Results

The purpose, sample methodology, specific sampling activities and conclusions of the OSDH investigation (OSDH, 1987) are unavailable at this time. The West Soldier Creek sampling location together with analytical results for the surface water and sediment samples are shown on Figure 2-6.

2.3.7 NPDES Surface Water Analytical Results

The purpose of the NPDES surface water investigation done by Tinker AFB (Tinker AFB, 1987b) personnel was to determine surface water concentrations of specific contaminants at prescribed locations downstream of the IWTP effluent discharge. The sample methodology, specific sampling activities and the conclusions of the NPDES water analytical results are unavailable at this time. Sampling locations are shown on Figure 2-7. The surface water analytical results are shown on Table 2-6.

SAMPLE NO. C-07

Metals	0-1.0 ft (4/86) (mg/kg)	0-1.0 ft (5/86) (mg/kg)
Cd	359	492
Cr	812	914
Pb	238	234
VOAs	(ug/kg)	(ug/kg)
Chloroform	133	ND
PCE	ND	ND
t-1,2-Dichl	ND	ND

SAMPLE NO. C-08

Metals	0-1.0 ft (4/86) (mg/kg)	0-1.0 ft (5/86) (mg/kg)
Cd	499	496
Cr	1260	900
Pb	293	261

SAMPLE NO. C-06 (5/86)

Metals	0-.5 ft (mg/kg)	0.5-1.0 ft (mg/kg)	1.0-1.5 ft (mg/kg)	1.5-2.0 ft (mg/kg)
Cd	68	162	275	337
Cr	405	473	1046	893
Pb	116	176	312	208

SAMPLE NO. C-05

Metals	0-1.5 ft (4/86) (mg/kg)	0-1.5 ft (5/86) (mg/kg)
Cd	76	405
Cr	650	887
Pb	163	309
VOAs	(ug/kg)	(ug/kg)
Chloroform	2	ND
PCE	ND	ND
t-1,2-Dichl	12	ND

SAMPLE NO. C-03

Metals	0-1.5 ft (5/86) (mg/kg)
Cd	32
Cr	332
Pb	135

LEGEND:

SOLDIER CREEK AND TRIBUTARIES

● SAMPLING LOCATION

NOTES:

- THE SAMPLE NUMBERING SYSTEM IS A RESULT OF THE HKS REPORT (HKS, 19
- SAMPLE LOCATIONS C-09, C-10, AND C- ARE UNDETERMINED AT THIS TIME

REFERENCE: NUS, 1989
HKS, 1986

0 300 600 900
FEET

N

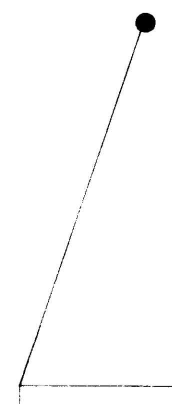
FIGURE 2-4
HKS 1986 SEDIMENT ANALYTICAL RESUL
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

TABLE 2-5

HKS 1986 SEDIMENT ANALYTICAL RESULTS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

SAMPLE	SAMPLE LOCATION	SAMPLER	DEPTH (ft)	DATE	UNITS	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Cu	Zn	Mn	Ni	Chloroform (ug/kg)	PCE (ug/kg)	t-1,2-dichloroethene (ug/kg)
6807	C-10	HKS	0-0.5	04/29/86	mg/kg	5	585	321	1140	170	ND	8	15	68	220	280	292	2	2	27
6808	C-11	HKS	0-0.5	04/29/86	mg/kg	3	372	233	838	206	ND	5	9	118	355	325	174	20	19	26
6804	C-07	HKS	0-1.0	04/29/86	mg/kg	1	392	359	812	238	ND	ND	9	145	375	388	173	133	ND	ND
6805	C-08	HKS	0-0.5	04/29/86	mg/kg	3	434	499	1260	293	ND	5	17	256	430	359	416	ND	ND	ND
6806	C-09	HKS	0-0.5	04/29/86	mg/kg	3	509	72	360	68	ND	8	12	32	90	560	94	ND	ND	ND
7006	C-08	HKS	0-0.5	05/27/86	mg/kg	ND	ND	496	900	261	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7007	C-07	HKS	0-1.0	05/27/86	mg/kg	ND	ND	492	914	234	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7008	C-05	HKS	0-1.5	05/27/86	mg/kg	ND	ND	405	887	309	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7009	C-03	HKS	0-1.5	05/27/86	mg/kg	ND	ND	32	332	135	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7010	C-06	HKS	1.5-2.0	05/27/86	mg/kg	ND	ND	337	893	208	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7011	C-06	HKS	0-0.5	05/27/86	mg/kg	ND	ND	68	405	116	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7012	C-06	HKS	0.5-1.0	05/27/86	mg/kg	ND	ND	162	473	176	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7013	C-06	HKS	1.0-1.5	05/27/86	mg/Kg	ND	ND	275	1046	312	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6809	C-05	HKS	0-1.5	04/29/86	mg/kg	ND	ND	76	650	163	ND	ND	ND	ND	164	ND	ND	2	2	12

ND = Not Detected



IWTP & STP AVG. DISCHARGE - 3/87 - 9/87	
VOAs	WATER (ug/l)
Benzene	15162.97
Bromodichloromethane	2.94
Carbon Tetrachloride	0.03
Chlorobenzene	17.05
2-Chloroethylvinyl Ether	0.79
Chloroform	11.99
Chloromethane	1.4
Dibromochloromethane	1.55
1,2-Dichlorobenzene	10.91
1,3-Dichlorobenzene	0.93
1,4-Dichlorobenzene	4.27
1,1-Dichloroethane	0.47
1,2-Dichloroethane	1.1
1,1-Dichloroethene	1.1
Trans-1,2-Dichloroethene	61.29
1,2-Dichloropropane	0.64
Cis-1,2-Dichloropropene	8.32
Ethyl Benzene	1.82
Methylene Chloride	142.64
1,1,2,2-Tetrachloroethane	2.52
Tetrachloroethene	32.46
Toluene	3.58
1,1,1-Trichloroethane	26.55
1,1,2-Trichloroethane	17.04
Trichloroethene	2.81
Trichlorofluoromethane	11.1

LEGEND:

SOLDIER CREEK AND TRIBUTARIE

● SAMPLING LOCATION

NOTES:

- SAMPLER OF THE IWTP AND STP DISCHARGES IS TINKER AFB

REFERENCE: NUS, 1989
TINKER AFB, 1987a

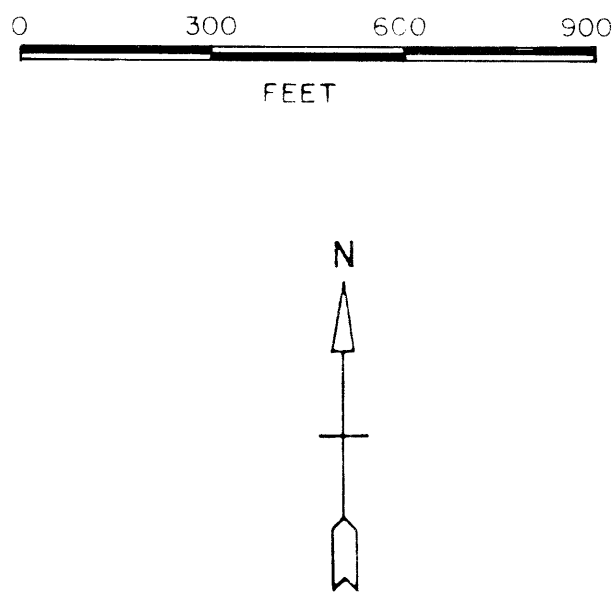


FIGURE 2-5
IWTP & STP DISCHARGE SURFACE WATE
ANALYTICAL RESULTS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

LEGEND:

——— SOLDIER CREEK AND TRIBUTARIES

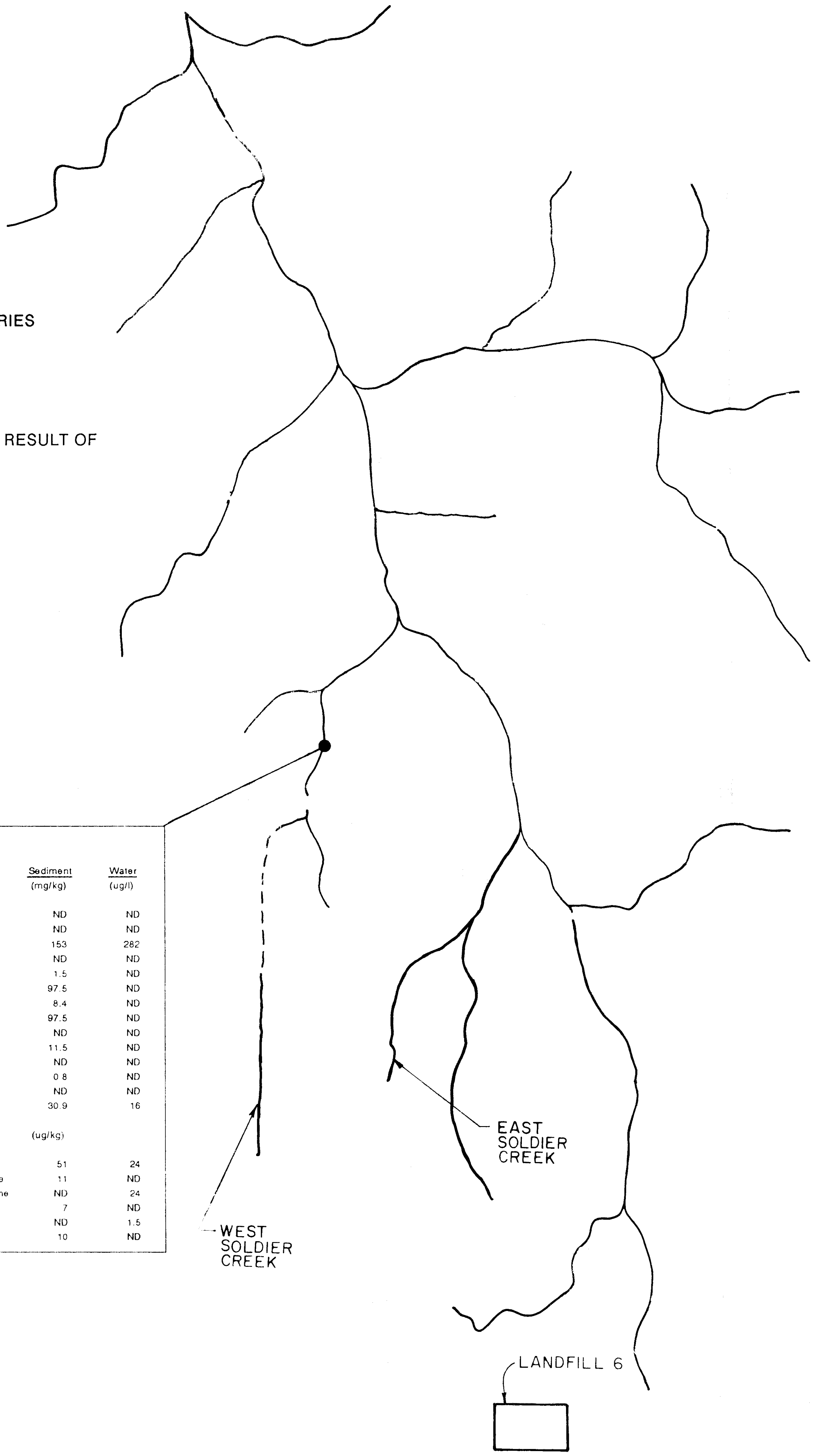
- - - - - - UNDERGROUND PORTION OF WEST SOLDIER CREEK

● SAMPLING LOCATION

NOTES:

-- SAMPLE NUMBERING SYSTEM IS A RESULT OF THE OSDH REPORT (OSDH, 1987)

REFERENCE: OSDH, 1987



SAMPLE NO T-2

Metals	Sediment (mg/kg)	Water (ug/l)
Sb	ND	ND
As	ND	ND
Ba	153	282
Be	ND	ND
Cd	1.5	ND
Cr	97.5	ND
Cu	8.4	ND
Pb	97.5	ND
Hg	ND	ND
Ni	11.5	ND
Se	ND	ND
Ag	0 8	ND
Th	ND	ND
Zn	30.9	16
VOCs	(ug/kg)	
Methylene Chloride	51	24
1 1,-Dichloroethene	11	ND
1,1,1-trichloroethene	ND	24
trichloroethene	7	ND
Tetrachloroethene	ND	1.5
Toluene	10	ND

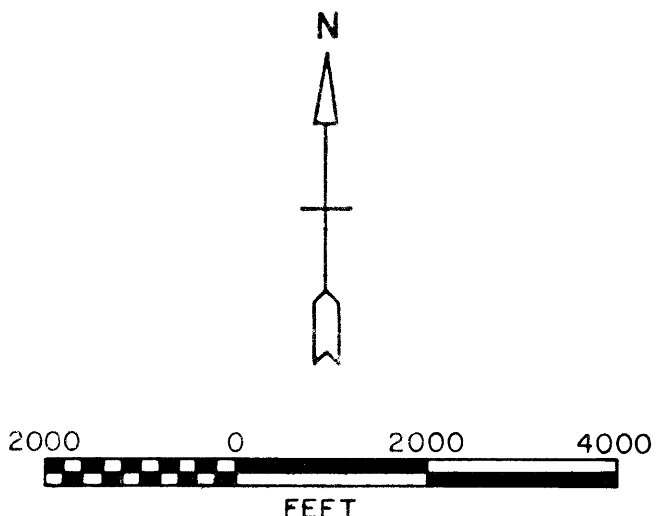
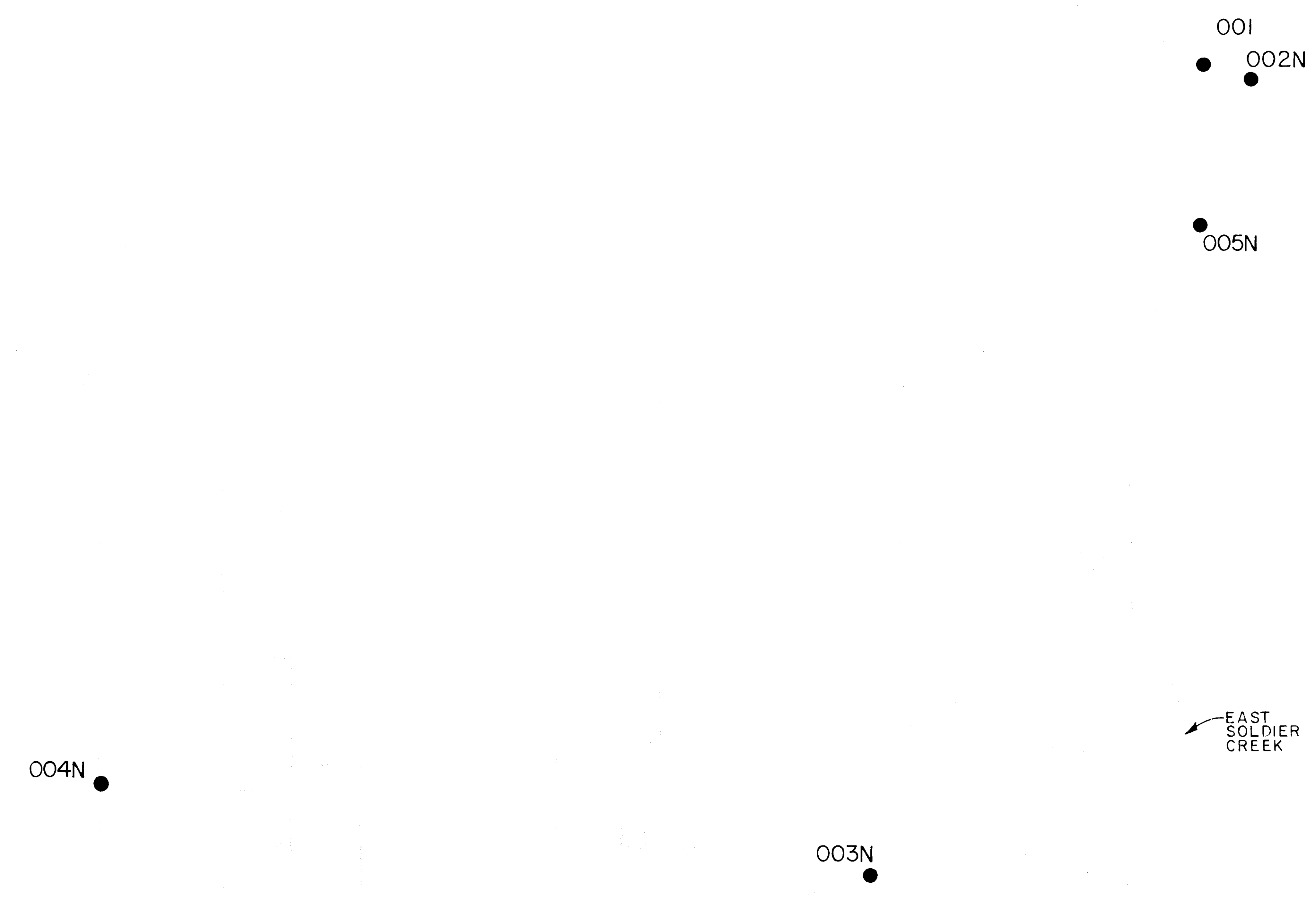


FIGURE 2-6
OSDH SEDIMENT AND SURFACE WATER ANALYTICAL RESULTS
TINKER AFB - SOLDIER CREEK RI/FS



LEGEND:

SOLDIER CREEK AND TRIBUTARIES

● NPDES SAMPLING LOCATIONS

NOTES:

- SAMPLER OF THE NPDES IS TINKER AI

REFERENCE: NUS, 1989
TINKER AFB, 1987b

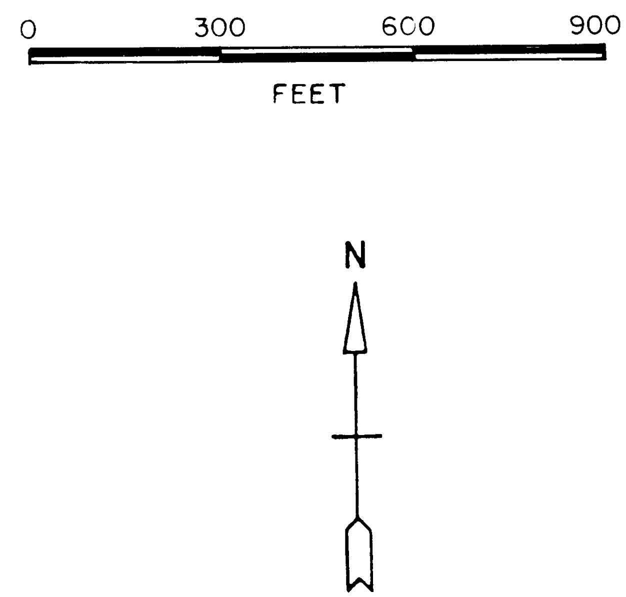


FIGURE 2-7
NPDES SURFACE WATER SAMPLING LOCATIO
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

TABLE 2-6

NPDES SURFACE WATER ANALYTICAL RESULTS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

DISCHARGE LOCATION	pH (MAX)	TSS LB/DY	TSS MG/L	OIL/GREASE LB/DY	OIL/GREASE MG/L	FLOW AVG	MGD MAX
001N	7.62	164.5	22.6	46.3	6.2	0.66	1.05
002N	7.98	NA	18.94	NA	7.2	0.32	0.71
003N	NA	NA	NA	NA	NA	0.17	NA
004N	9.2	NA	NA	NA	NA	ND	NA
005N	NA	NA	NA	NA	39.7	0.62	1.7
01SN	7.7	162.4	99.6	NA	NA	0.68	0.7

NA = Not Analyzed
ND = Not Detected

2.3.8 Groundwater Analytical Results

Quarterly groundwater sampling and analyses at Tinker AFB is conducted by the Tulsa COE as a part of the overall groundwater assessment at Tinker AFB and as a part of the remedial investigations at the Building 3001 site. As a part of the quarterly groundwater sampling, several wells, which are located in the vicinity of West and East Soldier Creeks and are screened in the perched aquifer, have been sampled. The results of the sample analyses have been presented in several reports prepared by the Tulsa COE (Tulsa COE, 1988d, Tulsa COE, 1989b; and Tulsa COE, 1989c) and are summarized on Tables 2-7 and 2-8 for samples from wells in the vicinity of West Soldier Creek and East Soldier Creek, respectively. The well locations are illustrated on Figure 2-8. The analytical results have not been summarized on a figure due to the large volume of data that is available. The sampling methodology is presented in the Tinker AFB Sampling and Analysis Quality Assurance/Quality Control Plan for Corps of Engineers Site Investigations (Tulsa COE, 1986).

The Building 3001 site remedial investigations indicated that the perched aquifer is contaminated with organic solvents, trace metals, and fuel product (Tulsa COE, 1988a). The areas with highest concentrations of contaminants are located beneath Building 3001, the North Tank Area, and the Southwest Tank Area. Trichloroethene (TCE) and chromium are considered the primary contaminants in the perched 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 include 1,2-dichloroethene, tetrachloroethene, acetone, toluene, benzene, and xylene. Other significant inorganic contaminants include lead, nickel, and barium.

The analytical results indicated that the source of the TCE contamination is primarily beneath Building 3001 and migration is away from the building in the east, west, and southwest directions. Highest concentrations of 1,2-dichloroethene were detected beneath and to the west of Building 3001. Tetrachloroethene was detected primarily beneath Building 3001 and appeared

TABLE 2-7

GROUNDWATER ANALYTICAL RESULTS FOR WELLS MONITORING
THE PERCHED AQUIFER IN VICINITY OF WEST SOLDIER CREEK
TINKER AFB-SOLDIER CREEK RI/FS
RI WORKPLAN

WELL NUMBER	DATE	UNITS	As	Ba	Cd	Cr	Hg	Pb	Ni	Se	TOC	pH	Conductivity (umhos/cm)	Chloro-benzene	1,2-Dichloro-ethene	Trichloro-ethene	1,2-Dichloro-benzene	1,4-Dichloro-benzene	Tetrachloro-ethene	Vinyl Chloride
MW 1-10B	05/02/86	ug/l	3/3	<500/540	<8/<8	<10/<10	0.7/0.4	25/30	68/170	<0.4/<0.4	5400	NA	NA	<5.000	<5.000	<5.000	NA	NA	<5.000	<10.000
MW 1-10B	10/22/87	ug/l	2	830	8	<10	<0.10	<25	18	<0.4	1100	7.25	800	<2.000	<2.000	10	NA	NA	<2.000	<2.000
MW 1-10B	03/14/88	ug/l	6	360	<8	<10	<0.10	60	35	0.4	3200	7.11	775	<5.000	<5.000	<5.000	NA	NA	<5.000	<10.000
MW 1-10B	06/07/88	ug/l	1/2	720/780	<5/<5	9/0	<0.10/<0.10	<10/<10	<5/<5	NA	2900	6.96	819	<5.000	<5.000	<5.000	NA	NA	<5.000	<10.000
MW 1-10B	09/19/88	ug/l	<1/<1	860/930	<5/<5	<5/<5	<0.10/<0.10	<10/<10	<5/<5	0.8/0.8	1400	8.52	528	<5.000	<5.000	<5.000	NA	NA	<5.000	<10.000
MW 1-10B	03/12/89	ug/l	2	850	<5	NA	<0.10	<10	<5	0.7	900	7.02	890	<1.000	<1.000	<1.000	<2.000	<2.000	<1.000	<2.000
MW 1-12B	09/10/86	ug/l	<1	<500	8	35	<0.4	83	76	<0.4	2600	7.33	970	<500.000	4600	47000	NA	NA	<500.000	<1000.000
MW 1-12B	10/28/86	ug/l	2/6	<500/720	<8/<8	<10/16	<0.4/<0.4	50/73	53/60	<0.4/<0.4	NA	7.17	796	32	2100	19000	NA	NA	<5.000	23
MW 1-12B	11/11/87	ug/l	<40	2200	<10	100	<2.0	<30	110	<50	1700	7.06	550	U160	2000	32000	NA	NA	U99	U65
MW 1-13B	09/11/86	ug/l	2	640	8	13	<0.4	63	38	<0.4	2100	7.43	505	<5.000	<5.000	<5.000	NA	NA	<5.000	<10.000
MW 1-13B	11/18/87	ug/l	<40	780	<10	<10	<2.0	<30	<10	<50	2600	7.34	528	NA	NA	NA	NA	NA	NA	NA
MW 1-13B	12/01/87	ug/l	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<2.000	<2.000	<2.000	NA	NA	<2.000	<2.000
MW 1-13B	02/10/88	ug/l	4	495	<8	<10	<0.10	35	15	<0.4	4600	7.47	555	<5.000	6	<5.000	<10.000	<10.000	U3	<10.000
MW 1-13B	06/08/88	ug/l	1/2	470/470	<5/<5	11/11	<0.10/<0.10	<10/12	<5/<5	NA	2000	7.09	544	<5.000	10	10	NA	NA	<5.000	<10.000
MW 1-13B	09/21/88	ug/l	3	460	<5	12	<0.10	<10	16	<0.4	400	7.68	425	<5.000	<5.000	<5.000	NA	NA	<5.000	<10.000
MW 1-13B	03/19/89	ug/l	2	390	<5	NA	<0.10	<10	<5	0.7	500	7.75	490	<5.000	<5.000	U1	<10.000	<10.000	<5.000	<10.000
MW 1-14B	09/18/86	ug/l	5	3300	13	240	<0.4	120	180	5	1700	NA	NA	<5.000	<5.000	20	NA	NA	<5.000	<10.000
MW 1-14B	10/29/86	ug/l	1/3	<500/890	<8/<8	46/46	<0.4/<0.4	43/63	58/100	<0.4/<0.4	NA	7.27	1310	<5.000	<5.000	35	NA	NA	<5.000	<10.000
MW 1-14B	10/19/87	ug/l	2	<500	<8	<10	<0.10	<25	18	<0.4	5100	6.48	1920	<2.000	<2.000	15	NA	NA	<2.000	<2.000
MW 1-14B	02/10/88	ug/l	4	300	<8	<10	0.9	48	33	<0.4	4300	7.43	1283	<5.000	<5.000	47	<10.000	<10.000	<5.000	<10.000
MW 1-14B	06/08/88	ug/l	1/2	110/200	<5/<5	9/0	<0.10/<0.10	<10/<10	17/22	NA	1700	6.86	878	<5.000	<5.000	<5.000	NA	NA	<5.000	<10.000
MW 1-14B	09/21/88	ug/l	1	150	<5	11	<0.10	<10	<5	1	700	7.31	1049	<5.000	<5.000	16	NA	NA	<5.000	<10.000
MW 1-14B	03/28/89	ug/l	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<5.000	<5.000	37	<10.000	<10.000	<5.000	<10.000
MW-71	01/20/88	ug/l	0.6	1300	<8	18	0.3	95	55	5	5300	6.82	558	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
MW-71	05/04/88	ug/l	1	310	7	<10	<0.10	<13	6	<0.4	3000	7.08	3330	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
MW-71	07/25/88	ug/l	<1	380	<5	21	<0.10	13	45	0.5	2600	6.94	643	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
MW-71	09/21/88	ug/l	<1	580	<5	89	<0.10	<10	81	<0.4	1500	7.66	654	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
MW-71	03/27/89	ug/l	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000

Notes: NA – Not Analyzed

For metals, values provided are given for Dissolved Metals/Total Metals or otherwise are given as Total Metals

References: Tulsa COE, 1988d; Tulsa COE, 1989b; and Tulsa COE, 1989c

TABLE 2-8

GROUNDWATER ANALYTICAL RESULTS FOR WELLS
MONITORING PERCHED AQUIFER IN VICINITY OF EAST SOLDIER CREEK
TINKER AFB-SOLDIER CREEK RI/FS
RI WORKPLAN

WELL NUMBER	DATE	UNITS	As	Ba	Cd	Cr	Hg	Pb	Ni	Se	TOC	pH	Conductivity (umhos/cm)	Chloro-benzene	1,2-Dichloro-ethene	Trichloro-ethene	1,2-Dichloro-benzene	1,4-Dichloro-benzene	Tetrachloro-ethene	Vinyl Chloride
MW-21B	10/27/87	ug/l	<5	1200	<10	<10	<2	20	<10	<5	2400	7.65	1258	<2.000	<2.000	7.7	NA	NA	<2.000	<2.000
MW-22B	05/07/86	ug/l	<1/<1	560/660	<8/<8	<10/13	<0.10/<0.10	<25/33	120/170	<0.4/<0.4	1800	7.13	1141	<5.000	<5.000	<5.000	NA	NA	<5.000	<10.000
MW-22B	10/28/87	ug/l	<5	690	<10	10	<2	12	10	<5	2400	7.07	816	<2.000	<2.000	<2.000	NA	NA	<2.000	<2.000
MW-22B	04/09/89	ug/l	2	608	<5	<5	<0.10	20	9	<0.4	7700	7.06	940	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
MW-23B	05/07/86	ug/l	<1/<1	1500/2300	<8/<8	<10/58	<0.10/<0.10	<25/<25	120/130	<0.4/<0.4	2200	6.80	655	<5.000	<5.000	<5.000	NA	NA	<5.000	<10.000
MW-23B	10/30/87	ug/l	<5	2150	10	<10	<2	7	<10	<5	2000	6.53	442	<2.000	<2.000	<2.000	NA	NA	<2.000	<2.000
MW 1-11B	05/05/86	ug/l	<1/<1	<500/1300	<8/<8	<10/13	<0.10/<0.10	28/28	110/140	<0.4/<0.4	4700	7.08	1388	6	<5.000	<5.000	NA	NA	<5.000	<10.000
MW 1-11B	10/15/87	ug/l	3	<500	<8	<10	<0.10	35	20	<0.4	1900	7.70	757	<2.000	<2.000	<2.000	NA	NA	<2.000	<2.000
MW 1-11B	03/15/88	ug/l	7	<300	<8	<10	<0.10	50	38	0.7	3800	7.02	1010	<5.000	<5.000	<5.000	NA	NA	<5.000	<10.000
MW 1-11B	06/06/88	ug/l	1/2	180/200	<5/<5	10/14	<0.10/<0.10	<10/10	0/8	NA	4100	6.94	868	<5.000	<5.000	<5.000	NA	NA	<5.000	<10.000
MW 1-11B	09/19/88	ug/l	1/1	240/240	<5/<5	11/12	<0.10/<0.10	<10/11	<5/<5	<0.4/<0.4	3000	7.61	1033	<5.000	<5.000	<5.000	NA	NA	<5.000	<10.000
MW 1-11B	03/23/89	ug/l	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	10	<5.000	<5.000	NA	NA	U4.0	<10.000
14WS	06/04/86	ug/l	12/12	<500/<500	<8/<8	25/30	<0.4/<0.4	25/<25	<10/<10	130/140	4000	7.78	655	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
14WS	09/24/86	ug/l	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.500	<0.500	<0.500	NA	NA	<0.500	<1.000
14WS	12/09/87	ug/l	<40	460	<10	40	<2.0	<30	<10	<50	2200	7.62	358	<0.700	U0.2	0.4	<10.000	<10.000	<1.3	<1.000
14WS	03/21/88	ug/l	4	<300	<8	15	<0.10	30	<10	42	1400	6.54	456	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
14WS	07/27/88	µg/l	11	280	<5	32	<0.10	<10	<5	66	<1000	8.20	538	<1.000	<1.000	<1.000	<10.000	<10.000	<1.000	<2.000
14WS	09/19/88	ug/l	10	350	<5	38	<0.10	<10	<5	68	<100	7.92	385	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
14WS	12/12/88	ug/l	<1	460	<5	7	0.1	<10	<5	<0.4	300	7.13	448	<1.000	<1.000	<1.000	<10.000	<10.000	<1.000	<2.000
15WS	06/04/86	ug/l	<1/<1	580/<500	<8/<8	<10/<10	<0.4/<0.4	<25/<25	20/10	<0.4/<0.4	8000	7.64	448	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
15WS	09/24/86	ug/l	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.500	<0.500	0.7	NA	NA	<0.500	<1.000
15WS	12/09/87	ug/l	<40	480	<10	60	<2.0	<30	20	<50	2100	7.48	345	<0.700	U0.4	0.9	<10.000	<10.000	<1.300	<1.000
15WS	03/17/88	ug/l	<1	<300	<8	<10	<0.10	62	<10	<0.4	1100	7.04	416	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
15WS	07/26/88	ug/l	<1	460	<5	11	<0.10	13	6	0.7	1200	7.50	413	<1.000	<1.000	<1.000	<10.000	<10.000	<1.000	<2.000
15WS	09/18/88	ug/l	<1	460	<5	<5	<0.10	<10	<5	2	<100	7.48	276	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
15WS	12/12/88	ug/l	<1	460	<5	6	<0.10	<10	<5	<0.4	400	7.33	405	<1.000	<1.000	<1.000	<9.000	<9.000	<1.000	<2.000
15WS	03/21/89	ug/l	1	410	<5	7	<0.10	<10	<5	1	200	7.11	410	<1.000	<1.000	<1.000	<10.000	<10.000	<1.000	<2.000

TABLE 2-8 (Continued)

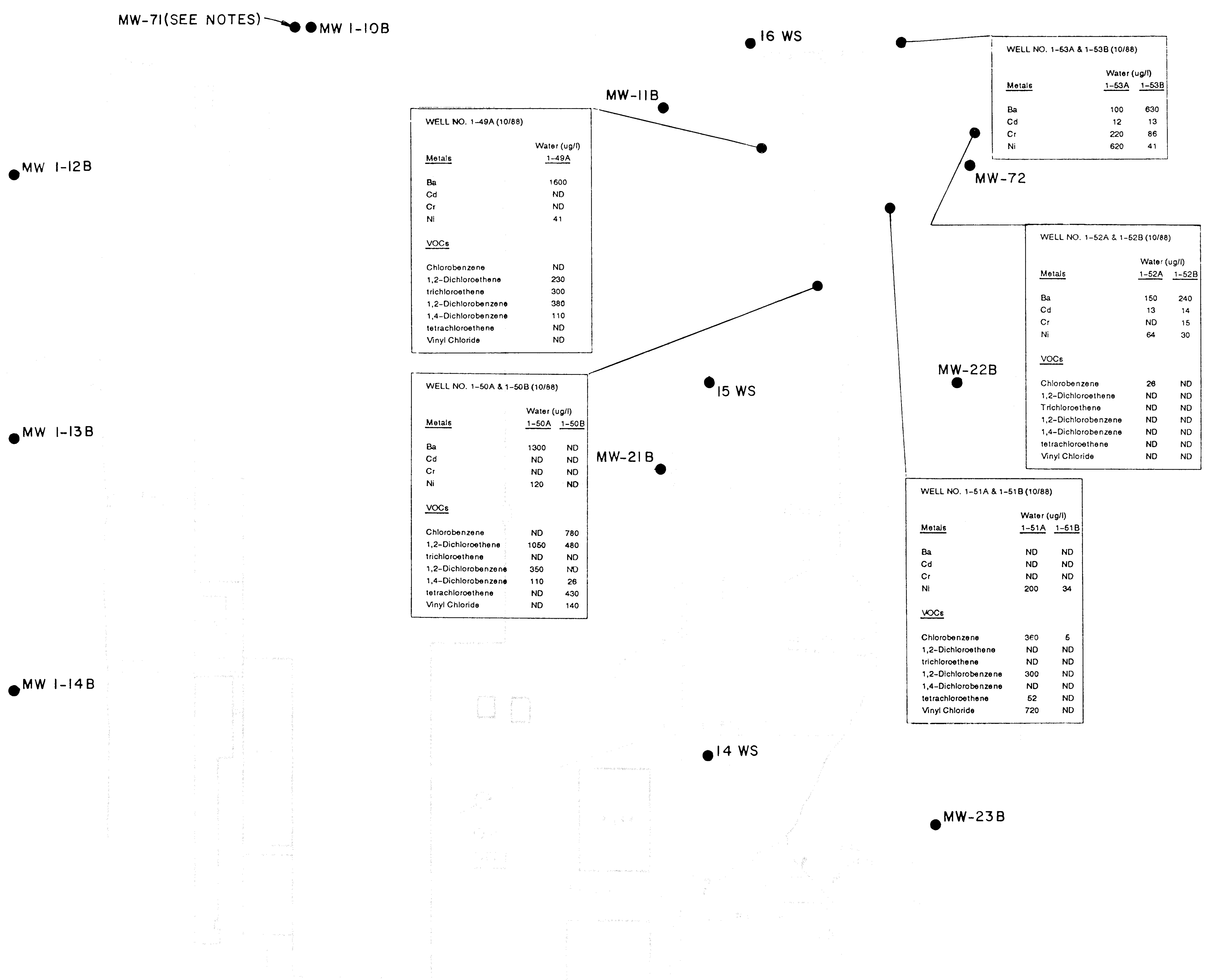
GROUNDWATER ANALYTICAL RESULTS FOR WELLS
MONITORING PERCHED AQUIFER IN VICINITY OF EAST SOLDIER CREEK
TINKER AFB-SOLDIER CREEK RI/FS
RI WORKPLAN

WELL NUMBER	DATE	UNITS	As	Ba	Cd	Cr	Hg	Pb	Ni	Se	TOC	pH	Conductivity (umhos/cm)	Chloro-benzene	1,2-Dichloro-ethene	Trichloro-ethene	1,2-Dichloro-benzene	1,4-Dichloro-benzene	Tetrachloro-ethene	Vinyl Chloride
16WS	09/24/86	ug/l	2/<1	900/680	8/13	10/10	<0.4/<0.4	<25/45	13/25	1/2	900	7.88	470	<0.500	1.9	1.9	<10.000	<10.000	0.7	<1.000
16WS	12/09/87	ug/l	<40	500	<10	60	<2.0	<30	20	<50	2200	7.66	380	<0.700	1.4	1.7	<10.000	<10.000	U0.6	<1.000
16WS	03/17/88	ug/l	<1	<300	<8	<10	<0.10	62	<10	<0.4	900	7.09	426	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
16WS	07/26/88	ug/l	<1	480	<5	12	0.5	12	8	0.4	1000	7.44	434	<1.000	<1.000	<1.000	<10.000	<10.000	<1.000	<2.000
16WS	09/22/88	ug/l	1	460	<5	<5	<0.10	<10	<5	0.7	300	7.42	421	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
16WS	12/12/88	ug/l	1	490	<5	8	<0.10	<10	<5	<0.4	500	7.31	401	<1.000	<1.000	<1.000	<10.000	<10.000	<1.000	<2.000
MW-72	01/21/88	ug/l	15	840	<8	<10	0.3	50	33	5	4900	7.09	1237	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
MW-72	05/04/88	ug/l	16	410	13	<10	<0.10	<13	8	<0.4	9800	7.02	8940	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
MW-72	07/25/88	ug/l	18	410	<5	9	<0.10	19	14	<0.4	11000	7.05	1570	<5.000	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
MW-72	09/13/88	ug/l	22	410	<14	<5	<0.10	10	5	<0.4	5300	7.00	1043	5	<5.000	<5.000	<10.000	<10.000	<5.000	<10.000
MW-72	03/26/89	ug/l	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<5.000	<5.000	<5.000	U2	U2	<5.000	<10.000

Notes: NA – Not Analyzed

For metals, values provided are given for Dissolved Metals/Total Metals or otherwise are given as Total Metals

References: Tulsa COE, 1988d; Tulsa COE, 1989b, and Tulsa COE, 1989c



WELL NO. 1-49A (10/88)

Metals	Water (ug/l) 1-49A
Ba	1600
Cd	ND
Cr	ND
Ni	41
VOCs	
Chlorobenzene	ND
1,2-Dichloroethene	230
trichloroethene	300
1,2-Dichlorobenzene	380
1,4-Dichlorobenzene	110
tetrachloroethene	ND
Vinyl Chloride	ND

WELL NO. 1-50A & 1-50B (10/88)

Metals	Water (ug/l) 1-50A	1-50B
Ba	1300	ND
Cd	ND	ND
Cr	ND	ND
Ni	120	ND
VOCs		
Chlorobenzene	ND	780
1,2-Dichloroethene	1050	480
trichloroethene	ND	ND
1,2-Dichlorobenzene	350	ND
1,4-Dichlorobenzene	110	26
tetrachloroethene	ND	430
Vinyl Chloride	ND	140

WELL NO. 1-53A & 1-53B (10/88)

Metals	Water (ug/l) 1-53A	1-53B
Ba	100	630
Cd	12	13
Cr	220	86
Ni	620	41

WELL NO. 1-52A & 1-52B (10/88)

Metals	Water (ug/l) 1-52A	1-52B
Ba	150	240
Cd	13	14
Cr	ND	15
Ni	64	30
VOCs		
Chlorobenzene	26	ND
1,2-Dichloroethene	ND	ND
Trichloroethene	ND	ND
1,2-Dichlorobenzene	ND	ND
1,4-Dichlorobenzene	ND	ND
tetrachloroethene	ND	ND
Vinyl Chloride	ND	ND

WELL NO. 1-51A & 1-51B (10/88)

Metals	Water (ug/l) 1-51A	1-51B
Ba	ND	ND
Cd	ND	ND
Cr	ND	ND
Ni	200	34
VOCs		
Chlorobenzene	360	5
1,2-Dichloroethene	ND	ND
trichloroethene	ND	ND
1,2-Dichlorobenzene	300	ND
1,4-Dichlorobenzene	ND	ND
tetrachloroethene	52	ND
Vinyl Chloride	720	ND

LEGEND:

SOLDIER CREEK AND TRIBUTARIES

● SAMPLING LOCATION

NOTES:

- MONITORING WELL NUMBERS WERE ASSIGNED BY THE TULSA COE PERSONNEL.
- MW-71 IS LOCATED APPROXIMATELY 2,100 FEET TO THE NORTH OF THE LOCATION WHERE IT IS SHOWN ON THIS FIGURE

REFERENCE: TULSA COE, 1988c
NUS, 1989
TULSA COE, DATE UNKNOWN

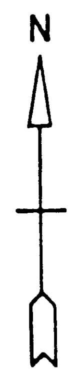


FIGURE 2-8
GROUNDWATER ANALYTICAL RESULTS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

to be moving east in the direction of East Soldier Creek. Analytical results indicated that the areal extent of chromium contamination was similar to the areal extent of TCE contamination.

The analytical results indicated that the contamination in the perched aquifer may be partially due to contaminants which were discharged into storm drains. Records indicated that West Soldier Creek had received discharges from storm drains that contained TCE. Therefore, the TCE contamination may partially be a result of leakage from storm drains and migration from storm drains and migration from West Soldier Creek.

Supplemental quarterly remedial investigations have indicated that the areal extent of TCE contamination has not changed significantly from the extent present in the RI Report (Tulsa COE, 1989b). The extent of chromium contamination appears to have increased slightly in area. All other contaminants have appeared to remain fairly stable with a general trend for lower concentration of metals (Tulsa COE, 1989b).

The basewide groundwater assessment has detected the same contaminants in the perched aquifer as the remedial investigations (Tulsa COE, 1989c). The Groundwater Assessment update specifically mentioned the presence of three metals in well MW-73 which was referred to as the discharge point of West Soldier Creek (Tulsa COE, 1989c). (Note: MW-73 is located along the eastern boundary of Tinker AFB, south of East Soldier Creek and slightly north of Southeast 59th Street. It is unclear if the "West Soldier Creek" referred to in the Groundwater Assessment Update is the same as the West Soldier Creek defined for the Soldier Creek RI/FS. Reports have indicated that an off-base tributary to Soldier Creek may also be referred to as "West Soldier Creek.")

In addition to the quarterly sampling and analysis, Tulsa COE sampled wells in the vicinity of Building 3001 and the IWTP in October 1988 to monitor groundwater contaminant concentrations in these areas as a part of the overall groundwater assessment. The sample methodology is presented in the

Tinker AFB Sampling and Analysis Quality Assurance/Quality Control Plan for Corps of Engineers Site Investigations (Tulsa COE, 1986). The sampling locations and analytical results are summarized in Table 2-9 and Figure 2-8. The specific sampling activities and the conclusions of this round of groundwater sampling are not available at this time.

2.3.9 NUS Surface Water Analytical Results

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.

As part of this investigation, seven surface water samples were collected at on-base outfall locations from Building 3001. The locations of these sampling stations are shown on Figure 2-9 together with pertinent volatile organic, oil and grease, and metal analytical results for each location.

Selected analytical results are shown on Figure 2-9. Surface water analytical results pertinent to the Soldier Creek site are summarized in Table 2-10.

Surface water samples were collected over a 24 hour period using an ISCO 2700 continuous samplers. Samples were collected through 3/8-inch diameter PVC tubing and automatically composited in a 3-gallon glass collection vessel. The composite samples were transferred from the collection vessel to individual sample bottles for shipment to the laboratory. Grab samples collected for volatiles and oil and grease analyses were obtained by filling the sample bottles directly from the storm water overflow at the v-notch. The sample bottles were tagged and sealed prior to shipment. Chain-of-custody forms were completed for all samples and sent with each container for tracking purposes. All sample collection bottles contained the required preservatives prior to being filled with surface water samples.

TABLE 2-9

1988 GROUNDWATER ANALYTICAL RESULTS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

BORING NO.	SWD NO.	DATE	UNITS	As	Ba	Cd	Cr	Hg	Pb	Ni	Se	TOC	pH	Conductivity (umhos/cm)	Chloro-benzene	1,2-Dichloro-ethene	Trichloro-ethene	1,2-Dichloro-benzene	1,4-Dichloro-benzene	Tetrachloro-ethene	Vinyl Chloride
1-52A	8-1510	10/01/88	ug/L	ND	150	13	ND	12	ND	64	ND	2	7	852	26	ND	ND	ND	ND	ND	ND
1-52B	8-1511	10/01/88	ug/L	ND	240	14	15	ND	11	30	ND	3	7	1235	ND	ND	ND	ND	ND	ND	ND
1-53A	8-1512	10/01/88	ug/L	1	1000	12	220	ND	ND	28	1	1	8	628	ND	ND	ND	ND	ND	ND	ND
1-53B	8-1513	10/01/88	ug/L	8	630	13	86	ND	ND	620	1	1	7	674	ND	ND	ND	ND	ND	ND	ND
1-49A	8-1514	10/01/88	ug/L	ND	1000	ND	ND	ND	ND	41	1	2	7	578	ND	ND	ND	ND	ND	ND	ND
1-50A	8-1515	10/01/88	ug/l	1	1300	ND	ND	ND	ND	120	1	2	7	8	ND	230	300	380	110	ND	ND
1-50B	8-1516	10/01/88	ug/L	ND	2400	ND	ND	ND	ND	77	1	2	7	577	ND	1050	ND	350	110	ND	ND
1-51A	8-1517	10/01/88	ug/L	ND	1400	ND	ND	ND	ND	200	1	4	7	974	780	480	ND	ND	26	430	140
1-51B	8-1518	10/01/88	ug/L	ND	370	ND	6	ND	ND	34	1	2	7	542	360	ND	ND	300	ND	52	720
															5	ND	ND	ND	ND	ND	ND

ND = Not Detected

OUTFALL A

Contaminant	8/17/89	8/18/89	8/19/89
Bromoform (ug/l)	<5	<5	<5
Copper (mg/l)	0.02	0.04	0.04
Oil & Grease (mg/l)	<5	<5	<5
tetrachloroethene (ug/l)	<5	<5	<5
t-1,2-dichloroethene (ug/l)	<5	<5	<5

OUTFALL D

Contaminant	8/17/89	8/18/89	8/19/89	11/3/89	11/4/89
Bromoform (ug/l)	<5	<5	<5	-	-
Copper (mg/l)	0.02	0.02	0.62	-	-
Oil & Grease (mg/l)	<5	<5	7	-	-
tetrachloroethene (ug/l)	<5	6.6	7.7	18	21
t-1,2-dichloroethene (ug/l)	<5	<5	11	15	26

OUTFALL E

Contaminant	8/17/89	8/18/89	8/19/89	11/3/89	11/4/89
Bromoform (ug/l)	<5	<5	<5	-	-
Copper (mg/l)	0.02	0.04	0.03	-	-
Oil & Grease (mg/l)	<5	<5	8	-	-
tetrachloroethene (ug/l)	<5	<5	<5	<2	<2
t-1,2-dichloroethene (ug/l)	<5	<5	<5	-	-

OUTFALL F

Contaminant	8/24/89	8/25/89	8/26/89
Bromoform (ug/l)	<5	100	11
Copper (mg/l)	0.02	0.03	0.04
Oil & Grease (mg/l)	24	12	<5
tetrachloroethene (ug/l)	<5	<5	<5
t-1,2-dichloroethene (ug/l)	<5	<5	<5

OUTFALL G

Contaminant	8/24/89	8/25/89	8/26/89	11/3/89	11/4/89
Bromoform (ug/l)	<5	100	11	19	27
Copper (mg/l)	0.19	0.19	0.20	-	-
Oil & Grease (mg/l)	18	65	5	-	-
tetrachloroethene (ug/l)	<5	<5	<5	-	-
t-1,2-dichloroethene (ug/l)	<5	<5	<5	-	-

OUTFALL H

Contaminant	8/24/89	8/25/89	8/26/89
Bromoform (ug/l)	<5	<5	<5
Copper (mg/l)	0.03	0.02	0.02
Oil & Grease (mg/l)	5	<5	10
tetrachloroethene (ug/l)	<5	<5	<5
t-1,2-dichloroethene (ug/l)	<5	<5	<5

OUTFALL I

Contaminant	8/24/89	8/25/89	8/26/89
Bromoform (ug/l)	<5	<5	<5
Copper (mg/l)	0.04	0.02	0.02
Oil & Grease (mg/l)	3	<5	32
tetrachloroethene	<5	<5	<5
t-1,2-dichloroethene (ug/l)	<5	<5	<5

LEGEND:

SOLDIER CREEK AND TRIBUTARI

● SAMPLING LOCATION

NOTES:

- OUTFALL NUMBERING SYSTEM IS A RESULT OF THE NUS REPORT.

REFERENCE: NUS, 1989

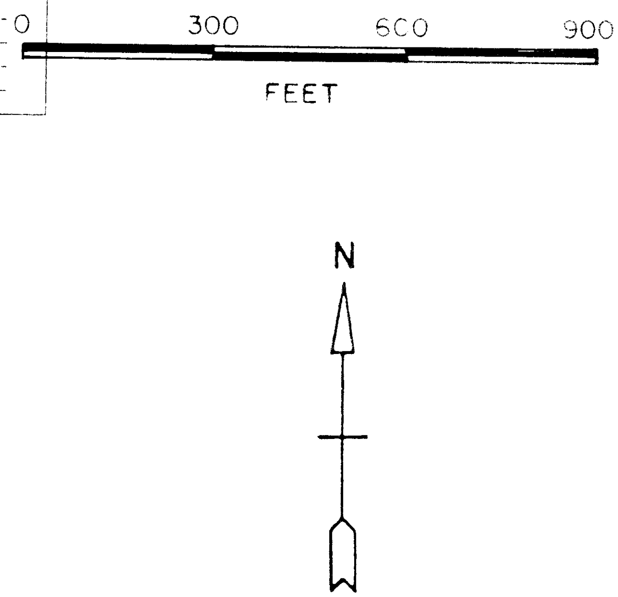


FIGURE 2-9
NUS SURFACE WATER ANALYTICAL RESULTS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

TABLE 2-10

NUS SURFACE WATER ANALYTICAL RESULTS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

SAMPLING LOCATION	SAMPLER	BROMOFORM (ug/l)					COPPER (mg/l)					OIL & GREASE (mg/l)					TETRACHLOROETHENE (ug/l)					t-1,2-DICHLOROETHENE (ug/l)				
		8/17	8/18	8/19	11/3	11/4	8/17	8/18	8/19	11/3	11/4	8/17	8/18	8/19	11/3	11/4	8/17	8/18	8/19	11/3	11/4	8/17	8/18	8/19	11/3	11/4
Outfall A	NUS	<5	<5	<5	NA	NA	0.02	0.04	0.04	NA	NA	<5	<5	<5	NA	NA	<5	<5	<5	NA	NA	<5	<5	<5	NA	NA
Outfall D	NUS	<5	<5	<5	NA	NA	0.02	0.02	0.02	NA	NA	<5	<5	7	NA	NA	<5	6.6	7.7	18	21	<5	11	<5	15	26
Outfall E	NUS	<5	<5	<5	NA	NA	0.02	0.04	0.03	NA	NA	<5	<5	8	NA	NA	<5	<5	<5	<2	<2	<5	<5	<5	NA	NA
		8/24	8/25	8/26	11/3	11/4	8/24	8/25	8/26	11/3	11/4	8/24	8/25	8/26	11/3	11/4	8/24	8/25	8/26	11/3	11/4	8/24	8/25	8/26	11/3	11/4
Outfall F	NUS	<5	100	11	NA	NA	0.02	0.03	0.04	NA	NA	24	12	<5	NA	NA	<5	<5	<5	NA	NA	<5	<5	<5	NA	NA
Outfall G	NUS	<5	100	11	19	27	0.19	0.19	0.2	NA	NA	18	65	5	NA	NA	<5	<5	<5	NA	NA	<5	<5	<5	NA	NA
Outfall H	NUS	<5	<5	<5	NA	NA	0.03	0.02	0.02	NA	NA	5	<5	10	NA	NA	<5	<5	<5	NA	NA	<5	<5	<5	NA	NA
Outfall I	NUS	<5	<5	<5	NA	NA	NA	0.02	0.02	NA	NA	3	<5	32	NA	NA	<5	<5	<5	NA	NA	<5	<5	<5	NA	NA

NA - Not Analyzed

Conclusions regarding the condition of Building 3001 outfalls with regard to on-base portions of East and West Soldier Creeks are presented below. The outfalls on West Soldier Creek vary from partial to total submergence as a result of vegetative growth occurring in the water channel. Because of the vegetative growth, a semi-swamp condition exists that both traps contaminants and raises the water level to the outfalls. NUS suggested that the on-base West Soldier Creek area should be reconstructed as an open lined culvert incorporating a weir and gate at its discharge end to both measure flows and control the discharge in case of a spill condition. NUS also suggested that the individual outfall discharges to this culvert should be designed to accept simple weir plates to provide measurement capabilities for possible future water studies.

East Soldier Creek Outfall L consists of a 30-inch line through which three 4-inch reinforced plastic pipes have been placed. The three pipes were out of service. NUS concluded that all three pipes should be removed from the inside of the outfall line.

2.4 ENVIRONMENTAL CONDITIONS

2.4.1 Climatology

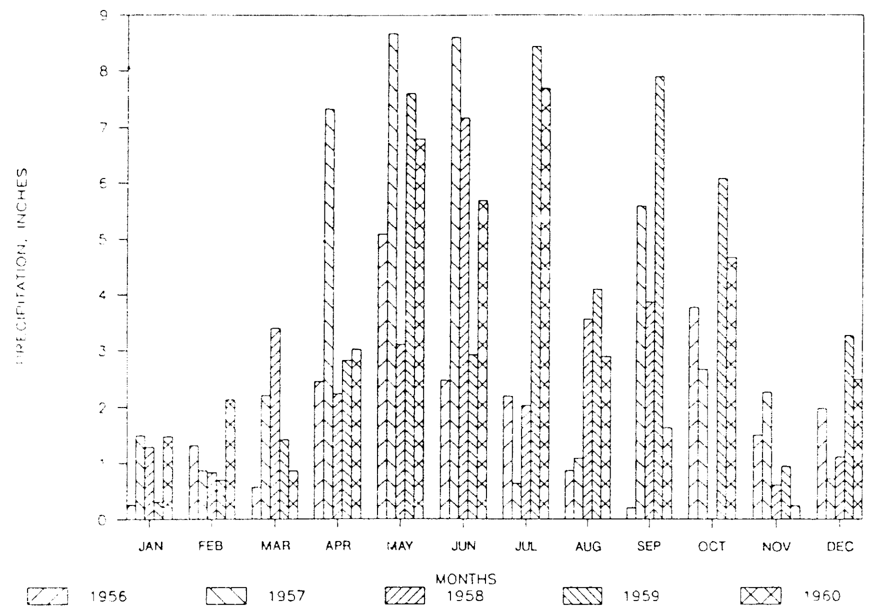
Meteorological information for the Soldier Creek site was compiled from weather data for the years 1956 through 1989 recorded at the Will Rogers World Airport (National Climatic Data Center, 1989, 1988, and 1985). Will Rogers World Airport is located approximately 10 miles to the west of Tinker AFB as shown on Figure 1-1. The meteorological information from Will Rogers World Airport was supplemented by weather data recorded at Tinker AFB for the years 1981 through 1989 (Tinker AFB, 1981-1989).

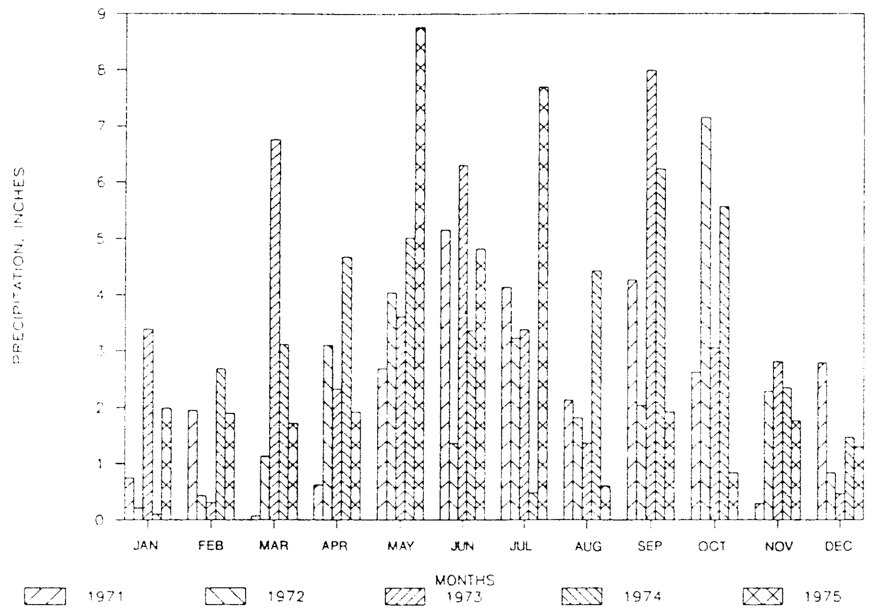
The mean annual precipitation for Will Rogers World Airport is 32.15 inches based on data from 1891 through 1988. From 1981 to 1988, the average annual precipitation was 39.20 inches for Will Rogers World Airport and 40.33 inches for Tinker AFB which are slightly greater than the long-term mean. The difference in reported annual precipitation for the two airports ranged from 2.5 to 17.8 percent over the eight year period, with Tinker AFB typically reporting higher annual precipitation than Will Rogers World Airport. This observation is based on a limited data set and additional information will be required before good correlations can be made between the data from Will Rogers World Airport and Tinker AFB.

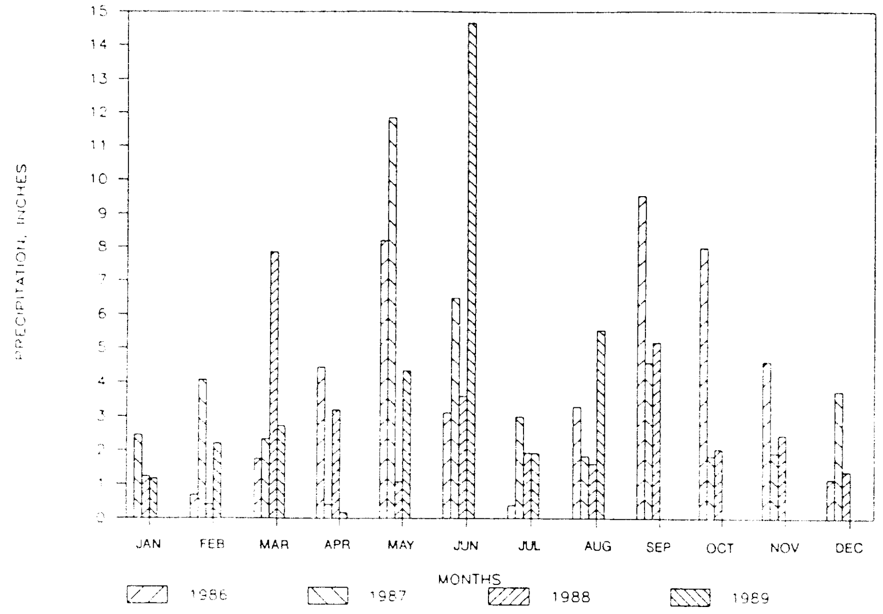
Figures 2-10 and 2-11 illustrate the monthly variation in precipitation for Will Rogers World Airport and Tinker AFB, respectively. According to data for Will Rogers World Airport, the highest average monthly precipitation is 5.21 inches and occurs in May. June, September, and April also have relatively high average precipitation with 4.00, 3.23, and 3.18 inches, respectively. Months with lowest average monthly precipitation are January, February, and December with averages of 1.26, 1.27, and 1.49 inches, respectively. The average monthly precipitation for the remainder of the year is between approximately 2 to 3 inches.

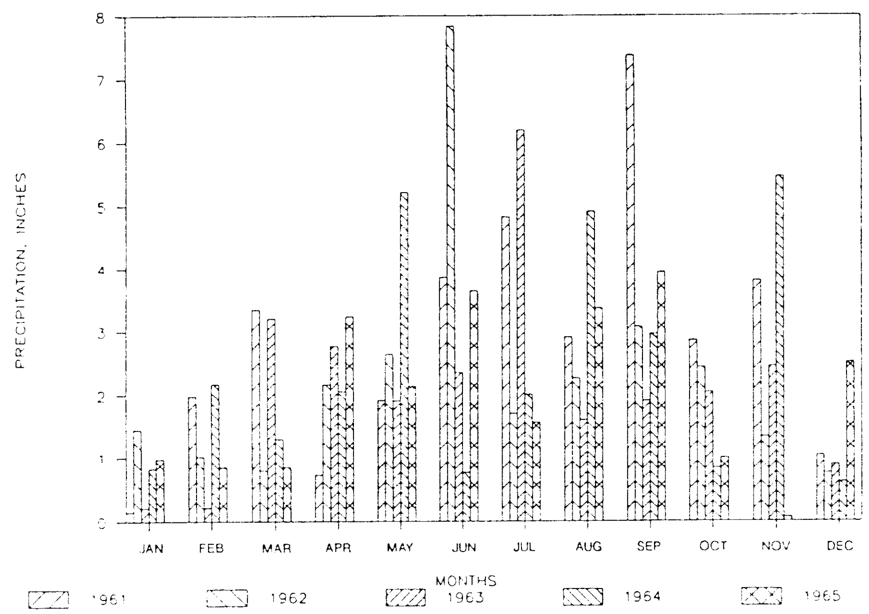
Snowfall typically occurs in the months of November through March with only trace amounts falling in October and April. The average yearly snowfall is 9.4 inches with the majority falling in January (average 3.1 inches) and February (average 2.6 inches).

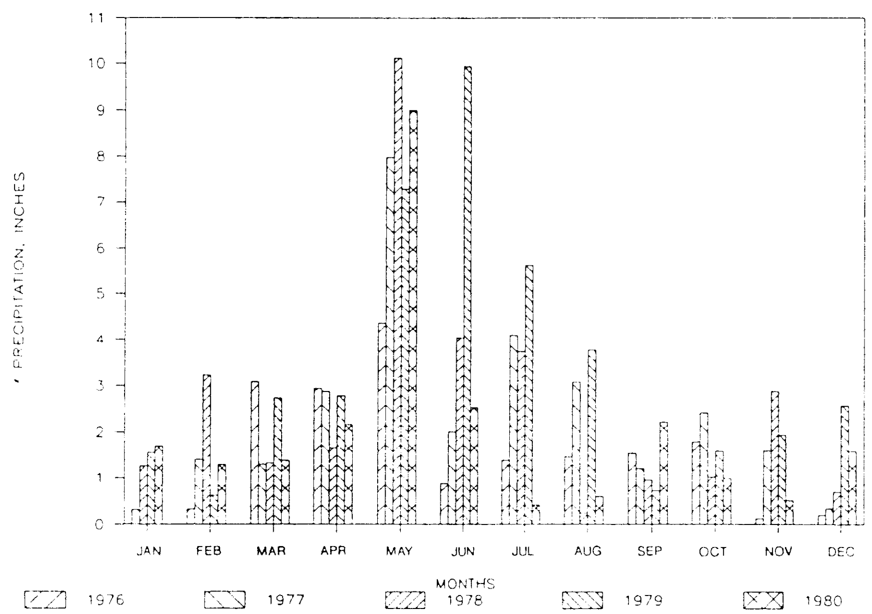
The average annual temperature recorded at Will Rogers World Airport is 60.1 F. The warmest months of the year are June and July with mean temperatures of 81.6 F and 81.3 F, respectively. The coldest months are January and December with mean temperatures of 36.9 F and 39.8 F, respectively. The normal daily maximum temperatures are highest in July (93.5 F) and August (92.8 F) and lowest in January (25.2 F), February (29.4 F), and December (29.1 F). This corresponds with the mean number of days per month with temperatures over 90 F. Both July and August have an average of approximately 23 days over 90 F. January and December have an average of over 20 days each with minimum temperatures below 32 F. The highest recorded temperature is 110 F and occurred in August 1980. The lowest recorded temperature is -4 F and occurred in January 1988.



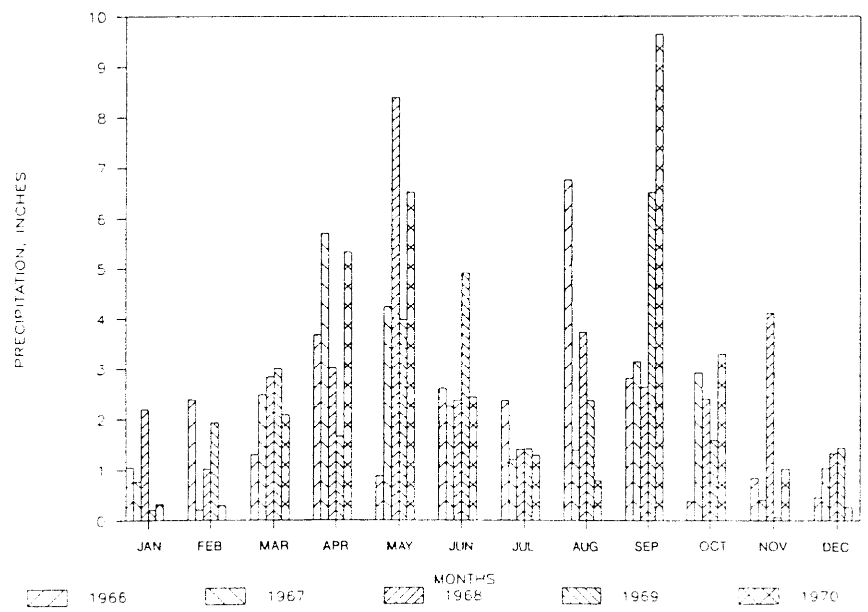








REFERENCE: NATIONAL CLIMATIC DATA CENTER, 1989, 1988, AND 1985



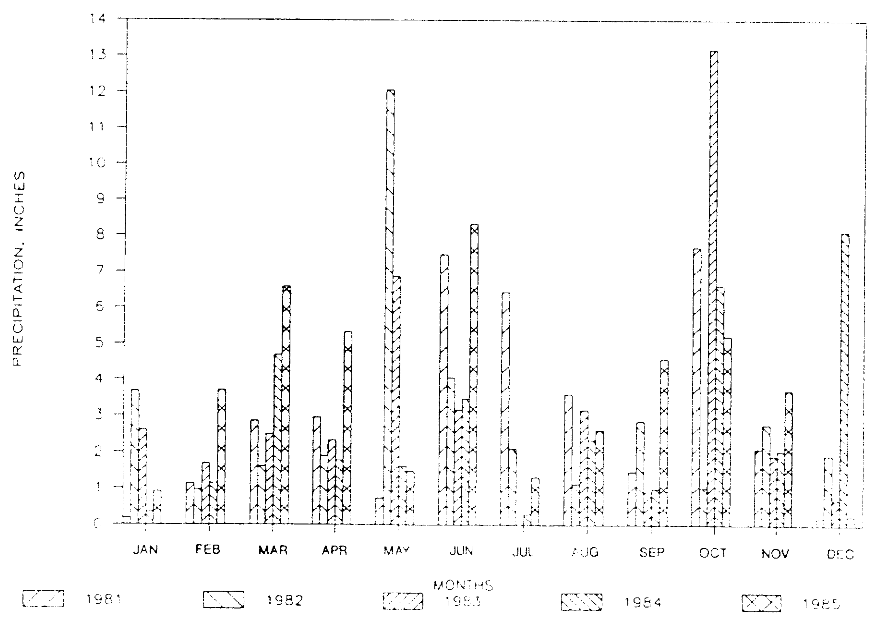
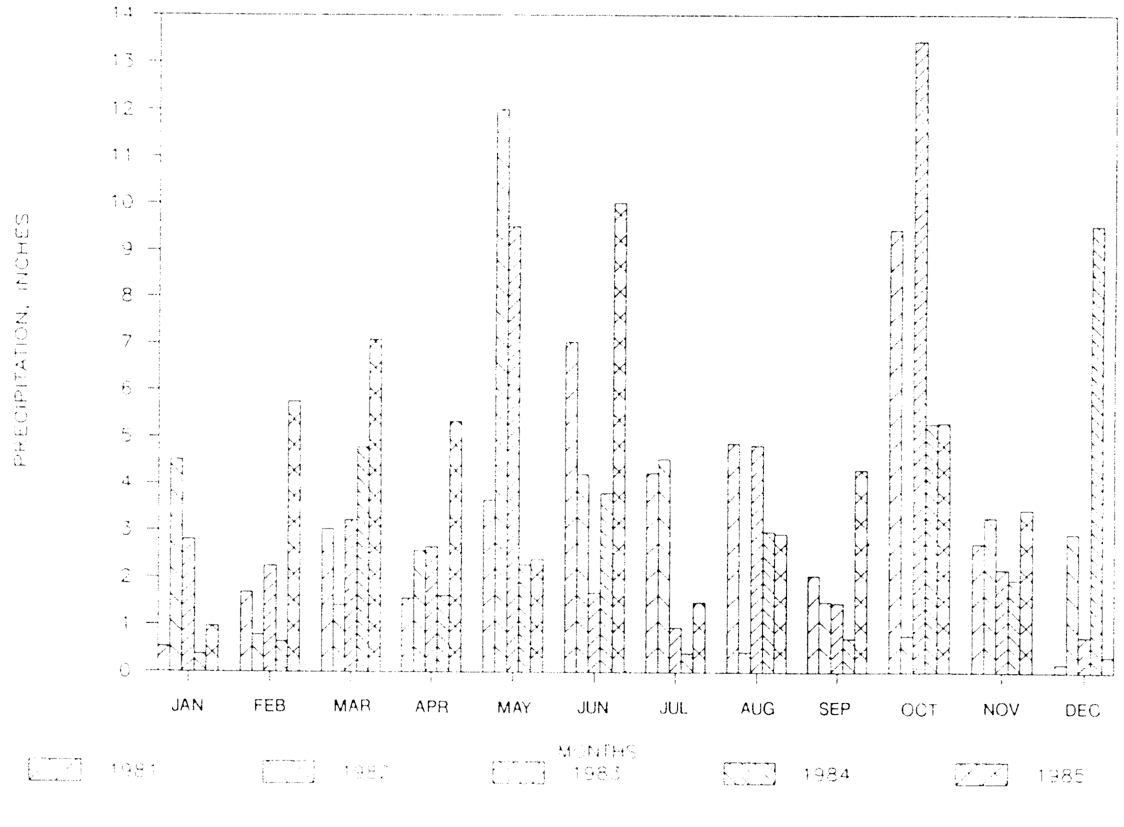
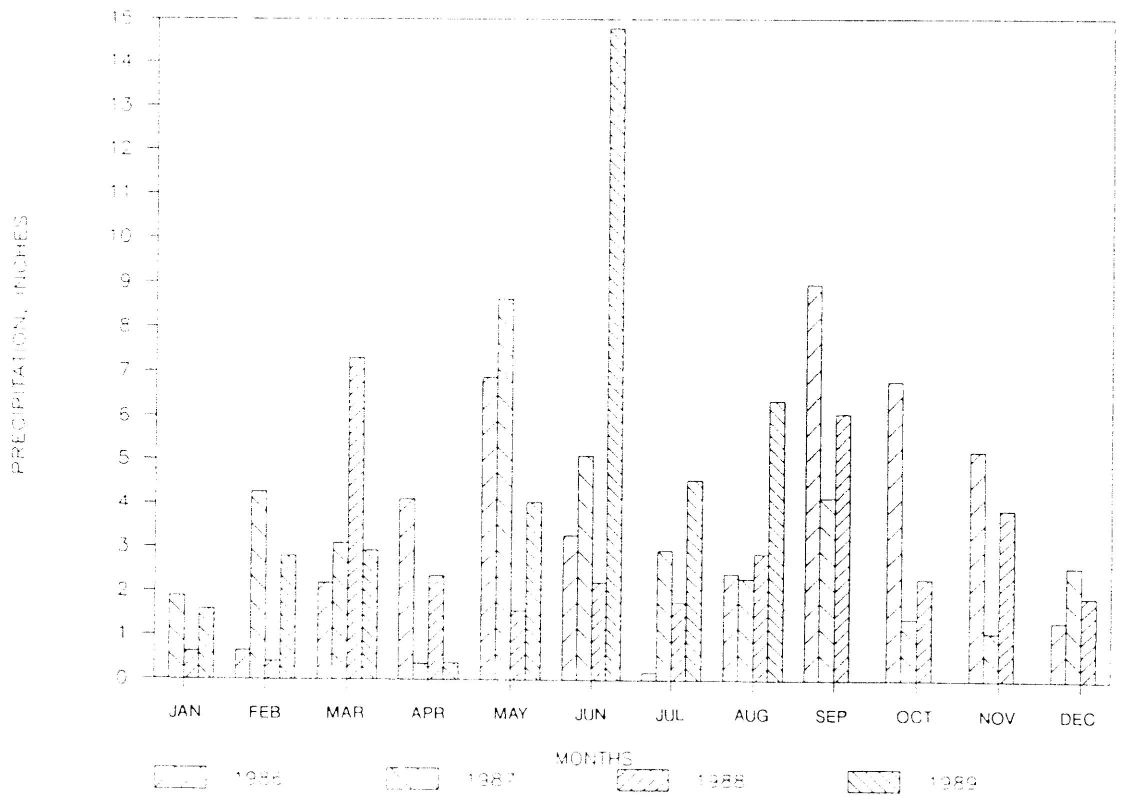


FIGURE 2-10
MONTHLY PRECIPITATION
WILL ROGERS WORLD AIRPORT
TINKER AFB-SOLDIER CREEK RI/FS
RI WORKPLAN





REFERENCE: TINKER AFB, 1981-1989

FIGURE 2-11
MONTHLY PRECIPITATION
TINKER AFB
TINKER AFB-SOLDIER CREEK RI/FS
RI WORKPLAN

The annual mean wind speed is 12.4 miles per hour (mph) 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. Highest mean monthly wind speeds occur in March and April with magnitudes of 14.6 and 14.4 mph, respectively. The prevailing wind directions during these months is from the south-southeast.

2.4.2 Topography and Surface Drainage

Tinker AFB is located in a regional area characterized by nearly level to gently rolling hills, broad flat plains and well-entrenched main streams. Local relief is primarily the result of dissection by erosional activity and stream channel development. At Tinker AFB, ground elevations range from 1,210 feet (on the northwest portion of the base) to about 1,320 feet mean sea level (at the southeast corner of the base) (Radian, 1985b).

The principal surface water drainage ways for Tinker AFB are Crutcho, Kuhlman, and Soldier Creeks. The extreme southern part of the base is drained by Elm Creek (Figure 2-12), an intermittent stream, which flows to the south and discharges into Stanley Draper Lake. Most of the base is drained by Crutcho Creek and its tributary, Kuhlman Creek. Crutcho Creek flows to the north and northwest and discharges into the North Canadian River. Soldier Creek, the focus of this study, is located mainly to the east of Tinker AFB. Soldier Creek flows to the north and discharges into Crutcho Creek approximately three miles upstream of the confluence of Crutcho Creek and the North Canadian River. Two tributaries of Soldier Creek receive surface water drainage from the eastern portion of Tinker AFB. East Soldier Creek, located on Tinker AFB, collects runoff from roads, parking areas and buildings on the eastern portion of the base, as well as discharge from several storm drains from the Building 3001 area. NPDES permitted discharges from the industrial waste and sewage treatment plants are also released into East Soldier Creek. West Soldier Creek, also located on Tinker AFB, collects runoff from the runway system and receives storm drain discharges from Building 3001. Figure 2-12 shows the location

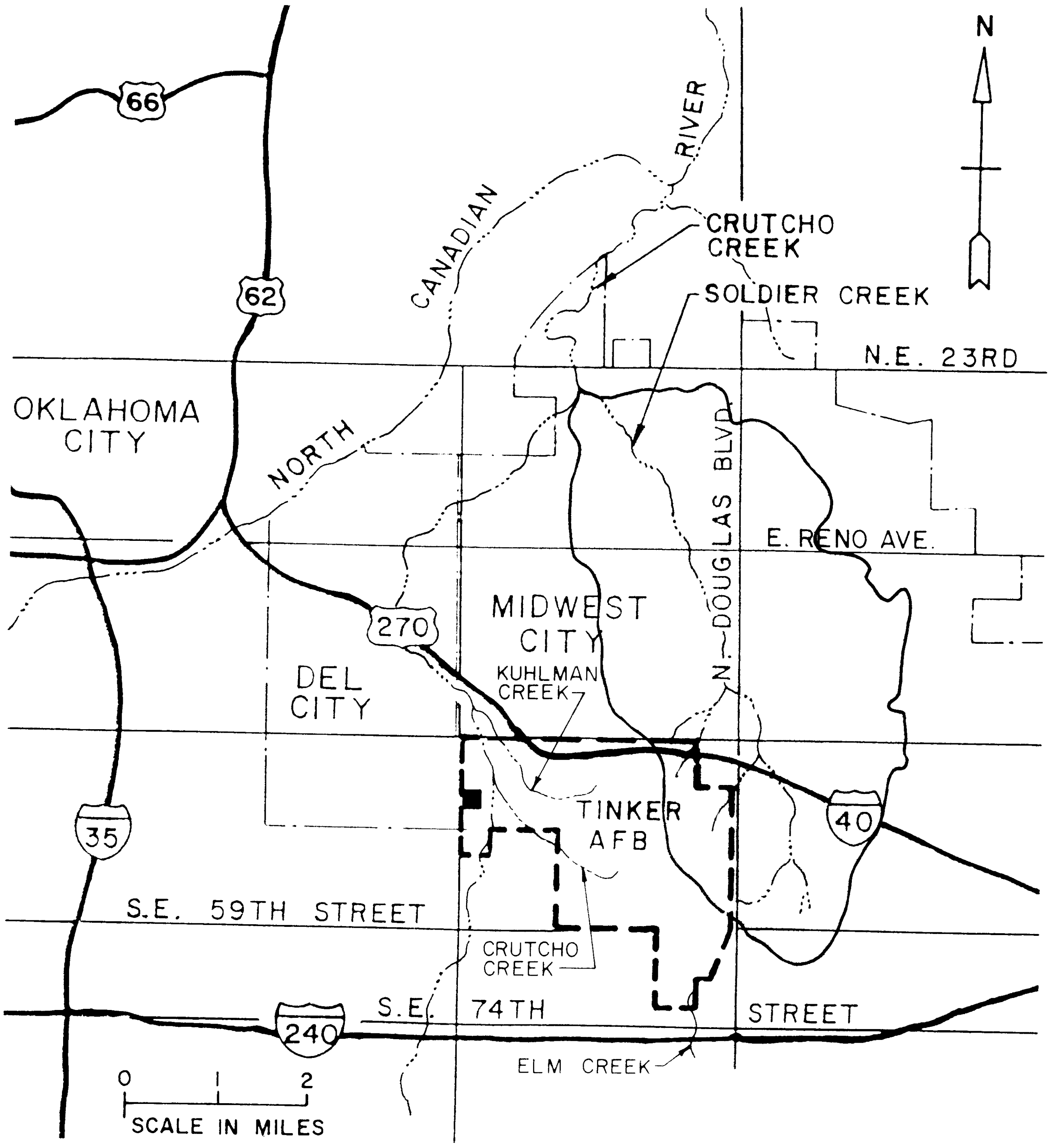


FIGURE 2-12
APPROXIMATE DRAINAGE BOUNDARY - SOLDIER CREEK
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

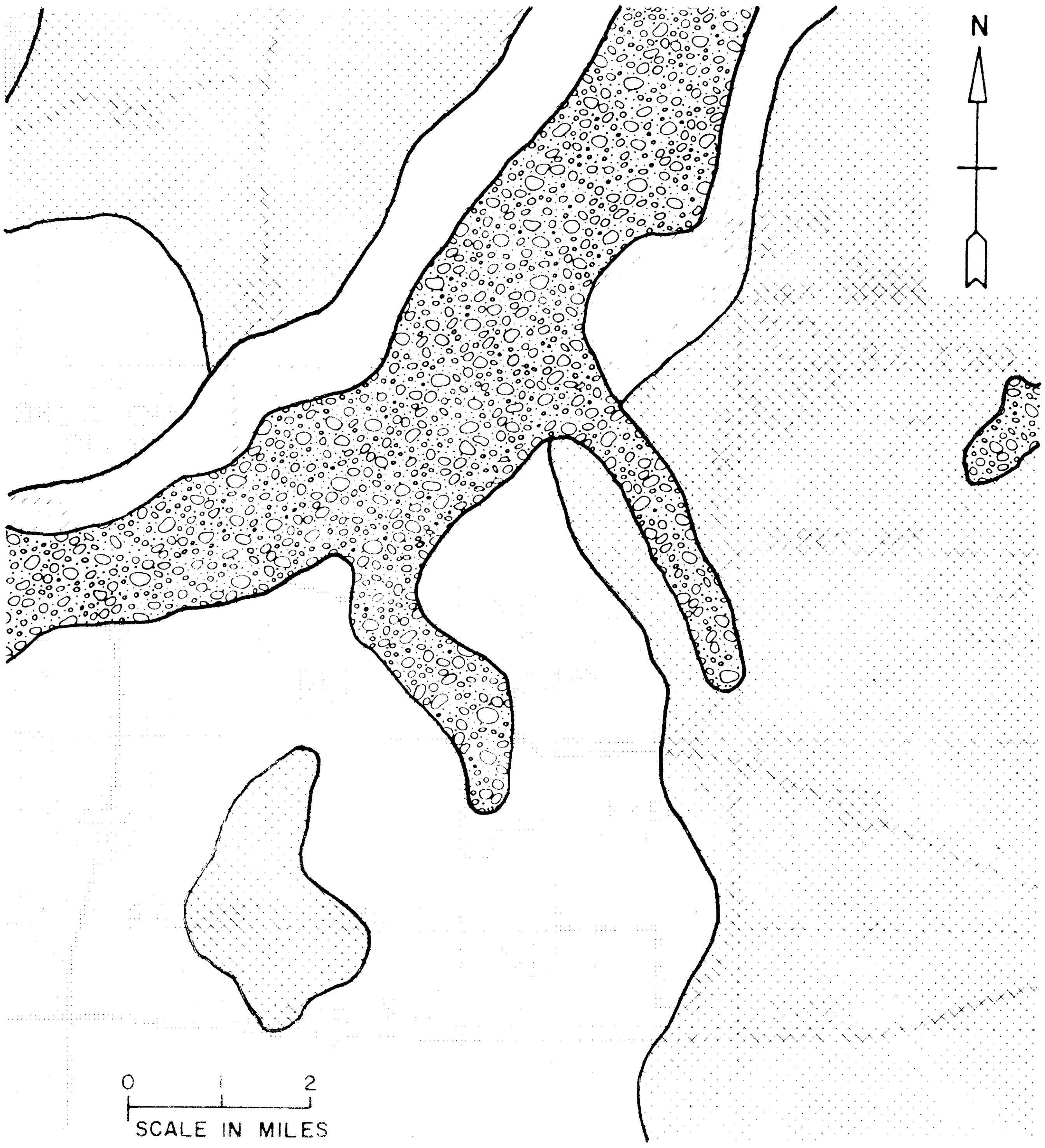
of Soldier Creek and its approximate drainage boundaries determined from the USGS topographic maps for the area (USGS, 1975 and 1986).

Based on a stream water quality investigation by EPA Region VI, it was concluded that the water quality of Crutcho and Soldier Creeks is poor due to the relatively large number of organics, metals, and other contaminants detected (EPA, 1985a). The analytical results of this investigation are presented in Section 2.3 of this report.

2.4.3 Geology and Soils

The four major surface soil associations occurring in the study area are shown on Figure 2-13. These soils are predominantly fine-grained residual and alluvial deposits. Residual soil associations, the Darnell-Stephenville, Dougherty-Norge-Teller, and Renfrow-Vernon-Bethany, are the product of in-place weathering of underlying bedrock (USDA, 1969). The Darnell-Stephenville association soils are described as sandy loam, sandy clay loam, and soft sandstone. Permeability of these soils varies from 1.4×10^{-3} to 4.4×10^{-3} centimeters per second. The Dougherty-Norge-Teller association soils are described as loamy sand, sandy clay loam, clay loam, and silty clay loam. Permeability of these soils ranges from 4.2×10^{-5} to 1.4×10^{-3} centimeters per second. The Renfrow-Vernon-Bethany association soils are comprised of silt and clay loam, and weathered shale. Permeability of these soils varies from less than 4.2×10^{-5} to 1.4×10^{-3} centimeters per second. The alluvial materials, Dale-Canadian-Port association, are stream deposited silts and sands, whose occurrence is generally restricted to the floodplains of area streams. These alluvial deposits consist of fine sandy loam, silty clay loam, loam and clay loam, and have a permeability range of 3.5×10^{-5} to 4.5×10^{-3} centimeters per second.

Soils of the Renfrow-Vernon-Bethany association exhibit slow infiltration rates, slow to very slow water transmission rates, and higher runoff potential. The engineering classification [Unified Soil Classification System (USCS)] of soils in this association include inorganic clay and silt



Source: USDA, 1969

SOIL ASSOCIATIONS

- Darnell-Stephenville association: Shallow and deep, gently sloping to strongly sloping, loamy soils on wooded uplands
- Renfrow-Vernon-Bethany association: Deep and shallow, nearly level to sloping, loamy and clayey soils on prairie uplands
- Dale-Canadian-Port association: Deep, nearly level, loamy soils on low benches along the North Canadian River and other large streams
- Dougherty-Norge-Teller association: Deep, gently sloping to strongly sloping or hummocky, sandy and loamy soils on wooded and prairie uplands

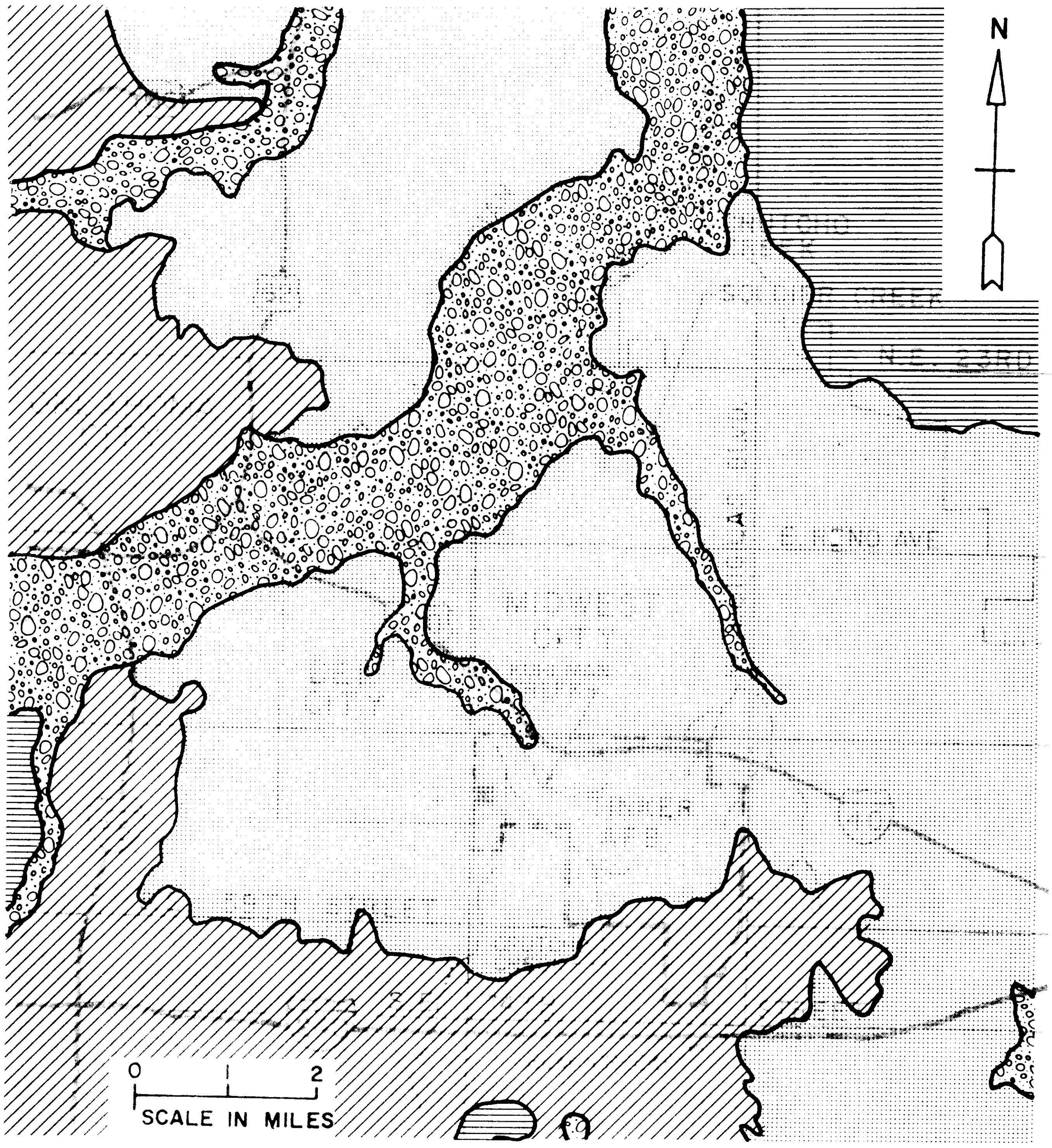
FIGURE 2-13
GENERAL STUDY AREA SOIL ASSOCIATIONS
TINKER AFB-SOLDIER CREEK RI/FS
RI WORKPLAN

with slight to medium plasticity (CL, ML) and inorganic clay and silt with high plasticity (CH, MH).

Soils of the Dougherty-Norge-Teller, Darnell-Stephenville, and the Dale-Canadian-Port associations are characterized by moderate to slow infiltration rates, moderate to slow water transmission rates, and moderate to high runoff potential. The engineering classification of soils (USCS) in the Dougherty-Norge-Teller association include silty and clayey sand (SM, SC) and inorganic clay and silt with slight to medium plasticity (CL, ML). Darnell-Stephenville Soils are classified as silty and clayey sand (SM, SC), and organic silt with slight plasticity (ML). Soils of the Dale-Canadian-Port association are classified as clay and silt of slight to medium plasticity (CL, ML), and silty sand (SM).

Tinker AFB is located within the Osage Plains section of the Central Lowland physiographic province of the Interior Plains division of the United States (Fenneman, 1946). A generalized geologic map of the study area, is shown on Figure 2-14. The stratigraphic correlation of geologic units in the area is shown on Figure 2-15. Geologic units which outcrop at various locations across the base consist of Quaternary alluvium and terrace deposits, the Permian Age Hennessey Group, and Garber Sandstone.

Quaternary alluvium, present along a portion of Crutcho Creek and Soldier Creek, consists of unconsolidated, interfingered lenses of sand, silt, clay and gravel. The Hennessey group, approximately 700 feet thick in the Tinker AFB area, is composed of deep-red clay shale containing thin beds of red sandstone and white or greenish bands of sandy shale. It is present under surficial deposits on the southern portion of the base. Units comprising this Group are the Kingman Siltstone and the Fairmont Shale. The Garber Sandstone, present on the northern portion of the base, is a deep-red to reddish orange, massive and cross bedded, fine grained sandstone interbedded and interfingered with red shale and siltstone. It is approximately 500 feet thick in the vicinity of Tinker AFB. The Wellington Formation, which is often difficult to distinguish from the overlying



Source: USGS, 1989

QUATERNARY
- Alluvium
- Terrace Deposits

PERMINAN
- Hennessey Group
- Garber Sandstone

FIGURE 2-14
GENERAL STUDY AREA GEOLOGY
TINKER AFB-SOLDIER CREEK RI/FS
RI WORKPLAN

Era	Period	Geologic unit	Hydrogeologic category
Cenozoic	Quaternary	Alluvium	Alluvium-Terrace
		Terrace deposits	
Paleozoic	Permian	El Reno Group	El Reno
		Hennessey Group	Hennessey
		Garber Sandstone	Garber-Wellington
		Wellington Formation	
		Chase Group	Chase-Admire
		Council Grove Group	
		Admire Group	
	Pennsylvanian	Vanoss Formation	Vanoss

Source: Modified from USGS, 1989

FIGURE 2-15
STRATIGRAPHIC CORRELATION
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

Garber Sandstone, is a deep-red to reddish orange massive and cross bedded, fine grained sandstone interbedded with red, purple, maroon, and gray shale. The Chase, Council Grove, and Admire Groups consist of beds of fine-grained, cross-bedded sandstone, shale, and thin limestone. The Hennessey Group, Garber Sandstone, Wellington Formation and the Chase, Council Grove and Admire Groups were deposited during the Permian period, (230 to 280 million years ago) and are typical of redbed deposits characteristic of that period.

Sediment samples were taken from Crutcho and Soldier Creeks in 1985. Sediment collected from West Soldier Creek, just inside the base boundary, was reported as sandy material. Sediment samples from Soldier Creek taken directly east of Building 3001 were reported to vary from sandy gravel to soft silty clay (Radian, 1985b).

Tinker AFB lies within a tectonically stable area. No major faults or fracture zones have been mapped near the base. Most of the consolidated rock units of the Oklahoma City area are nearly flat-lying. The reported regional dip is to the west at about 50 feet per mile (USGS, 1989).

2.4.4 Hydrogeology

Tinker AFB lies within the limits of the Garber-Wellington Groundwater Basin. The Garber Sandstone, Wellington Formation, and the Chase, Council Grove and Admire Groups comprise the Central Oklahoma Aquifer. Regionally, groundwater in the overlying alluvium and terrace deposits, the Hennesey Group, the Garber Sandstone, the Wellington Formation, and in the Chase, Council Grove, and Admire Groups is part of the same flow system (USGS, 1989). The Central Oklahoma Aquifer, often referred to as Garber-Wellington Aquifer, will be referred to as the Garber-Wellington Aquifer in this report to remain consistent with past investigations. The sandstone, siltstone and shale constituting the Garber Wellington Aquifer tend to be loosely cemented and have a maximum thickness of 1,000 feet. Regionally, groundwater flows to the southwest in the Garber-Wellington Aquifer under both confined and unconfined conditions, depending on the presence of overlying shale beds. The Garber-Wellington Aquifer is exposed at ground surface or covered by a thin layer of soil over the northern half of Tinker AFB. The aquifer is probably overlain by a thin, discontinuous sequence of Hennessey Group sediments (Kingman Siltstone and Fairmont Shale) in the southern half of the base.

Recharge of the Garber-Wellington Aquifer is accomplished principally by rainfall infiltration and surface water infiltration from streams in contact with outcrops. Because the aquifer outcrops in the Tinker AFB area, it is assumed that the base is situated in a recharge zone (Engineering Science, 1982).

Regionally, the Garber-Wellington Aquifer is the single most important source of potable groundwater in the Oklahoma City area. The quality of groundwater derived from the Garber-Wellington Aquifer is generally good, although wide variations in the concentrations of some constituents such as hardness, sulfate, chloride, fluoride, nitrate, or dissolved solids, are known to occur (Wood and Burton, 1968). A saline zone, encountered at depths greater than 900 feet below ground surface is present beneath Tinker AFB and its immediate surrounding area.

The local ground water flow direction is complex due to the highly variable geology. Water-bearing zones present on site from shallowest to deepest are as follows: perched aquifer, top of regional aquifer zone, regional aquifer (Central Oklahoma Aquifer) zone, and the producing zone.

Shallow alluvial and residual water bearing units exist within Tinker AFB and the surrounding area where zones of alluvium border streams and where shallow, sandy, residual soil collects precipitation. At Tinker AFB, sandy residual soil overlying bedrock form such units. These water bearing units may be recharged directly by precipitation. Seasonally, they may gradually lose water as local streams and underlying bedrock aquifers deplete limited supplies.

Alluvial deposits in nearby streams appear to be hydrologically connected to a perched aquifer. The perched water system, fed primarily by precipitation, recharges area streams during periods of low discharge, and is recharged by the same streams during periods of high discharge (Tulsa COE, 1988a).

Based on a study conducted by the Tulsa COE, contaminants were detected in the perched water system, which is believed to be hydraulically associated with the surface water system. Wells screened in this perched water system in the vicinity of Soldier Creek yielded samples containing chromium, selenium and nickel above background levels. Chlorobenzene and benzene were detected on singular occasions. Other water quality analyses of perched groundwater samples detected concentrations of sulfate above the background level. The perched groundwater, where present, is quite distinct from the potentiometric surface of the regional aquifer. The perched groundwater system occurs above shale deposits in the more permeable residual overburden and in the alluvial deposits. It is not necessarily continuous over all of the base, and may occur in several strata at the same location which are separated by zones of low permeability (Tulsa COE, 1987).

Information gathered from previous investigations indicate that the perched system may not be directly hydraulically connected across the northeastern corner of the base. Specifically, the areas of interest include the perched groundwater under the Building 3001 complex, and the perched groundwater under the IWTP area. Groundwater flow paths and chemical data reviewed to date indicate that perched water in these areas may not be hydraulically connected to each other (BVWST, 1989a).

2.4.5 Surrounding Land Use

Tinker AFB lies within an area representing a transition from residential and industrial/commercial land use on the north and west to agricultural land use to the east and south. Soldier Creek, which flows northwest through the area, appears to be bordered mainly by recreational and residental areas with some areas supporting commercial and industrial land use (Midwest City, 1984 and Oklahoma City, date unknown). Drainage into West Soldier Creek flows north from Tinker AFB, through mostly residential areas. Some industry such as a metal plating facility (Figure 1-2), 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 former sanitary landfill. In addition, three schools, Soldier Creek Elementary, Steed Elementary, and Monroney Junior High exist within the drainage basin.

2.4.6 Ecological Conditions

The following information discusses the different species of mammals, birds, insects, aquatic life, and plants present on and around Tinker AFB. Information was obtained from the "F16 Beddown Environmental Assessment" prepared by Argonne National Laboratories for Tinker AFB (Tulsa COE, 1988d), and from the Oklahoma Natural Heritage Inventory (ONHI).

Several federal threatened or endangered bird species may occasionally occur in the Tinker AFB area. The threatened species are the Arctic peregrine falcon and the piping plova. The endangered species are the bald eagle, American peregrine falcon, whooping crane, and the interior population of the least tern. However, the potential for the occurrence of these species in the immediate vicinity of Tinker AFB is low because preferred habitat and known areas of congregation for these species are not located near the base (Tulsa COE, 1988d).

Although no endangered plant species have been reported for the Tinker AFB area (Township 11 North (T11N), Range 2 West (R2W), Oklahoma County), three species should be given special attention because of potential endangered or threatened species listing in the future. Two populations of the Oklahoma Beardtongue (Penstemon oklahomensis) were confirmed within T11N, R2W, Oklahoma County. Because this plant species is suffering a decline in population due to loss of habitat, it is currently being studied to determine if it should be petitioned to include it on the U.S. Fish and Wildlife Services list of endangered or threatened species (ONHI, 1989). Ozark poverty grass (Sporobolus ozarkanus) and a sedge (Carex fissa) are candidates 2 for federal listing as endangered or threatened species.

Although no populations of Ozark poverty grass or Carex fissa are confirmed within T11N, R2W, Oklahoma County; this area is within the known range of the species (ONHI, 1989).

One species of insect which is unconfirmed in the area, but is likely to occur in a habitat similar to Oklahoma Beardtongue is the Prairie Mole Cricket (Gryllotalpa major). It is a candidate 2 species for federal listing (ONHI, 1989).

Mammals common to habitats at Tinker AFB include the eastern fox, squirrel, thirteen-lined ground squirrel, plains pocket gopher, eastern cottontail rabbit, white-footed mouse, striped skunk, raccoon, opossum, Norway rat, and the house mouse. The habitats most suited for wildlife occur primarily in mowed grassy fields and undeveloped areas associated with drainages (Tulsa COE, 1988d).

The most common species of birds from the Oklahoma City area which are common to habitat types occurring at Tinker AFB are the Canada goose, killdeer, rock dove, mourning dove, common night hawk, chimney swift, scissor-tailed flycatcher, American crow, American robin, European starling, common grackle, and the house sparrow. The area is in the central flyways for migratory waterfowl (Tulsa COE, 1988d).

Creeks and ponds constitute the aquatic habitats on Tinker AFB. Ponds are managed for largemouth bass and channel catfish. Other fish that could occur in these habitats include red shiner, plains minnow, carp, black bullhead, green sunfish and bluegill (Tulsa COE, 1988d).

Most of the on-base vegetated areas are mowed and landscaped. Little natural habitat exists. The varieties of grass present include bluestem, poverty grass, triple lawn, and Johnson. Scattered trees and shrubs occur around many buildings, the golf course, and on less developed portions of the base. The largest wood habitats occur along the watercourses. Woody species include oaks, elms, willows, cottonwoods, box elders, sycamores, redbuds, ashes, and sumacs (Tulsa COE, 1988d).

3.0 PRELIMINARY RISK ASSESSMENT

Several studies to investigate environmental contamination on Tinker AFB have been completed over the past five years. These investigations have gathered limited data on surface water and sediment contamination; however, extensive data is available regarding the nature and extent of groundwater contamination associated with portions of the base. Groundwater investigations have focused on areas in and around the Building 3001 site located in the northeast portion of the base (Tulsa COE, 1988a) and an RI is currently underway for the IWTP. A risk assessment for the Building 3001 site was completed in 1988 (Tulsa COE, 1988b).

While much is known about the groundwater contamination and associated risk for the Building 3001 site, little is known about the nature and extent of contamination associated with the Soldier Creek site. The purpose of this preliminary risk assessment is to introduce the preliminary contaminants of concern for the Soldier Creek site and the potential risks associated with their migration.

The preliminary risk assessment provides a qualitative (conceptual) analysis of the current and future health risks that may be associated with the site. The preliminary risk assessment performs the following functions:

- Focuses the planning of the RI field activities to collect data which allow a more detailed quantitative risk assessment evaluation to be conducted.
- Provides a foundation for the development of remedial action objectives.

Several components comprise the preliminary risk assessment:

- Identification of the preliminary contaminants of concern [as defined in the Superfund Public Health Evaluation Manual (EPA 1986), Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual (EPA, 1989a), and other guidance] which will be the primary focus of the remedial investigation.

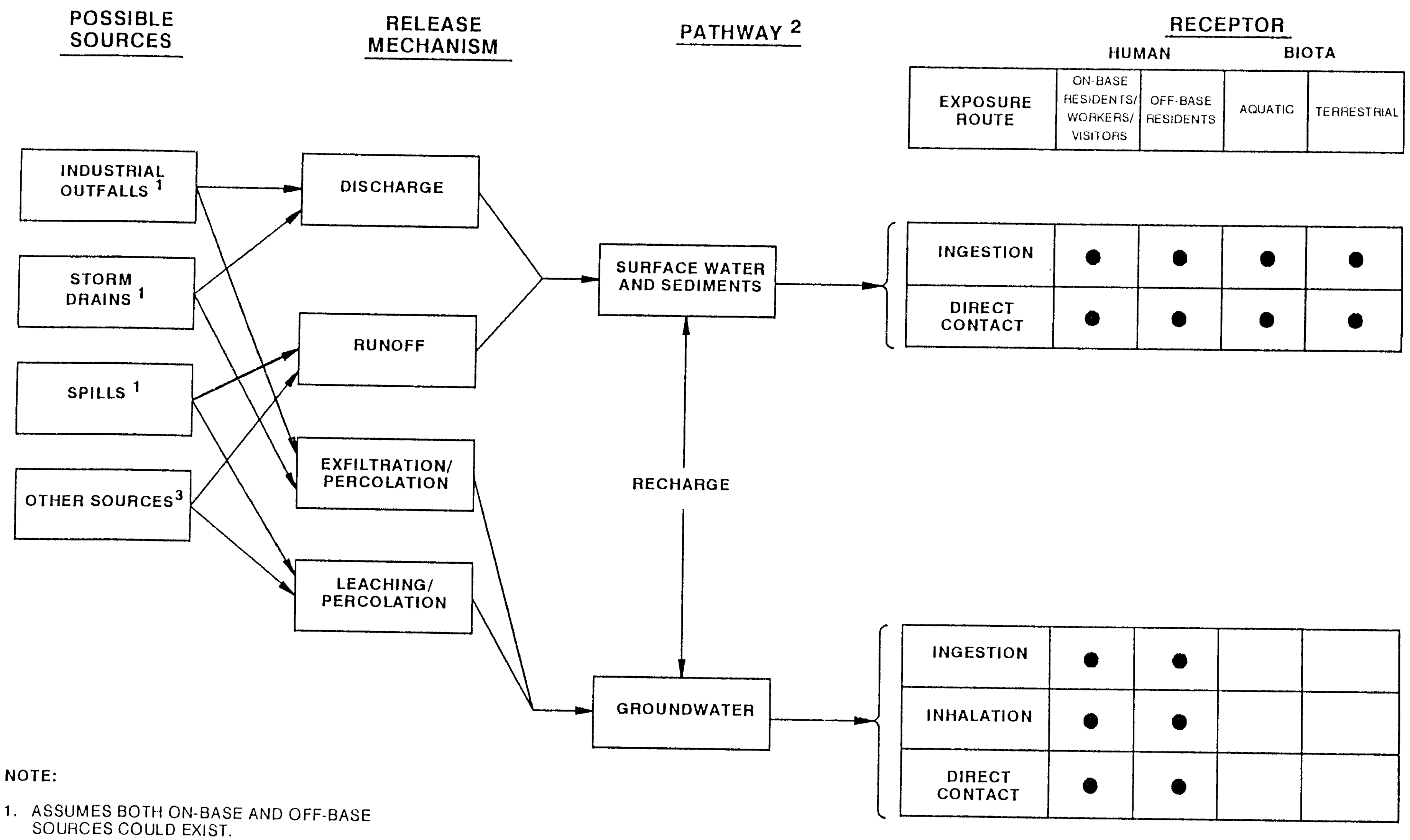
- Characterization of the toxicity of the selected preliminary contaminants of concern.
- Identification of potential exposure pathways.
- Identification of potential receptors and routes of exposure for both the present and future land use.
- Identification of data gaps requiring the collection of additional information during the RI to perform the quantitative risk assessment.

As part of the data quality objective process undertaken to scope the Soldier Creek RI, a conceptual model of the site was developed based on relevant existing data. The Soldier Creek conceptual site model is presented in Figure 3-1. As part of the model, possible contaminant sources, potential migration pathways, and potential receptors were identified for the site. This information, in concert with the available toxicity information for each identified preliminary contaminant of concern, was used to develop the components of the preliminary risk assessment presented below.

3.1 PRELIMINARY CONTAMINANTS OF CONCERN

The contaminants of concern for the Soldier Creek site include all volatile organics, BNAs, metals, cyanide, and other contaminants that have been identified during previous investigations in and around the site. Table 3-1 presents the list of contaminants of concern for the site, their corresponding Chemical Abstract Service (CAS) numbers, and information regarding the toxicity of the contaminants.

The chemicals of concern were identified by reviewing existing remedial investigation data for Building 3001 and existing data for Soldier Creek, including sediment, surface water, and groundwater sampling results. Contaminants present in the perched aquifer beneath the IWTP in the northeast section of the Tinker AFB were also considered, since the hydrologic relationship of this water table with the perched aquifer located below Building 3001 is uncertain and the two tables could potentially be connected. The comprehensive list of contaminants of



NOTE:

1. ASSUMES BOTH ON-BASE AND OFF-BASE SOURCES COULD EXIST.

2. MODEL ASSUMES UNDISTURBED SITE CONDITIONS. EXCAVATION OR OTHER INTRUSIVE ACTIVITIES COULD INTRODUCE AIR AS AN ADDITIONAL PATHWAY OF CONCERN

3. OTHER SOURCES MAY INCLUDE THE PLATING FACILITY, LANDFILL 6, AND THE COMMERCIAL LANDFILL.

FIGURE 3-1
CONCEPTUAL SITE MODEL SCHEMATIC
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

TABLE 3-1

CONTAMINANTS OF CONCERN AND TOXICITY DATA
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

Chemical Name	Detection Medium	CAS No.	Reference Dose Inhalation mg/m^3	Reference Dose Oral mg/kg/day	EPA Group/Slope Factor Inhalation $(ug/m^3)^{-1}$	EPA Group/Slope Factor Oral $(mg/kg/day)^{-1}$
INORGANIC CHEMICALS						
Arsenic	(2)	7440-38-2	ND	1E-3	A/4.3E-3	A/NA
Barium	(1)(2) (4)	7440-39-3	5E-4/5E-3	5E-2		
Cadmium	(2) (4)	7440-43-9	ND	5E-4/ND	B1/1.8E-3	ND/ND
Chromium	(2) (4)	7440-41-7	ND	5E-3/2E-2	A/1.2E-2	ND/ND
Copper	(2) (5)	7440-50-8	ND	1.3 mg/l		
Cyanide	(1)	57-12-5	ND	2E-2		
Iron	(1)(2)	7435-89-6	DI	DI		
Lead	(2)	7435-52-1	ND	ND	B2/ND	B2/ND
Mangenese	(2)	7439-96-5	1E-3	2E-1/5E-1		
Mercury	(2)	7439-97-6	ND	3E-4		
Nickel	(2) (4)	7440-02-0	ND	2E-2	A/4.8E-4	ND/ND
Selenium	(2)	7782-49-2	4E-3	3E-3/4E-3		
Silver	(2)	7440-22-4				
Zinc	(1)(2)	7440-66-6	ND	2E-1		
ORGANIC CHEMICALS						
Acenaphthylene	(2)	208-96-8	DI	DI		
Anthracene	(2)	120-12-7				
Benzene	(3)	71-43-2			A/8.3E-6	A/2.9E-2
Benzo(a)anthracene	(2)	56-55-3				
Benzo(k)fluoranthene	(2)	207-08-9				
Benzo(g,h,i)perylene	(2)	191-24-2				
Benzo(a)pyrene	(2)	50-32-8			B2/ND	B2/ND
Bis(2-ethylhexyl)phthalate	(2)	117-81-7	ND	2E-2	B2/ND	B2/1.4E-2
Bromodichloromethane	(3)	75-27-4	ND	2E-2	B2/ND	B2/1.3E-1
Bromoform	(5)	75-25-2	ND	2E-2/2E-1	D/ND	D/ND
Carbon Tetrachloride	(3)	56-23-2	ND	7E-4/7E-3	B2/1.5E-5	B2/1.3E-1

TABLE 3-1 (CONTINUED)

CONTAMINANTS OF CONCERN AND TOXICITY DATA
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

Chemical Name	Detection Medium	CAS No.	Reference Dose Inhalation mg/m^3	Reference Dose Oral mg/kg/day	EPA Group/Slope Factor Inhalation (ug/m^3)$^{-1}$	EPA Group/Slope Factor Oral (mg/kg/day)$^{-1}$
ORGANIC CHEMICALS (CONTINUED)						
Chlorobenzene	(2)(3)(4)	108-90-7	2E-2/2E-1	2E-2/2E-1		
Chloroform	(2)(3)	67-66-3	ND	1E-2	B2/2.3E-5	B2/6.1E-3
2-Chloroethyl Vinyl Ether	(3)	110-75-8				
Chloromethane	(3)	74-87-3			C/1.8E-6	C/1.3E-2
Chrysene	(2)	218-01-9				
Dibenzo(a,h)anthracene	(2)	53-70-3				
Dibromochloromethane	(3)	124-48-1	ND	2E-2/2E-1	B2/ND	B2/8.4E-2
1,2-Dichlorobenzene	(3)(4)	95-50-1	2E-1/2	9E-2/9E-1	D/ND	D/ND
1,3-Dichlorobenzene	(3)	541-73-1	DI	DI	D/ND	D/ND
1,4-Dichlorobenzene	(3)(4)	106-46-7	7E-1	ND	B2/ND	B2/2.4E-2
1,1-Dichloroethane	(3)	75-34-3	5E-1/5	1E-1/1	ND/ND	B2/9.1E-2
1,2-Dichloroethane	(3)	107-06-2				
1,1-Dichloroethene	(2)(3)(4)	75-35-4	ND	9E-3	C/5E-5	C/6E-1
t-1,2-Dichloroethene	(2)(3) (5)	540-59-0	ND	2E-2		
1,2-Dichloropropane	(3)	78-87-5			B2/ND	B2/6.8E-2
cis-1,3-Dichloropropene	(3)	514-75-6				
Di-n-butylphthalate	(2)	84-74-2	ND	1E-1/1		
Di-n-octylphthalate	(2)	117-84-0	DI	DI		
Ethyl Benzene	(3)	100-41-4	ND	1E-1/1		
Fluoranthene	(2)	206-44-0				
Flourene		86-73-7			D/ND	D/ND
Indeno(1,2,3-cd)pyrene	(2)	193-39-5				
Methylene Chloride	(1)(2)(3)	75-09-2	3	6E-2	B2/4.7E-7	B2/7.5E-3
Naphthalene	(2)	91-20-3	ND	4E-1		
Pesticides	(2)	VARIOUS	VARIOUS	VARIOUS	VARIOUS	VARIOUS
Phenanthrene		85-01-8	DI	DI		
Phenol		108-95-2	ND	6E-1		

TABLE 3-1 (CONTINUED)

CONTAMINANTS OF CONCERN AND TOXICITY DATA
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

Chemical Name	Detection Medium	CAS No.	Reference Dose Inhalation mg/m^3	Reference Dose Oral mg/kg/day	EPA Group/Slope Factor Inhalation (ug/m^3)$^{-1}$	EPA Group/Slope Factor Oral (mg/kg/day)$^{-1}$
ORGANIC CHEMICALS (CONTINUED)						
Polychlorinated Biphenyls		VARIOUS			B2/ND	B2/7.7
Pyrene	(2)	129-00-0	DI	DI		
1,1,2,2-Tetrachloroethane	(3)	79-34-5				
Tetrachloroethene	(1)(2)(3)(4)(5)	127-18-4	ND	1E-2/1E-1		
Toluene	(2)(3)	108-88-3	2	3E-1/4E-1		
1,1,1-Trichloroethane	(1) (3)	71-55-6	1/10	9E-2/9E-1		
1,1,2-Trichloroethane	(3)	79-00-5	ND	4E-3/4E-2	C/1.6E-5	C/5.7E-2
Trichloroethene	(2)(3)(4)	79-01-6			B2/1.7E-2	B2/1.1E-2
Trichlorofluoromethane	(3)	75-69-4	7E-1/7	3E-1/7E-1		
Vinyl Chloride	(4)	75-01-4			A/4.2E-5	A/2.3
Xylol (commercial grade xylene)	(2)	1330-20-7	SEVERAL	SEVERAL		

Notes regarding Detection Medium:

(1) Detected in one or more surface water samples (EPA, 1984; OSDH, 1987).
(2) Detected in one or more surface water samples (EPA, 1984; HKS, 1984 and 1986; OSDH, 1987; Radian, 1984b).
(3) Average discharge sample from IWTP and STP (Tinker AFB, 1987a).
(4) Detected in one or more groundwater samples taken from monitoring well (Tulsa COE, 1988c).
(5) Detected in samples taken during the Final Storm Sewer Investigation (NUS, 1989).

Source of CAS No.: Sax and Lewis, 1987.

Notes regarding Reference Doses, EPA Groups, and Slope Factors:

(1) Reference doses (Rfds) are for noncarcinogenic effects. If the reference dose for chronic effects differs from the one for subchronic effects then the values given are chronic RfD/subchronic RfD.
(2) EPA Group refers to the EPA weight-of-evidence categories for potential carcinogens and are defined (EPA, 1986) as follows:

Group A	Human Carcinogen	Sufficient evidence from epidemiologic studies to support a casual association between exposure and cancer
Group B1	Probable Human Carcinogen	Limited evidence of carcinogenicity in humans from epidemiologic studies

TABLE 3-1 (CONTINUED)

CONTAMINANTS OF CONCERN AND TOXICITY DATA
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

Chemical Name	Detection Medium	CAS No.	Reference Dose		EPA Group/Slope Factor	
			Inhalation mg/m^3	Oral mg/kg/day	Inhalation $(ug/m^3)^{-1}$	Oral $(mg/kg/day)^{-1}$

Notes regarding Reference Doses, EPA Groups, and Slope Factors (continued):

Group B2	Probable Human Carcinogen	Sufficient evidence of carcinogenicity in animals, inadequate evidence of carcinogenicity in humans
Group C	Possible Human Carcinogen	Limited evidence of carcinogenicity in animals
Group D	Not Classified	Inadequate evidence of carcinogenicity in animals
Group E	No Evidence of Carcinogenicity in Humans	No evidence for carcinogenicity in at least two adequate animal tests or in both epidemiologic and animal studies

(3) NA - Not applicable or not available
ND - Not determined
DI - Data Inadequate for Quantitative Risk Assessment
(4) If a particular value is blank for a particular chemical, then no value was available for that chemical.
(5) Reference: EPA, 1989b. The values have been provided for comparison purposes only. The reader should refer to the referenced document for a clearer understanding of the values and the basis for their development.

concern for the Soldier Creek site was reviewed by selected primary data users and reduced to a focused list of preliminary contaminants of concern for the Soldier Creek RI. This reduced list includes the following preliminary contaminants of concern:

- Metals
  - Cadmium
  - Chromium
  - Copper
  - Lead
- Volatile Organics
  - trans-1,2-Dichloroethene
  - Trichloroethene
  - Tetrachloroethene
  - 1,2-Dichlorobenzene
  - 1,4-Dichlorobenzene
- Others
  - Cyanide

These chemicals were selected based on criteria for identification and selection of contaminants of concern (EPA, 1986) and include such factors as chemical toxicity, mobility, persistence, and prevalence as indicated by existing data. These preliminary contaminants of concern for the Soldier Creek site do not represent the comprehensive listing of contaminants of concern for the site. Identification of the preliminary contaminants of concern focuses sampling efforts and analytical requirements toward detection of the above and related compounds in each environmental medium of interest.

3.2 INHERENT TOXICITY

Toxicity information for each of the preliminary contaminants of concern is presented below. The primary purpose of this discussion is to illustrate the hazardous nature of the preliminary contaminants of concern for the Soldier Creek site. An evaluation of toxicity of the contaminants of concern identified by the RI will be conducted for the final risk assessment. The toxicological characteristics of each identified contaminant of concern can then be evaluated in the context of the actual or potential human or environmental exposures.

As discussed in the previous section, the list of preliminary contaminants of concern represents a subset of the total list of chemicals identified during previous investigations at the site. Many of the other chemicals present are equally toxic. Once additional data have been collected to characterize the extent of contamination at the site, an evaluation of the toxic effects associated with potential human or environmental exposures to the contaminants of concern will be conducted.

In addition to the following discussions, reference doses (RfDs) and cancer slope factors for the potential contaminants of concern are included in Table 3-1. The RfDs have been established to characterize risks associated noncarcinogenic effects. Cancer slope factors are the upper 95 percent confidence limits on the slope of the dose-response curve. Cancer slope factors are used to estimate potential carcinogenic risk. As provided in Table 3-1, the RfDs and cancer slope factors are for comparison purposes only. The cited reference should be consulted for more detailed information concerning each value and the references used in developing the values.

3.2.1 Cadmium

Cadmium concentrations were detected in sediment samples from several on-base and off-base portions of Soldier Creek. Short-term exposures to high doses of cadmium are rare, however, acute exposures to high levels of cadmium compounds are highly irritating to the epithelial cells of the gastrointestinal or respiratory tract. Other tissues affected by high doses, especially when given to animals by injection, include the liver and testes. Oral doses ranging from 1,500 to 8,900 mg have proven to be fatal in humans, and an acute oral LD50 of 50 to 300 mg/kg (body weight) has been reported for animals. LD50 is defined as that quantity of a substance necessary to kill 50 percent of exposed populations within a specified time. Fatality from the inhalation of cadmium fumes is primarily the result of marked pulmonary edema. An inhalation LD50 for animals exposed to cadmium oxide at 500 to 4,000 (mg/m^3)-min for 10 to 30 minutes has been reported (ATSDR, 1987a).

Chronic low-level exposure to cadmium by either the oral or inhalation route is of a greater health concern. Long-term exposure may result in kidney damage, leading to the formation of kidney stones and skeletal effects, or lung damage such as fibrosis or emphysema. Cadmium exposure is reported to cause high blood pressure in animals, and affect the liver, testes, immune system, nervous system, and blood in humans and animals. In addition, there exists adequate evidence from animal studies to conclude that chronic inhalation of cadmium chloride is associated with increased frequency of lung tumors. However, there is limited evidence to support that cadmium is carcinogenic to humans (ATSDR, 1987a).

3.2.2 Chromium

Chromium concentrations were detected in sediment and groundwater samples from several on-base and off-base portions of Soldier Creek. Chromium (VI) compounds are more highly toxic than chromium (III) compounds since they are more readily absorbed via all routes of exposure (inhalation, ingestion, direct contact). Acute doses of chromium (VI) compounds may result in kidney damage. Chromium is an essential element for human life; the recommended daily dietary intake for adults ranges from 50 to 200 mg/day. Oral LD50 ranges for humans have been reported to be from 16.7 to 22.5 mg/kg soluble chromium (VI)(ATSDR, 1987b).

Dermal exposure to chromium compounds can also be highly toxic. The reported LD50 for a rabbit exposed to chromium (VI) compounds ranges from 100 to 1,640 mg/kg, and is dependent upon compound administered. At one time, an ointment containing chromium (VI) was used as an antiscorbutic. Application of the ointment resulted in necrosis of the skin, kidney damage, and death (ATSDR, 1987b).

Exposure to chromium compounds for a moderate period of time causes nasal mucosal ulceration and perforation at peak levels of 0.02 to 0.046 mg/m^3. Chromium (VI) exposure can also cause nasal mucosal atrophy and irritation at levels as low as 0.0025 to 0.011 mg/m^3. Chromium (VI) exposure can also cause transient decreases in lung function. Chromium (VI), in animal studies, has been shown to be developmentally and reproductively toxic. In addition, in vivo assays of the genotoxicity of chromium (VI) in nonhuman systems have shown positive results for mutations, chromosome effects, and cell transformations (ATSDR, 1987b).

Long-term, chronic exposure to chromium (VI) compounds in occupational settings can be associated with respiratory tract cancer. Studies have shown that a dose-related increase in lung cancer death rates exist among chromate production workers. Exposure to chromium (VI) compounds has also been shown to affect the immune system, nervous system, and the liver (ATSDR, 1987b).

3.2.3 Copper

Copper was detected in sediment samples from on-base and off-base portions of Soldier Creek and in storm sewer discharges from Building 3001 on Tinker AFB (NUS, 1989). Copper dusts, mists, or fumes can adversely affect the body if they are inhaled or if they come into contact with the eyes or skin. Powdered copper or dusts, or mists of copper salts may cause a feeling of illness similar to the common cold with sensations of chills and stuffiness of the head. Small copper particles may enter the eye and cause irritation, discoloration, and damage (HHS, 1978a). Copper fume causes irritation of the eyes, nose, and throat, and a flu-like illness called metal fume fever. Symptoms of metal fume fever include fever, muscle aches, nausea, chills, dry throat, cough, and weakness. Copper fume may also cause a metallic or sweet taste in the mouth. Reported or prolonged exposure may cause skin irritation or discoloration of the skin or hair (HHS, 1978b).

Inhalation of dusts and mists of copper and copper salts result in irritation of the upper respiratory tract, with occasional ulceration and perforation of the nasal septum. Inhalation of copper and its compounds by animals causes injury to the lungs and liver with hemochromatosis. Access of sheep to salt licks containing 5 to 9 percent copper sulfate caused the sudden onset of hemolytic anemia, icterus, and hemoglobinuria followed by death in a day or two; at necropsy, the liver, kidneys, and spleen showed severe degenerative changes. Workers exposed to copper dusts in concentrations of 0.075 to 0.120 mg/m^3 complained of mild nasal discomfort. Upon ingestion, copper salts act as irritants and cause nausea, vomiting, abdominal pain, hemorrhagic gastritis, and diarrhea. Copper salts splashed in the eye cause conjunctivitis, corneal ulceration, and turbidity, and may produce palpebral edema. Copper particles embedded in the eye result in pronounced foreign-body reaction with characteristic discoloration of ocular tissue (HHS, 1978a).

Copper fume is an irritant to the upper respiratory tract. Exposure of workers to copper concentrations of 1 to 3 mg/m^3 for short periods resulted in altered taste response but no nausea; levels of from 0.02 to 0.4 mg/m^3 produced no complaints. Transient irritation of the eyes has been documented following exposure to a fine dust of oxidation products of copper produced in an electric arc (HHS, 1978b).

3.2.4 Lead

Concentrations of lead were detected in the sediments of on-base and off-base portions of Soldier Creek. Exposure to lead, either orally or by inhalation, causes adverse developmental effects in fetuses and children. Fetal exposure to lead can result in preterm birth, reduced birth weight, and decreased intelligence quotient (IQ). Later in life, exposure can lead to decreased IQ scores, growth reduction in children, and increased blood pressure in middle-age men. The lowest lethal oral dose of lead reported for a dog and guinea pig are 191 and 313 mg/kg, respectively (ATSDR, 1988a).

Lead affects four principal target organs or systems: the central nervous system (CNS), the peripheral nervous system, the kidney, and the hematopoietic system (Cassarett and Doull, 1980). Several factors can influence the toxicity of lead on these systems, including the chemical form of lead encountered and composition of the diet.

Lead's impact on the CNS ranges from lead neuropathy to subtle behavioral and neurological changes. Lead neuropathy is characterized by symptoms varying from dullness, restlessness, irritability, headache, muscular tremor to convulsions, coma, and death. Lead neuropathy is associated with chronic or subchronic exposures to high lead levels (Cassarett and Doull, 1980).

The effect of lead on the peripheral nervous system is characterized by demyelination and degeneration of peripheral nerves which results in the slowing of nerve conduction velocity (Cassarett and Doull, 1980). At high lead exposure levels, this damage to the peripheral nerves can be manifested as weakness in the extensor muscles or "lead palsy." Reduction in nerve conduction velocity has also been detected at very low levels of lead exposure but the impact on muscular function has not always been detectable.

Two categories of kidney toxicity have been associated with lead exposure. The first category is characterized by damage to the proximal tubules and is reversible with treatment. The second category, appears to be associated with longer term exposures and involves a progressive disease characterized by interstitial fibrosis, sclerosis of kidney vessels, and glomerular atrophy which may continue even after exposures have ended (Cassarett and Doull, 1980).

Other toxic effects associated with lead include anemia and carcinogenicity. Studies of rats given orally administered lead acetate at 25 mg/kg/day (500 ppm lead) for 2 years showed that the rats had increased incidences of kidney tumors (ATSDR, 1988a).

3.2.5 Trans-1,2-Dichloroethene

Trans-1,2-Dichloroethene was identified as a chemical of concern in the groundwater beneath Tinker AFB during the risk assessment for Building 3001 (Tulsa COE, 1988b). Trans-1,2-DCE is included as a preliminary a contaminant of concern for the Soldier Creek site due to potential for migration of the chemical from the perched aquifer beneath Building 3001 to Soldier Creek via recharge. Short-term exposure of t-1,2-DCE vapor is narcotic and irritating to the mucous membrane in humans. The lowest concentration of vapor causing detrimental effects in humans is reported to be 4,800 mg/m^3 for a 10 minute exposure period. Exposure at these limits causes behavioral problems including excessive sleep, hallucinations, and distorted perceptions. The oral LD50 for mice is reported to be 2,122 mg/kg with somnolence and ataxia resulting before death occurs. A study that placed a sample of t-1,2-DCE in the intraperitoneal cavities of mice yielded an LD50 of 4,019 mg/kg (HHS, 1987).

Intermediate exposure of animals to t-1,2-DCE vapors has been shown to cause fatty changes in the liver and minor changes in the lungs following exposure at 200 ppm for 16 weeks (EPA, 1984). A microsomal assay conducted on common yeast cultures showed that t-1,2-DCE was a teratogen, a mutagen, and a carcinogen to the yeast cells at a concentration of 80 mmole/l (HHS,1987).

3.2.6 Trichloroethene

Trichloroethene (TCE) concentrations were detected in the groundwater samples taken from the aquifer located beneath the IWTP and from on-base and off-base sediment samples of Soldier Creek. TCE affects the human CNS when breathed in air at high concentrations, causing effects such as dizziness, headache, slowed reaction time, sleepiness, and facial numbness. Eye, nose, and throat irritation occur at similar concentrations, and the effects are more pronounced after longer exposures. A lethal inhalation dose of 2,900 ppm has been reported for humans. Four-hour inhalation LD50s of 12,400 ppm for rats and 8,450 ppm for mice have been reported. Inhalation studies with mice and rats indicate that TCE is fetotoxic, but not teratogenic (ATSDR, 1988b).

Oral and inhalation exposure of animals to high levels of TCE produced liver and kidney damage, effects on the immune system and blood, and cancer of the liver, kidney, and lung. Oral LD50s of 7,330 mg/kg for rabbits and 5680 mg/kg for dogs have been reported. A single dose of 7,000 mg/kg of TCE is known to be lethal to humans. Chronic oral exposure to TCE produces increased incidences of hepatocellular carcinomas in mice and marginally significant increased incidences of renal adenocarcinomas in rats (ATSDR, 1988b).

3.2.7 Tetrachloroethene

Groundwater samples from the perched aquifer beneath the IWTP contained concentrations of tetrachlorethene (PCE) greater than the allowable state water quality standards. As with t-1,2-DCE, PCE is included as a preliminary contaminant of concern for the Soldier Creek site due to the potential for migration of the chemical from the perched aquifer to Soldier Creek via recharge.

Single exposures of high concentrations of PCE in air can affect the human CNS causing dizziness, headache, sleepiness, confusion, nausea, difficulty in speaking and walking, unconsciousness, and even death. The threshold concentrations for adverse effects are reported to be as low as 100 to 200 ppm for a 5.5 to 7 hour exposure. The 14-day LD50s for male and female rats are reported to be 3,835 and 3,005 mg/kg, respectively. At one time, PCE was orally administered to humans as an antihelminthic at doses of 60 to 86 mg/kg (2.8 to 4.0 ml). Ingestion of 60 to 80 mg/kg of PCE produces effects similar to drinking alcohol (ATSDR, 1987c).

The consequences of long-term exposure by breathing lower levels (less than 100 ppm) or ingesting low levels of PCE found in water supplies are unclear, however, animal studies suggest the potential for liver and kidney damage, developmental effects on fetuses, toxicity to pregnant animals, liver cancer, and leukemia. PCE also affects the CNS of mice at concentrations as low as 60 ppm. Long-term exposure to PCE vapors has been reported to increase the incidences of mononuclear cell leukemia in both male and female rats exposed to 200 or 400 ppm PCE. In addition, for male and female mice treated by gavage 5 days per week for 78 weeks with 300 to 550 mg/kg/day time weighted average doses of PCE, it was reported that increased incidences of heptacellular carcinomas occurred in both the male and female mice. Based on animal evidence, experts presume that PCE is carcinogenic in humans (ATSDR, 1987c).

3.2.8 1,2-Dichlorobenzene

1,2-Dichlorobenzene has been detected in groundwater samples from the perched water table beneath the IWTP in the northeast portion of Tinker AFB. It is not known at this time whether or not this aquifer is hydrologically connected to the perched aquifer beneath Building 3001.

Short-term exposure to 1,2-dichlorobenzene vapor may cause irritation of the upper respiratory tract and eyes. Higher concentrations may cause drowsiness, unconsciousness, or even death. Dermal contact with 1,2-dichlorobenzene may result in burning of the skin and eyes, with permanent tissue damage. Prolonged dermal exposure can result in sensitization dermititis, and pure liquid remaining on skin may produce blistering. Prolonged or repeated inhalation of high concentrations of vapor may cause liver or kidney damage (HHS, 1978c).

Inhalation of vapor at high concentrations is highly toxic to the liver and kidneys of animals. Inhalation of 1,2-dichlorobenzene vapors was fatal to rats exposed at 977 ppm for 7 hours, but the rats survived when exposed for only 2 hours. At exposure concentrations of 535 ppm for 3 hours, animals incurred marked centrolobular necrosis of the liver, as well as cloudy swelling of the tubular epithelium of the kidneys. Animals exposed to 93 ppm for 7 hours per day showed no adverse effects. Daily occupational exposure of workers at 15 ppm did not result in any adverse impacts to worker health (HHS, 1978c).

3.2.9 1,4-Dichlorobenzene

Groundwater samples from the perched aquifer beneath the IWTP contained concentrations of 1,4-dichlorobenzene greater than the allowable state water quality standards. Inhalation exposure to 1,4-dichlorobenzene in concentrations associated with potential occupational exposure can cause headaches and dizziness. Exposure levels that could result in death would only be associated with an odor so intense and intolerable, that it would serve as a warning sign. A study of the oral lethality of 1,4-dichlorobenzene to rats and guinea pigs showed that a single dose of 4,000 and 2,800 mg/kg, respectively, resulted in the death of 100 percent of the test specimens, while doses of 1,000 and 1,600 mg/kg did not result in death (ATSDR, 1987d).

1,4-dichlorobenzene is toxic to the CNS, the liver, and the kidneys. Short-term (20 to 30 minutes) inhalation exposure of animals to high concentrations (16,000 ppm) resulted in CNS depression, muscle twitching, tremors, and nystagmus. Hepatic effects include liver degeneration, necrosis, porphyria, and enzyme level changes. These effects have been reported in animal studies by both oral and inhalation exposure routes for short- and long-term exposures. 1,4-dichlorobenzene is also reported to be developmentally toxic to rats gavaged with 500 mg/kg/day during days 6 through 15 of gestation. 1,4-dichlorobenzene was also found to be an oral carcinogen in both rats and mice continuously fed a diet containing the chemical for two years. In the same study, it was reported that the incidences of hepatocellular carcinomas in high-dose males and the incidences of hepatocellular adenomas in both high- and low-dose males and in high-dose females were increased (ATSDR, 1987d).

3.2.10 Cyanide

Cyanide concentrations exceeding state water quality standards were reported in surface water samples from Soldier Creek (EPA, 1984b). Brief exposure to high levels of cyanide compounds or vapors adversely affects the human CNS, the respiratory and cardiovascular systems. Short-term exposure to extreme levels can result in coma or death. Exposure at lower cyanide levels can lead to rapid, deep breathing, shortness of breath, convulsions, or loss of consciousness. However, the effects are reversible over time since cyanide does not remain in the body. Inhalation of hydrogen cyanide gas is immediately fatal to humans at concentrations of 270 ppm, fatal after 0.5 to 1 hour at concentrations of 110 ppm, and is slightly toxic to humans when exposed for several hours at concentrations of 18 ppm. The human LD50 for cyanide is reported to be 1.52 mg/kg (body weight). Dermal contact with dust from cyanide suits causes skin irritation and ulcerations (ATSDR, 1988c).

Long-term exposure to cyanide can be neurotoxic, resulting in deafness, visual problems, or loss of muscle coordination; and thyrotoxic, leading to cretinism or formation of an enlarged thyroid gland. A study showed that fumigation workers who had experienced episodes of acute hydrogen cyanide intoxication, showed EKG abnormalities when tested. Another study showed that 56 percent of workers occupationally exposed to cyanide at concentrations of 6.4 to 10.4 ppm for 5 to 15 years had enlarged thyroids. Gavage of pregnant rats to a cyanide-containing diet resulted in fetotoxicity. Cyanide is not a proven human or animal carcinogen (ATSDR, 1988c).

3.3 POTENTIAL MIGRATION PATHWAYS

A migration pathway is defined as the route by which contaminants of concern are transported from a source to a potential receptor (EPA, 1986). The health risks associated with the identified contaminants of concern occur when the potential for exposure to humans exists. The exposure potential increases when:

- Activities bring receptors into contact with the source of contamination.
- Contaminants of concern migrate via a pathway to receptor exposure points.

The potential for contaminants to migrate to or from the Soldier Creek site is dependent upon the physical and chemical properties of the contaminants, the environmental processes affecting them, and the media through which the contaminants are migrating. Three potential migration pathways are the (1) surface water/sediment route, (2) groundwater route, and (3) air route.

3.3.1 Surface Water/Sediment

Contaminants could be transported into Soldier Creek via direct discharge from IWTP and STP outfalls into East Soldier Creek or storm sewers into East and West Soldier Creeks, runoff from on-base and off-base spill sources, and recharge of the stream at various points from contaminated groundwater. Existing data does not permit evaluation of the extent to which migration has occurred.

East Soldier Creek is fed primarily by effluent discharge from IWTP and STP, and by surface runoff, storm drains, and recharge of perched groundwater. The east side of Building 3001 drains to the creek. In addition, East Soldier Creek potentially recharges the top of the regional aquifer. West Soldier Creek is primarily a drainage ditch which receives surface runoff and cooling waters from Building 3001. West Soldier Creek is known to recharge the perched aquifer which lies under Building 3001. Improper connections between industrial wastewater lines and storm drains have in the past caused the discharge of industrial wastes into both East and West Soldier Creeks. The presence of hazardous materials in the storm water sewer, and subsequently the creek, could also be the result of past washing down or possible dumping of waste liquids or solvents into the drains. The majority of the discharge points to the creek have now been closed off (Tulsa COE, 1988b).

Once in the creek, volatile contaminants within the surface water column could escape to the atmosphere. The transportable sediment fraction contaminated with VOCs, metals, and other contaminants could be moved downstream by increases in stream velocity. During periods of heavy rains, the potential for contaminant migration would be greater since contaminated material could be more easily transported downstream. In addition, an increase in surface runoff could result in increased leaching of contaminants to the surface water from contaminated surface soils.

3.3.2 Groundwater

Existing information suggests that groundwater is a potential migration pathway since the perched aquifer is recharged by West Soldier Creek at various points. Percolation of surface water and precipitation through contaminated sediments could also result in the migration of contaminants into the groundwater system. In addition, if the perched aquifer beneath Building 3001 is hydrologically connected to the perched aquifer situated beneath the northeast portion of the site, the potential exists for contaminants to migrate within the groundwater beneath the base and be transported to the surface water and sediment of Soldier Creek via recharge. Previous investigations show that the perched water table below the IWTP is contaminated with a different array of contaminants than the aquifer below Building 3001 (Tulsa COE, 1988b).

3.3.3 Air

Volatilization of certain organic compounds may occur in Soldier Creek if VOCs reach the water column and the stream is flowing at a rapid enough rate for volatilization to occur. Metals and less volatile organic chemicals (i.e. BNAs), however, will tend to stay adsorbed onto sediment and soil particles, and will not volatilize into the atmosphere. Based on review of existing data, it does not appear that exposure to VOCs via volatilization from Soldier Creek surface water is a significant exposure pathway.

Migration of contaminants to the air from contaminated surface soils and sediments may also be considered. At this time, however, there is no data to suggest that there may be exposure to on-base or off-base residents, workers, or visitors, by airborne contaminants from the Soldier Creek site. If intrusive activities, including but not limited to excavation of contaminated surface or subsurface materials, is required, potential exposure to contaminants via the air pathway shall be evaluated at that time.

3.4 POTENTIAL RECEPTORS AND ROUTES OF EXPOSURE

The risks associated with contaminant transport via the migration pathways can be assessed after determination of the potential receptors for the site. Potential receptors are defined as the human or environmental populations that could be exposed to contaminants of concern (EPA, 1986). Examples of current and future potential human receptors for the Soldier Creek site include, but are not limited to:

- Residents, workers, and visitors of Tinker AFB.
- Off-base human populations using a public or private water supply which could be adversely affected by the contaminants of concern.

Examples of environmental receptors of the contamination from Soldier Creek include:

- Aquatic populations of Soldier Creek.
- Wildlife drinking Soldier Creek surface water.

Evaluation of the potential adverse impacts of Soldier Creek on public health and the environment requires an understanding of the nature and degree of human and environmental receptor exposure to site contaminants. The conditions of exposure help determine the actual doses received by the organism and, therefore, the type of toxic effect that may be expected.

This section presents the potential scenarios for human or biotic exposure to contaminants associated with the Soldier Creek site. The scenarios, listed in Tables 3-2 and 3-3, identify the activities which make exposure to contaminants of concern possible, the route (oral, inhalation, dermal) by which the exposure might occur, and the population potentially affected. The purpose of these scenarios is to identify additional information which needs to be collected before assessment of the significance of the exposures can proceed.

These scenarios are largely conceptual. However, they are based on the contaminant transport pathways discussed in the previous section and

TABLE 3-2

POTENTIAL HUMAN EXPOSURE SCENARIOS
TINKER AFB -SOLDIER CREEK RI/FS
RI WORKPLAN

MEDIUM	SCENARIO	POPULATION-AT-RISK
Sediment	Direct contact with contaminated Soldier Creek sediment.	Tinker AFB residents, workers, and visitors, as well as off-base residents.
Surface Water	Ingestion of and dermal contact with contaminated surface water (on-base and off-base).	Tinker AFB residents, workers, and visitors. Off-base residents.
	Ingestion of contaminated fish from Soldier Creek.	Recreational fishermen and their families.
Groundwater	Ingestion of contaminated groundwater from private and municipal water supply wells.	Town populations and private residences using municipal and private wells affected by the site.
	Inhalation of volatile organic contaminants released during showers or other household uses of groundwater.	Town populations and private residences using wells affected by the site.

TABLE 3-3

POTENTIAL ENVIRONMENTAL EXPOSURE SCENARIOS
TINKER AFB -SOLDIER CREEK RI/FS
RI WORKPLAN

MEDIUM	SCENARIO	POPULATION-AT-RISK
Sediment	Direct contact with or ingestion of contaminated sediment.	Burrowing mammals and insects. Aquatic populations (frogs, turtles, etc.).
	Ingestion of contaminated organisms.	Burrowing mammals and birds. Aquatic populations.
Surface Water	Ingestion of contaminated Soldier Creek surface water.	Wildlife drinking from Soldier Creek.
	Ingestion of contaminated fish from Soldier Creek.	Raccoons, ducks, and other avian fisheaters.

activities that are known to have been associated with the site. The exposure scenarios are subject to change pending additional site information.

3.5 RISK ASSESSMENT DATA GAPS

This section of the preliminary risk assessment presents the additional data to be collected during the remedial investigation to allow a quantitative human risk assessment and a qualitative environmental risk assessment to be conducted. A summary of the risk assessment data gaps is presented in Table 3-4. Collection of additional data to allow the following items to be evaluated is of particular importance:

- Determination of receptor populations potentially exposed to contamination within Soldier Creek.
- Characterization, by medium, of the nature and extent of contamination in Soldier Creek.

These data requirements are addressed in the design of the remedial investigation, and are subject to change pending additional site information.

TABLE 3-4

SUMMARY OF RISK ASSESSMENT DATA GAPS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

CATEGORY	INFORMATION MISSING
MIGRATION PATHWAY	
Sediment	o Depth of contamination within stream sediment.
	o Downstream extent of contamination within Soldier Creek which may be attributable to Tinker AFB.
	o Sediment particle size fraction(s) which may be transport mechanism(s) for adsorbed contaminants
Surface Water	o Rate and volume of flow at specific locations along Soldier Creek and major tributaries from Tinker AFB.
	o Potential losing and gaining segments of Soldier Creek and major tributaries from Tinker AFB.
	o Contaminant concentrations within Soldier Creek water column.
	o Off-base inflow points to Soldier Creek and major tributaries from Tinker AFB which may contribute to flow and/or contamination of the stream.
Groundwater	o Water levels in selected existing off-base wells located within the Soldier Creek drainage basin.
	o Contaminant concentrations of groundwater collected from selected existing off-base wells.
	o Hydrological relationship of perched aquifers.

TABLE 3-4 (Continued)

SUMMARY OF RISK ASSESSMENT DATA GAPS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

CATEGORY	INFORMATION MISSING
RECEPTOR	
Human	o Current and potential future land use surrounding Soldier Creek.
	o Demographics for the Soldier Creek site vicinity.
	o Municipal/recreational use of Soldier Creek.
Biotic	o Aquatic Biota in Soldier Creek.
	o Endangered species in Soldier Creek site vicinity.
	o Terrestial and avian wildlife use of Soldier Creek.

4.0 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

Section 121(d) of CERCLA, as amended by SARA, states that any remedial action selected for a site must, at a minimum, attain a degree of cleanup which assures protection of human health and the environment. In addition, at the completion of the remedial action, a level or standard of control under federal or state environmental law that meets legally applicable or relevant and appropriate requirements (ARARs) must be attained for any hazardous substance, contaminant, or pollutant that remains onsite.

EPA's Interim Guidance on Compliance with Applicable or Relevant and Appropriate Requirements (EPA, 1986) and CERCLA Compliance with Other Laws Manual, Parts I and II, Interim Final (EPA, 1988 and 1989c) establish how requirements of federal and state laws are generally identified and applied to remedial actions at hazardous waste sites. ARARs are identified by applying a two-tier test to first determine if the requirement is applicable, and second, if it is not applicable, to determine if it is relevant and appropriate. The guidances provide the following definitions of "applicable" and "relevant and appropriate" requirements:

- Applicable requirements are "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant or contaminant, remedial action, location, or other circumstances at a CERCLA site" (EPA, 1988).

- Relevant and appropriate requirements are "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. However, in some circumstances, a requirement may be relevant but not appropriate for the site-specific situation" (EPA, 1988).

The judgment as to the relevance and appropriateness of a requirement can be made based on several factors, including the type of the remedial action contemplated, the hazardous substances in question, or the physical characteristics of the site. Only portions of requirements may be relevant and appropriate for a remedial action; however, any requirement or portion thereof that is determined to be relevant and appropriate must be fulfilled to the same degree as if it were applicable.

There are three types of ARARs. Chemical-specific ARARs establish health or risk-based concentration limits for the various environmental media. The chemical-specific ARARs may set a level of cleanup or discharge. Location-specific ARARs set limitations on remedial activities as a result of the site characteristics. These can include restrictions for activities performed in wetlands, flood plains, and historical sites. Action-specific ARARs establish controls on the remedial activities that are a part of the remedial solution.

- Chemical-Specific ARARs
  - Chemical-specific ARARs (1) set levels that are considered protective of human health and the environment for the contaminants of concern in the designated media or (2) indicate an acceptable level of discharge, if discharge occurs as part of a remedial activity. If a contaminant has more than one requirement that is applicable or relevant and appropriate, the most stringent one generally requires compliance.

- Location-Specific ARARs
  - Location-specific ARARs establish restrictions on concentrations of hazardous substances or on conducting activities solely because they are in specific locations such as wetlands, flood plains, historical places, and sensitive habitats.

- Action-Specific ARARs
  - Action-specific requirements are not established for a specific contaminant but rather by the activities that are selected to accomplish a remedy. They may establish performance levels, actions, or technologies as well as specific levels for discharged or residual contaminants.

Tables 4-1, 4-2, and 4-3 present the preliminary list of potential chemical-specific, location-specific, and action-specific ARARs, respectively, for the Soldier Creek site. Since ARAR selection is a dynamic process and subject to change, Table 4-1 lists only the ARARs selected based on the currently identified contaminants of concern and available site information. The list of ARARs to be considered may increase as further information pertaining to site contaminants and conditions is gathered.

TABLE 4-1

POTENTIAL CHEMICAL-SPECIFIC ARARS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

Standard, Requirement, Criteria, or Limitation	Description
Federal Chemical-Specific ARARs	
Safe Drinking Water Act (40 USC Section 300)	
National Primary Drinking Water Standards (40 CFR Part 141)	Establishes health-based standards for public water systems (maximum contaminant levels).
National Secondary Drinking Water Standards (40 CFR Part 143)	Establishes welfare-based standards for public water systems (secondary maximum contaminant levels).
Maximum Contaminant Level Goals (Pub. Law No. 99-339, 100 Statute 642, 1986)	Establishes drinking water quality goals set at levels of no known or anticipated adverse health effects, with an adequate margin of safety.
Clean Water Act (33 USC Section 1251-1376)	
Water Quality Criteria (40 CFR Part 13)	Sets criteria for water quality based on toxicity to aquatic organisms and human health.
EPA Regulations on Criteria and Standards for NPDES (40 CFR 125)	Establishes treatment requirements, permit issuance guidelines, compliance variances, and alternative effluent limitations.
Solid Waste Disposal Act (40 USC Section 6901-6987)	
Identification and Listing of Hazardous Waste (40 CFR Part 261)	Defines those solid wastes which are subject to regulation as hazardous waste under 40 CFR Parts 262-265 and Parts 124, 270, and 271.
Land Disposal Restrictions (40 CFR Part 268)	Establishes a timetable for restriction of burial of wastes and other hazardous materials.
Clean Air Act (42 USC Section 7401-7642)	
National Primary and Secondary Ambient Air Quality Standards (40 CFR Part 50)	Establishes standards for ambient air quality to protect public health and welfare (including standards for particulate matter and lead).

TABLE 4-1 (CONTINUED)

POTENTIAL CHEMICAL-SPECIFIC ARARS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

Standard, Requirement, Criteria, or Limitation	Description
Federal Chemical-Specific ARARs (Continued)	
Clean Air Act (Continued) (42 USC Section 7401-7642)	
EPA Regulations on National Emission Standards for Hazardous Air Pollutants (40 CFR Part 61)	Establishes emission standards for specific hazardous contaminants for stationary facilities.
EPA Regulations for Assessment and Collection of Non-compliance Penalties. (40 CFR Part 66)	Sets forth procedures by which EPA will administer a non-compliance penalty as provided by Section 120 of the Clean Air Act.
EPA Guidelines Establishing Test Procedures for the Analysis of Pollutants (40 CFR Part 136)	EPA regulations on test procedures for the analysis of pollutants.
EPA Designation, Reportable Quantities, and Notification (40 CFR Part 302)	Designation of reportable quantities and notification requirements for hazardous substances under CERCLA
Oklahoma Chemical-Specific ARARs	
Oklahoma Water Quality Standards (82 O.S. Supp. 1988, Sections 926.1-926.13)	Establishes numerical water quality criteria for groundwater and surface waters based on use classifications. The uses designated for Soldier Creek include agricultural, industrial and manufacturing process and cooling water, aesthetics, habitat limited fishery, and secondary body contact recreation.
Oklahoma Air Pollution Regulations (Oklahoma State Department of Health)	Establishes quantitative limits for air emissions from specific sources and of specific contaminants, including organic materials, VOCs, solvents, and other hazardous and toxic air pollutants.

TABLE 4-2

POTENTIAL LOCATION-SPECIFIC ARARS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

Standard, Requirement, Criteria, or Limitation	Description
Federal Location-Specific ARARs	
National Historic Preservation Act (16 CFR Part 470, et seq.)	Requires Federal agencies to take into account the effect of any Federally-assisted undertaking or licensing on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register of Historic Places.
Archaeological and Historic Preservation Act (16 USC Section 469, 36 CFR Part 65)	Establishes procedures to provide for preservation of historical and archeological data which might be destroyed through alteration of terrain as a result of a Federal construction project or a Federally licensed activity or program.
Historic Sites, Buildings and Antiquities Act (16 USC Section 461-467, 40 CFR Section 6.301(a))	Requires Federal agencies to consider the existence and location of landmarks on the National Registry of Natural Landmarks to avoid undesirable impacts on such landmarks.
Fish Wildlife Coordination Act (16 USC Section 661-666)	Requires consultation when Federal department or agency proposes or authorizes any modification of any stream or other water body and adequate provision for protection of fish and wildlife resources.
Endangered Species Act (16 USC 1531 et seq., 50 CFR Part 200, 50 CFR Part 402)	Requires action to conserve endangered species within critical habitats upon which endangered species depend, includes consultation with Department of Interior
Rivers and Harbors Act of 1899 (33 USC Section 403)	
Executive Order on Flood Plain Management (Executive Order No. 11,988)	Requires Federal agencies to evaluate the potential effects of actions they may take in a flood plain to avoid, to the extent possible, the adverse impacts associated with direct and indirect development of a flood plain.
Scenic River Act (16 USC Section 1271 et seq. 40 CFR 6.302(e))	Prohibits adverse effects on scenic rivers.

Standard, Requirement, Criteria, or Limitation	Description
Federal Location-Specific ARARs (Continued)	
Clean Water Act (33 USC Section 1251 et seq.)	
Dredge or Fill Requirements Section 404 (40 CFR Parts 230 and 231)	Requires permits for discharge of dredged or fill material into navigable waters.
Fish and Wildlife Service List of Endangered Species and Threatened Wildlife and Plants (50 CFR Section 17.11)	Provides a list of endangered species and threatened wildlife and plants.
Federal Water Pollution Control Act (40 CFR Part 231)	EPA regulations on disposal site location determination.

TABLE 4-3

POTENTIAL ACTION-SPECIFIC ARARS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

Standard, Requirement, Criteria, or Limitation	Description
Federal Action-Specific ARARs	
Resource Conservation and Recovery Act of 1976 (42 USC Sections 6901-6987)	
Criteria for Classification of Solid Waste Disposal Facilities and Practices (40 CFR Part 257)	Establishes criteria for use in determining which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on health, and thereby constitute prohibited open dumps.
Hazardous Waste Management Systems General (40 CFR Part 260)	Establishes procedures and criteria for modification or revocation of any provision in 40 CFR Parts 260-265 and 268.
Identification and Listing of Hazardous Wastes (40 CFR Part 261)	Defines those solid wastes which are subject to regulation as hazardous wastes under 40 CFR Parts 262-265 and Parts 124, 270, and 271.
Standards Applicable to Generators of Hazardous Waste (40 CFR Part 262)	Establishes standards for generators of hazardous waste.
Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR Part 264)	Establishes minimum national standards that define the acceptable management of hazardous waste for owners and operators of facilities that treat, store, or dispose hazardous waste.
Interim Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR Part 265)	Establishes minimum national standards that define the acceptable management of hazardous waste during the period of interim status and until certification of final closure or, if the facility is subject to post-closure requirements, until post-closure responsibilities are fulfilled.
Land Disposal Restrictions (40 CFR Part 268)	Establishes a timetable for restriction of land disposal of wastes and other hazardous materials.

TABLE 4-3 (Continued)

POTENTIAL ACTION-SPECIFIC ARARS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

Standard, Requirement, Criteria, or Limitation	Description
Federal Action-Specific ARARs (Continued)	
Hazardous Waste Permit Program (40 CFR Part 270)	Establishes provisions covering basic EPA permitting requirements.
Occupational Safety and Health Act (29 USC Sections 651-678)	Regulates worker health and safety.
Clean Water Act (33 USC Sections 1251-1376)	
National Pollutant Discharge Elimination System (NPDES) (40 CFR Parts 122, 125)	Requires permits for the discharge of pollutants from any point source into waters of the United States.
National Pretreatment Standards (40 CFR Part 403)	Sets standards to control pollutants that pass through or interfere with treatment.
Toxic Pollutant Effluent Standards (40 CFR Part 129)	Establishes effluent standards or prohibitions for toxic pollutants, such as, aldrin/dieldrin, DDT, endrin, toxaphene, benzidine, PCBs.
Clean Air Act (42 USC Sections 7401-7642)	
National Ambient Air Quality Standards (40 CFR 50, 53 and 61)	Treatment technology standards for emissions to air from: incinerators, surface impoundments, waste piles, landfills, and fugitive emissions.
Hazardous Materials Transportation Act (49 USC Sect. 1801-1813)	
Hazardous Materials Transportation Regulations (49 CFR Parts 107, 171-177)	Regulates transportation of hazardous materials.

POTENTIAL ACTION-SPECIFIC ARARS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

Standard, Requirement, Criteria, or Limitation	Description
Oklahoma Action-Specific ARARs	
Oklahoma Pollution Remedies Law (82 0.S.)	
Oklahoma Water Quality Standards (82 0.S. Supp. 1988, Sections 926.1-926.13)	Designed to enhance the quality of Oklahoma's waters; to protect their beneficial uses; and to aid in the prevention, control, and abatement of water pollution in the State of Oklahoma. Beneficial uses for Soldier Creek includ agriculture, industrial and manufacturing process and cooling water, aesthetics, habitat limited fishery and secondary body contact recreation.
Oklahoma Pollution Control Coordinating Act of 1968 (82 0.S. Sections 931-943)	Provides for the adoption and promulgation of rules, regulations, and standards, and enforcement of the enacted laws.
Oklahoma Water Pollution Control Laws (63 0.S.)	Regulations pertaining to discharge of wastewaters and sewage, sanitary sewers, and water reservoirs.
Oklahoma Clean Air Act (63 0.S.)	Regulates air emissions so as to achieve and maintain atmospheric purity necessary for the protection and enjoyment of human, plant, or animal life.
Oklahoma Air Pollution Regulations (Oklahoma State Department of Health)	Regulations and standards for air emissions from stationary sources including permitting, prohibitions, control of emissions, and acceptable emission levels.

5.0 SITE REMEDIAL ACTION OBJECTIVES AND PRELIMINARY IDENTIFICATION OF REMEDIAL ALTERNATIVES

The preliminary identification of remedial action objectives and remedial alternatives is used during the remedial investigation workplanning process to identify and scope the collection of data needed to develop and evaluate mitigation measures for the site. Remedial action objectives were developed in concert with the Tinker AFB - Soldier Creek RI/FS project objectives, the RI objectives, and the risk assessment objectives during the DQO development process (Section 2.0 of the DQO Report). Together, these objectives provide the framework upon which the RI Workplan is developed to provide a scope for the field work to gather data which allows site characterization and provides the basis for the site feasibility study and subsequent remedial design/ remedial action.

The following sections present the remedial action objectives and preliminary remedial alternatives for the Soldier Creek site by medium.

5.1 REMEDIAL ACTION OBJECTIVES

Remedial action objectives are goals which, when fulfilled, reduce the threat of receptor exposure to contaminants of concern. Once defined, remedial objectives serve as the basis of workplanning efforts by focusing the direction of the project toward consideration of remediation activities which: (1) eliminate the source(s) of contamination, (2) mitigate contaminant transport via migration pathways, and (3) prevent receptor exposure to the contaminants at their source. Remedial objectives provide the foundation for the development of preliminary remedial alternatives and subsequent remedial investigation activities. They become the basis for the effectiveness assessment in the remedial alternatives evaluation activity during the feasibility study.

The establishment of the remedial action objectives for the Soldier Creek site began with the identification of preliminary contaminants of concern, contaminant migration pathways and potential receptors, all of which are defined in the Preliminary Assessment of Risks (Section 3.0) and the DQO Report. The common theme of the remedial action objectives is to prevent contact between the receptors (populations at risk) and the contaminant sources. Remedial action objectives were developed for the following site media: (1) sediments, (2) surface water, and (3) groundwater. The potential receptors for each media and the corresponding remedial action objectives are discussed below. It should be noted that these source-specific remedial action objectives are dynamic and may be modified throughout the RI/FS process as new data becomes available.

5.1.1 <u>Sediments</u>

The sediments in Soldier Creek could be contaminated as a result of past and current storm water and industrial discharges to the creek from Tinker AFB. In addition, sediments at some stream locations may be contaminated via recharge of contaminated groundwater from the perched water system. The contaminants may leach from the sediments and contaminate the perched groundwater system in areas where the creek recharges this system. Contaminated sediments could become resuspended in the surface water and deposited further downstream. Receptors and remedial action objectives applicable to the sediments include the following:

- Receptors
  - Humans or animals coming in contact with contaminated sediment (on-base and off-base).
  - Humans or animals ingesting contaminated sediment (on-base and off-base).
  - Humans or animals ingesting game animals that have been contaminated while on-base or off-base.
- Remedial Action Objectives
  - Prevent human and animal contact with contaminated sediment (on-base and off-base).
  - Prevent contaminant release into surface water.

- Prevent contaminant release into groundwater.

- Prevent contaminant transport from distributing contaminants further downstream.

5.1.2 Surface Water

The surface water associated with Soldier Creek could be contaminated as a result of storm water and industrial discharge and surface runoff from Tinker AFB, and recharge from the contaminated perched groundwater system. Contaminants in the surface water could adhere to sediment particles. Contaminated surface water could recharge the perched groundwater system. Receptors and remedial action objectives applicable to the surface water include the following:

o Receptors

  - Humans or animals coming in contact with contaminated surface water (on-base and off-base).

  - Humans or animals ingesting contaminated surface water (on-base and off-base).

o Remedial Action Objectives

  - Prevent human or animal contact with contaminated surface water (on-base and off-base).

  - Prevent degradation of downstream surface water by on-base sources of surface water contamination.

  - Prevent degradation of groundwater via recharge by contaminated surface water.

5.1.3 Groundwater

At least one perched aquifer exists beneath Tinker AFB. The perched aquifer has become contaminated by past disposal practices at Tinker AFB. The contaminated perched aquifer could recharge into Soldier Creek, thereby contaminating the surface water. The perched aquifer could be used as a nonpotable water supply (e.g. gardening, irrigation) by off-base users. The perched aquifer could be a source of contamination for the top of the regional aquifer zone which may be a potable water supply source for off-base users. Receptors and remedial action objectives applicable to the groundwater include the following:

- Receptors
  - Humans coming in contact with contaminated groundwater (off-base).
  - Humans ingesting contaminated groundwater (off-base).
  - Humans inhaling contaminants via use of contaminated groundwater (off-base).
- Remedial Action Objectives
  - Prevent human contact with contaminated groundwater (off-base).
  - Prevent degradation of surface water via recharge by contaminated groundwater.

5.2 PRELIMINARY IDENTIFICATION OF REMEDIAL ALTERNATIVES

In planning the remedial investigation, it is important to consider the potential remedial alternatives that will most likely be developed and evaluated during the feasibility study. Certain data will be required to screen the alternatives on the basis of effectiveness, implementability, and cost. In order to provide a basis for evaluating data needs associated with developing and evaluating remedial alternatives, a preliminary list of potential alternatives was developed by combining remedial technologies applicable to the site.

During the feasibility study process, remedial alternatives are developed for the identified site remedial action objectives according to a multi-phased process. The following consecutive steps are generally followed in developing and evaluating remedial alternatives:

- Identification of the areas of contaminated media, and the volume of material requiring remediation.

- o Identification of general response actions that address the remedial action objectives.

- o Identification of remedial technologies and process options for each general response action.

- o Screening of the remedial technologies and process options on the basis of their technical implementability, effectiveness, and cost.

- o Development of remedial alternatives that meet the remedial action objectives by combining technologies and process options which have passed screening.

- o Completion of the initial screening of the developed alternatives on the basis of implementability, effectiveness, and cost.

- o Completion of a detailed evaluation and comparison of the alternatives that remain after the initial screening.

During the scoping stage of the remedial investigation, this process cannot be followed in its entirety since only limited information is available to evaluate the technologies and process options. Instead, potential general response actions, remedial technologies, and process options were identified which could be incorporated into a remedial alternative. These technologies for sediments, surface water, and groundwater are listed in Tables 5-1, 5-2, and 5-3, respectively. These lists are not intended to be comprehensive, but rather they include readily identifiable technologies and process options for the different media. As information becomes available during the RI, these lists will be modified as necessary to include additional technologies and process options applicable to Soldier Creek site conditions.

According to the Interim Final Guidance for Conducting RI/FS Under CERCLA (EPA, 1988c) the following types of alternatives should be developed:

- o A no action alternative.

- o Containment alternatives which protect human health and the environment by preventing exposure, and/or reducing the mobility of contaminants.

TABLE 5-1

PRELIMINARY LIST OF POTENTIAL REMEDIAL TECHNOLOGIES
AND PROCESS OPTIONS FOR CONTAMINATED SEDIMENTS
TINKER AFB -SOLDIER CREEK RI/FS
RI WORKPLAN

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTIONS
No Action	None	None
Institutional Controls	Access Restrictions	Fencing Warning Signs
	Use Restrictions	Surface Water Use Restrictions
	Monitoring	Groundwater NPDES Permits
Containment	Surface Controls	Grading Drainage Controls Channel Diversions Cofferdams
	In Situ Control	Retaining Dikes and Berms Cover Methods Surface Sealing
Removal	Mechanical Dredging	Backhoe Dragline
Treatment	Physical/Chemical	Soil Washing Chemical Reduction/Oxidation Stabilization/Solidification Chemical Extraction
	Biological	Composting Slurry-Phase Anaerobic
	Thermal	Rotary Kiln Incinerator Fluidized Bed Incinerator Circulating Bed Incinerator Infrared Thermal Wet Air Oxidation Pyrolysis-Incineration Vitrification

TABLE 5-1 (Continued)

PRELIMINARY LIST OF POTENTIAL REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS FOR CONTAMINATED SEDIMENTS TINKER AFB -SOLDIER CREEK RI/FS
RI WORKPLAN

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTIONS
Treatment (Continued)	In Situ	Stabilization/Solidification Vitrification Soil Flushing
Disposal	On-Base	RCRA-Compliant Landfill Single-lined Cell
	Off-Base	RCRA-Permitted Landfill Class 2 Landfill

TABLE 5-2

PRELIMINARY LIST OF POTENTIAL REMEDIAL TECHNOLOGIES
AND PROCESS OPTIONS FOR CONTAMINATED SURFACE WATER
TINKER AFB -SOLDIER CREEK RI/FS
RI WORKPLAN

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTIONS
No Action	None	None
Institutional Controls	Access Restrictions	Fencing
	Use Restrictions	Surface Water Use Restrictions
	Monitoring	Groundwater NPDES Permits
Collection	Collection	Surface Controls Diversion
Treatment	Physical/Chemical	Chemical Reduction/Precipitation Air Stripping Steam Stripping Reverse Osmosis GAC Adsorption Electrochemical Precipitation Ion Exchange Chemical Oxidation Oxidation/UV Photolysis
	Biological	Activated Sludge Fixed Film Anaerobic Digestion
Disposal	Discharge	Publicly-owned Treatment Works (POTW) Soldier Creek

TABLE 5-3

PRELIMINARY LIST OF POTENTIAL REMEDIAL TECHNOLOGIES
AND PROCESS OPTIONS FOR CONTAMINATED GROUNDWATER
TINKER AFB -SOLDIER CREEK RI/FS
RI WORKPLAN

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTIONS
No Action	None	None
Institutional Controls	Alternate Water Supply	Surface Water Municipal Water Supply Wells Installed in Deeper Aquifer Bottled Water
	Use Restrictions	Deed Restrictions Reasonable Use
	Monitoring	Groundwater
Containment	Physical Barriers	Slurry Wall Grout Curtain Sheet Piling
	Hydraulic Barriers	French Drain Extraction Wells Well Points
Collection	Extraction	Extraction Wells Subsurface Pipe Drains French Drain Well Points
Treatment	Physical/Chemical	Chemical Reduction/Precipitation Air Stripping Steam Stripping Reverse Osmosis GAC Adsorption Electrochemical Precipitation Ion Exchange Chemical Oxidation Oxidation/UV Photolysis

TABLE 5-3 (Continued)

PRELIMINARY LIST OF POTENTIAL REMEDIAL TECHNOLOGIES
AND PROCESS OPTIONS FOR CONTAMINATED GROUNDWATER
TINKER AFB -SOLDIER CREEK RI/FS
RI WORKPLAN

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTIONS
Treatment (Continued)	Biological	Activated Sludge Fixed Film Anaerobic Digestion
Disposal	Discharge	POTW Soldier Creek IWTP

- o Treatment alternatives which range from ones that use treatment options to address the primary threats to ones that minimize long-term management.

Preliminary remedial alternatives for each medium were identified by combining the remedial technologies listed in Tables 5-1, 5-2, and 5-3 into potentially viable mitigation measures which fall within each of these types, to the extent feasible. Institutional controls were included as part of the no action alternative to provide a means of reducing the potential exposure to human populations. During a feasibility study, institutional controls would be included separately from the no action alternative as a "limited action alternative". For purposes of simplifying the preliminary alternatives development in this Workplan, the no action and limited action alternative were combined and referred to as "no-action alternative". The containment and treatment options listed in this workplan are very general, and in some cases, do not specify technologies or process options. During later stages of the RI/FS process, these alternatives will be further refined and separated into more distinct alternatives to provide a wider range of alternatives for evaluation and comparison. These preliminary remedial alternatives are presented by medium in the following subsections.

5.2.1 Sediment

Four preliminary remedial alternatives were developed as possible means of mitigating contaminated sediment in Soldier Creek. Each identified sediment preliminary remedial alternative is designated with an "S". These remedial alternatives are listed in Table 5-4 and discussed below.

5.2.1.1 Alternative S1-No Action. Alternative S1, No Action, was developed in accordance with the NCP and SARA which require the evaluation of a no-action alternative as a baseline against which the other alternatives can be evaluated. The no action alternative does not provide for any means of remediating the sediments. Institutional controls could be included to reduce the potential exposure to human populations.

TABLE 5-4

PRELIMINARY LIST OF POTENTIAL ALTERNATIVES
FOR CONTAMINATED SEDIMENTS
TINKER AFB-SOLDIER CREEK RI/FS
RI WORKPLAN

	NO ACTION	CONTAINMENT		TREATMENT
REMEDIAL TECHNOLOGY	ALTERNATIVE S1	ALTERNATIVE S2	ALTERNATIVE S3	ALTERNATIVE S4
NO ACTION	X			
INSTITUTIONAL CONTROLS				
ACCESS RESTRICTIONS	X			
USE RESTRICTIONS	X	X	X	
MONITORING	X	X	X	X
CONTAINMENT				
SURFACE CONTROLS		X	X	X
IN SITU CONTROL		X	X	
REMOVAL				
MECHANICAL DREDGING				X
TREATMENT				
PHYSICAL/CHEMICAL				X
BIOLOGICAL				X
THERMAL				X
IN SITU			X	
DISPOSAL				
ON-BASE				X
OFF-BASE				X

Institutional controls could include access restrictions, use restrictions, and monitoring. Alternative S1 does not attain any of the remedial action objectives.

5.2.1.2 Alternative S2-Containment. Alternative S2 was developed to provide containment of contaminated sediments by implementing in situ control measures. These measures could include surface controls, such as channel diversions or drainage controls, and in situ controls, such as retaining dikes or cover methods, to reduce the downstream migration of contaminated sediments.

5.2.1.3 Alternative S3-Containment and Treatment. Alternative S3 is similar to Alternative S2 which provides in situ containment of contaminated sediments. The main difference between Alternatives S2 and S3 is that Alternative S3 also includes in situ treatment of a portion of the contaminated sediments. In areas where it is feasible, such as in dry drainage ways, contaminated sediments would be treated by processes such as stabilization or vitrification.

5.2.1.4 Alternative S4-Treatment. Alternative S4 includes five main components to provide permanent treatment of contaminated sediment. First, contaminated sediments would be removed by dredging with a backhoe or dragline. Surface controls would be implemented to control surface water flow during dredging. Sediments contaminated with inorganics would be treated by physical/chemical processes. Sediments contaminated with organics would be treated by biological, thermal, or physical/chemical processes. After treatment, the sediments would be disposed either on-base or off-base. The method of disposal would depend on the characteristics of the treated sediments. Monitoring would be required for regulatory compliance of on-base disposal areas.

5.2.2 Surface Water

Two preliminary remedial alternatives were developed for contaminated surface water in Soldier Creek, a no action and a treatment alternative. Due to the nature of stream environments, it would be difficult to implement a remedial alternative that provides only containment of the contaminated water. For this reason, a containment alternative was not developed for surface water. Table 5-5 lists the technologies associated with each surface water preliminary remedial alternative.

5.2.2.1 Alternative SW1-No Action. Alternative SW1, No Action, was developed in accordance with the NCP and SARA which require the evaluation of a no-action alternative as a baseline against which the other alternatives can be evaluated. The no action alternative does not provide for any means of remediating the surface water. Institutional controls could be included to reduce potential exposure to human populations. These controls could include access restrictions, use restrictions, and monitoring. Alternative SW1 does not attain any of the remedial action objectives.

5.2.2.2 Alternative SW2-Treatment. Alternative SW2 includes collection of the contaminated surface water for treatment and then discharge of treated water back into Soldier Creek or to a wastewater treatment facility. This alternative would provide collection of contaminated surface water using surface controls and diversions. After collection, the contaminated surface water would be treated using physical/chemical processes for removal of inorganics and physical/chemical or biological processes for removal of organic contaminants. The treated water would be discharged to Soldier Creek, or to a wastewater treatment facility if additional treatment is necessary.

5.2.3 Groundwater

Four groundwater remedial alternatives were developed as ways to mitigate possible groundwater contamination. Investigations of potential groundwater contamination at Tinker AFB were previously completed for the Building 3001 site. A feasibility study was conducted to assess potential remediation scenarios for the contaminated groundwater identified during the various Building 3001 investigations (Tulsa COE, 1988a). For the purposes of the Soldier Creek RI, it was assumed that groundwater

TABLE 5-5

PRELIMINARY LIST OF POTENTIAL ALTERNATIVES
FOR CONTAMINATED SURFACE WATER
TINKER AFB-SOLDIER CREEK RI/FS
RI WORKPLAN

REMEDIAL TECHNOLOGY	NO ACTION ALTERNATIVE SW1	TREATMENT ALTERNATIVE SW2
NO ACTION	X	
INSTITUTIONAL CONTROLS		
ACCESS RESTRICTIONS	X	
USE RESTRICTIONS	X	
MONITORING	X	
COLLECTION		
COLLECTION		X
TREATMENT		
PHYSICAL/CHEMICAL		X
BIOLOGICAL		X
DISPOSAL		
DISCHARGE		X

contamination in the perched and top of regional aquifers will be remediated through implementation of the Building 3001 remedy (BVWST, 1989b). If contaminated groundwater is identified during the Tinker AFB - Soldier Creek RI/FS which will not be remediated by the Building 3001 remedy, then the remedial alternatives detailed in the following subsections could potentially be implemented for the Soldier Creek site. Table 5-6 details the technologies included in each of the preliminary groundwater alternatives.

5.2.3.1 Alternative GW1-No Action. Alternative GW1, No Action, was developed in accordance with the NCP and SARA which require the evaluation of a no-action alternative as a baseline against which the other alternatives can be evaluated. The no action alternative does not provide for any means of remediating the groundwater. Institutional controls could be implemented to reduce potential exposure to human populations. These controls could include an alternate water supply, use restrictions, and monitoring. Alternative GW1 does not attain any of the remedial action objectives.

5.2.3.2 Alternative GW2-Physical Containment. The major component of Alternative GW2 is a physical barrier which would contain the contaminated groundwater to reduce the potential for contaminant migration. Typical physical barriers include slurry walls, grout curtains, or in some cases, sheet piling which can be installed to create an impervious barrier. Along with a physical barrier, institutional controls would need to be implemented to reduce potential human exposure. The controls would include an alternate water supply, use restrictions, and monitoring. Groundwater monitoring would also be implemented as a means of assessing the reliability and effectiveness of the physical barrier.

5.2.3.3 Alternative GW3-Hydraulic Containment. Alternative GW3 reduces potential contaminant migration by implementing hydraulic containment and changing the hydraulic gradient. Possible hydraulic containment technologies which could be used include french drains or a series of

TABLE 5-6

PRELIMINARY LIST OF POTENTIAL ALTERNATIVES
FOR CONTAMINATED GROUNDWATER
TINKER AFB-SOLDIER CREEK RI/FS
RI WORKPLAN

	NO ACTION	CONTAINMENT		TREATMENT
REMEDIAL TECHNOLOGY	ALTERNATIVE GW1	ALTERNATIVE GW2	ALTERNATIVE GW3	ALTERNATIVE GW4
NO ACTION	X			
INSTITUTIONAL CONTROLS				
ALTERNATE WATER SUPPLY	X	X	X	
USE RESTRICTIONS	X	X	X	
MONITORING	X	X	X	X
CONTAINMENT				
PHYSICAL BARRIERS		X		
HYDRAULIC BARRIERS			X	
COLLECTION				
EXTRACTION				X
TREATMENT				
PHYSICAL/CHEMICAL			X	X
BIOLOGICAL			X	X
DISPOSAL				
DISCHARGE			X	X

wellpoints. This type of barrier would remove contaminated groundwater, therefore treatment options will be required. Treatment could include physical/chemical processes for removal of organic and inorganic constituents, and possibly biological treatment for removal of organic contaminants. Discharge options would be required for the water removed as a part of the containment system. Possible options include discharge of treated water to Soldier Creek, to a wastewater treatment facility, or reinjecting the treated water into the aquifer to aid the containment system. Institutional controls would need to be implemented, including groundwater monitoring to assess the effectiveness of the containment system.

5.2.3.4 Alternative GW4-Treatment. Alternative GW4 includes extraction of the contaminated groundwater to provide active restoration of the aquifer. Extraction would be accomplished by using extraction wells, a french drain, or extraction and injection wells. After extraction, contaminated groundwater would be treated by physical/chemical processes for removal of organic and inorganic constituents, or possibly biological processes for removal of organic compounds. Following treatment, the groundwater would be discharged into Soldier Creek or to a wastewater treatment facility. Monitoring would be required to assess the effectiveness of the extraction system.

6.0 REMEDIAL INVESTIGATION SCOPE OF WORK

This section details the proposed scope of work for the remedial investigation at the Soldier Creek site. A listing of the tasks and subtasks which comprise the scope of work is presented in Table 6-1. The proposed work schedule is presented in Section 7.0.

6.1 PHASE I FIELD INVESTIGATION

The Phase I field investigation will be conducted to determine the extent of contamination of Soldier Creek. The Phase I investigation will have a limited study area and will include Soldier Creek from its headwaters located to the north of Southeast 59th Street to as far downstream as East Reno Avenue.

6.1.1 Easements and Permits

All right-of-entry permits, easements, and/or leases will be obtained by the Tulsa COE Real Estate Division. The contractor will support the Tulsa COE in obtaining access agreements from landowners for surveying, surface water and sediment sampling, private well sampling, or any other necessary activities on private property. The support activities will include providing the Tulsa COE with information concerning sampling locations and procedures.

6.1.2 Support

This subtask covers all activities associated with overall support of the individual field work subtasks. It includes implementation of the QAPP, SAP, HSP, and DQO Report; equipment procurement and mobilization; analytical laboratory subcontracting and acquisition of sample bottles and shipping containers. The following paragraphs detail the scope of the field work support activities.

6.1.2.1 QAPP/SAP/HSP/DQO Implementation. The implementation of the QAPP/SAP/HSP/DQO includes on-site safety briefings, initial contact with local authorities and institutions such as the local police, fire

TABLE 6-1

REMEDIAL INVESTIGATION TASKS AND SUBTASKS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

Task	Subtask
Phase I Field Investigation	Easements and Permits Support Sediment Surface Water Groundwater Field Survey RI-Derived Waste Disposal
Phase I Sample/Data Analysis	Sample and Data Management Data Validation and Reduction Data Evaluation
Phase II Field Investigation	Remedial Investigation Plans Easements and Permits Support Sediment Surface Water Groundwater Field Survey RI-Derived Waste Disposal
Phase II Sample/Data Analysis	Sample and Data Management Data Validation and Reduction Data Evaluation
Assessment of Risks	
Chemical-specific ARARs Development	
Remedial Investigation Report	Draft RI Report Draft Final and Final RI Reports
Miscellaneous Activities	RI Secondary Reports Review Conferences Monthly Progress Reports

department, and the hospital closest to the site. Also included is office support of the field work activities such as map reproduction, senior level consultations with field staff, and other support functions while field work is underway.

6.1.2.2 Equipment Procurement and Mobilization. A listing of the equipment and on-base support facilities required to perform the RI field investigation are included in Table 6-2. The items required will either be rented from the equipment pool or outside organizations, or purchased for use on this project. Mobilization activities will include the movement of project personnel and equipment to the site, establishing the field office, and coordination of field activities prior to implementation of the sampling effort. It is assumed that the field office space will be provided in an on-base location by Tinker AFB and that all utility and telephone services will be provided.

6.1.2.3 Analytical Laboratory Subcontracting. Subcontracting arrangements for analytical services will be finalized with a CLP analytical laboratory. In addition, the contractor will coordinate with the CLP analytical laboratory to arrange for receipt of sample and shipping containers, scheduling laboratory space, and other miscellaneous items required for completion of the analytical procedures necessary during the field investigation.

6.1.3 Sediment

This subtask includes all activities associated with sampling of sediment from Soldier Creek for chemical and physical analyses. Potential on-base sampling locations for East and West Soldier Creeks during the Phase I field investigation were established based on locations of outfalls reported in the Final Storm Sewer Investigation for Soldier Creek (NUS, 1989). Potential off-base sampling points for the overall RI were established based on the following sampling intervals for the entire off-base length of Soldier Creek:

- Every 250 feet until first confluence of tributaries which directly emanate from Tinker AFB.

TABLE 6-2

EQUIPMENT FOR PHASE I FIELD INVESTIGATION
TINKER AFB-SOLDIER CREEK RI/FS
RI WORKPLAN

EQUIPMENT	QUANTITY	EQUIPMENT	QUANTITY
NONEXPENDABLE ITEMS		EXPENDABLE ITEMS (CONTINUED)	
MONITOX CYANIDE MONITOR	1 UNIT	ALCONOX DETERGENT	2 BOXES
MONITOX CYANIDE GENERATOR	1 UNIT	REAGENT GRADE ETHANOL	2 GALLONS
HNU PHOTOIONIZATION DETECTOR (PI-101)	1 UNIT	FIELD LOG BOOK	5 UNITS
HNU PHOTOIONIZATION PROBE (11.7 EV)	1 UNIT	SURVEYOR'S FLAGGING	5 ROLLS
PH METER	1 UNIT	SURVEYOR'S WOODEN LATHS	2 BUNDLES
S-C-T METER	1 UNIT	FOLDING WOODEN RULE (6 FOOT)	3 UNITS
ELECTRONIC DISSOLVED OXYGEN (DO) METER	1 UNIT	HAND CORE SAMPLER CORE CATCHER	235 UNITS
NATIONAL BUREAU OF STANDARDS THERMOMETER	1 UNIT	HAND CORE SAMPLER LINER TUBES	235 UNITS
AIR PURIFYING RESPIRATOR (APR)	6 UNITS	HAND CORE SAMPLER NOSEPIECE	3 UNITS
FIRE EXTINGUISHER	1 UNIT	PLASTIC CAPS	65 UNITS
FIRST AID KIT	1 UNIT	NALGENE FILTER UNITS (500 ML)	20 UNITS
NEOPRENE BOOTS	6 PAIRS	NALGENE PREFILTERS	20 UNITS
HIP WADERS	3 PAIRS	STAINLESS STEEL PANS	6 UNITS
CHEST WADERS	2 PAIRS	STAINLESS STEEL BOWLS	6 UNITS
DRAGER PUMP AND KIT	1 UNIT	STAINLESS STEEL KNIVES	6 UNITS
RADIATION DETECTOR	1 UNIT	STAINLESS STEEL SPOONS	6 UNITS
HAND BORE SEDIMENT SAMPLER	3 UNITS	POLYETHYLENE LADLE	3 UNITS
SURFACE WATER FLOW MEASURER	1 UNIT	CLEAR PLASTIC TAPE	6 ROLLS
WATER LEVEL INDICATOR	1 UNIT	STRAPPING TAPE	6 ROLLS
TEFLON BAILER	1 UNIT	DUCT TAPE	12 ROLLS
NALGENE VACUUM PUMP	1 UNIT	FILM (35MM)	6 ROLLS
ELECTRONIC DISTANCE MEASURER (EDM)	1 UNIT	NYLON ROPE (1/2 INCH)	100 FEET
TRIPOD	1 UNIT	HPLC WATER	13 GALLONS
ELECTRONIC RECORDER	1 UNIT	DISTILLED WATER	20 GALLONS
PRISM ROD	1 UNIT	DEIONIZED WATER	5 GALLONS
35MM CAMERA	1 UNIT	TRASH BAGS	3 BOXES
STEEL TAPE (100 FOOT)	2 SETS	HEAVY PLASTIC SHEETING	1 ROLL
WALKIE TALKIES	1 SET	DECONTAMINATION BUCKETS	5 UNITS
DECONTAMINATION STATION	1 STATION	55-GALLON DRUMS	*
SPLIT SPOON SAMPLER	2 UNITS	PLASTIC BAGS	10 BOXES
DRIVE HAMMER	1 UNIT	ICE	25 POUNDS
		TLD BADGES	7 UNITS
		ALARM HORN	3 UNITS
EXPENDABLE ITEMS		HAND AND FACE WASHING TUBS	2 UNITS
ALUMINUM FOIL	3 ROLLS	HAND SPRAYERS	3 UNITS
POLYPROPYLENE ROPE	400 FEET	SQUEEZE BOTTLES	3 UNITS
COTTON GLOVES	30 PAIRS	DRINKING WATER COOLER	1 UNIT
SURGICAL GLOVES	12 BOXES	DISPOSABLE CUPS	3 PACKAGES
18-INCH NITRILE GLOVES	75 SETS	PAPER TOWELS	15 ROLLS
SARANEX TYVEKS	120 SETS	PACKING FOAM/BUBBLE WRAP	1 ROLL
TYVEKS	85 SETS	WOODEN STAKES	10 UNITS
COTTON COVERALLS	6 SETS	NAILS	1 POUND
LATEX BOOT COVERS	65 SETS	SPRAY PAINT	3 CANS
APR CARTRIDGES (GMC-H)	40 UNITS	PERMANENT BLACK MARKERS	1 PACKAGE
MSA CLEANER/SANITIZER	5 PACKS	WATERPROOF PENS	2 PACKAGES
APR WIPES	1 BOX	LIFELINE	1 UNIT
ISOBUTYLENE CALIBRATION GAS	3 CYLINDERS	CLIPBOARDS	3 UNITS
PH BUFFER	3 BOTTLES	AA BATTERIES	1 SET
CONDUCTIVITY CALIBRATING FLUID	2 BOTTLES	RUBBER BANDS	1 PACKAGE
VERMICULITE OR POLY-FOAM COOLERS	15 UNITS	FIELD KNIVES (STAINLESS STEEL BLADE)	3 UNITS
SCISSORS	2 UNITS	LIFE PRESERVERS	1 UNIT
DRAGER TUBES	45 UNITS	TEFLON SHEETING/WRAP	3 ROLLS

* NUMBER OF DRUMS WILL BE DETERMINED PRIOR TO MOBILIZATION.

- Every 500 feet on all Soldier Creek stream segments until second confluence.
- Every 1000 feet downstream from second confluence.

Existing data on the transect sediment samples indicate that sediment contaminated with metals and BNAs was removed to a five foot depth along on-base portions of East and West Soldier Creeks. Considering the physical characteristics and low mobility indices of metals & BNAs, these contaminants will tend to stay in place and not mitigate to lower depths. Therefore, since five feet of sediment was removed, collecting samples from 0-6 inches and 6-12 inches on-base should define the existing vertical extent of contamination contained in the majority of the on-base and off-base portions of Soldier Creek and its major tributaries.

Proposed sampling locations for the Phase I field investigation were selected to cost-effectively determine the extent of contamination and to determine the stream segments which may require a more focused and intensive sampling effort during the Phase II field investigation. The Phase I sampling locations were selected from the potential sampling locations established for the overall RI based on the following criteria:

- Upstream and downstream of known on-base outfalls (NUS, 1989).
- Upstream and downstream of each tributary along Soldier Creek and East and West Soldier Creeks emanating from Tinker AFB, from their headwaters to East Reno Avenue.
- Upstream of the confluence of East Soldier Creek with the main branch of Soldier Creek to evaluate possible contaminant contributions from other sources.
- At a minimum of every 2,000 feet along Soldier Creek unless dictated otherwise by confluences of the Creek or other physical field conditions. Preference will be given to previous sample locations.
- One background sampling location.

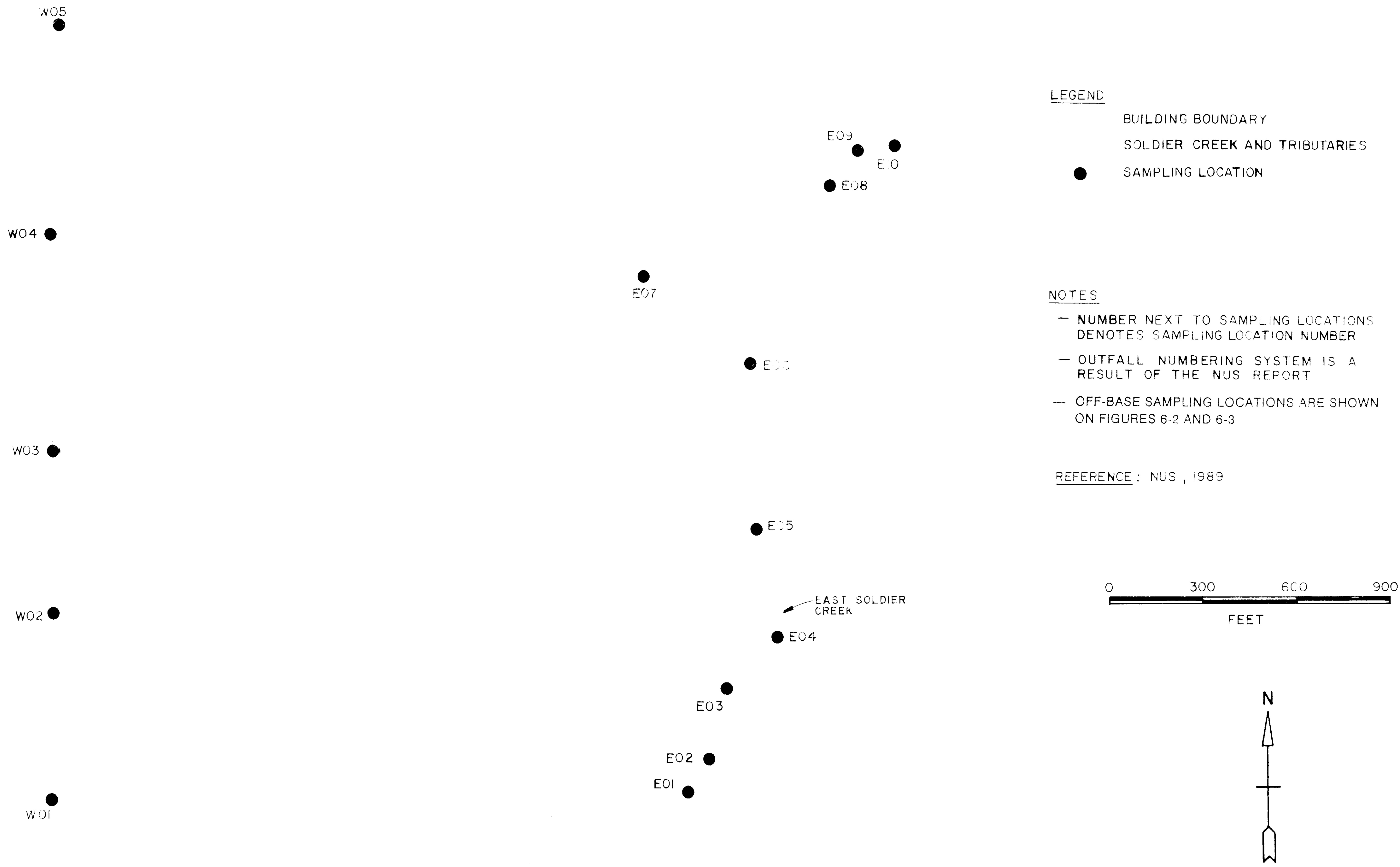
Proposed Phase I on-base and off-base sampling locations are shown on Figures 6-1 and 6-2, respectively. Approximately 84 sediment samples will be submitted for chemical analysis, not including the quality control samples. Approximately 16 additional sediment samples will be submitted for physical analyses.

Composite sediment samples across a transect at each sampling location will be collected for two depth intervals (0-6 inches and 6-12 inches). The composite samples will be analyzed for acid, base/neutral (BNA) extractables, metals, and cyanide on the Target Compound List (TCL) and Target Analyte List (TAL) using routine analytical services (RAS) procedures and detection limits. The TCL and TAL detection limits are presented in Appendix C of the Sampling and Analysis Plan. Results will be presented on a dry weight basis. In addition, total organic carbon (TOC) analyses will be conducted on all of the sediment samples using special analytical services (SAS). The following SAS physical analyses will be conducted on 20 percent of the sediment samples:

- Atterberg limits.
- Sediment particle size.
- Density.
- Sediment permeability.

Sediment samples will be collected in accordance with methods described in the National Handbook of Recommended Methods for Water-Data Acquisition (USGS, 1980) and the SAP. The composite samples will be collected using the Equal-Width Increment (EWI) method, therefore the number of aliquots used to form the composite samples will be dependent upon the width of the stream at each sampling location.

At each sampling location, one grab sediment sample will be taken at each depth and analyzed for volatile organics on the TCL using RAS procedures and detection limits. This grab sediment sample will be obtained along the transect at the location which is most likely to contain volatile organic contamination based upon stream morphology and visual observations.



LEGEND

BUILDING BOUNDARY

SOLDIER CREEK AND TRIBUTARIES

● SAMPLING LOCATION

NOTES

— NUMBER NEXT TO SAMPLING LOCATIONS DENOTES SAMPLING LOCATION NUMBER

— OUTFALL NUMBERING SYSTEM IS A RESULT OF THE NUS REPORT

— OFF-BASE SAMPLING LOCATIONS ARE SHOWN ON FIGURES 6-2 AND 6-3

REFERENCE : NUS , 1989

FIGURE 6-1
ON-BASE SAMPLING LOCATIONS
TINKER AFB - SOLDIER CREEK RI/FB
RI WORKPLAN

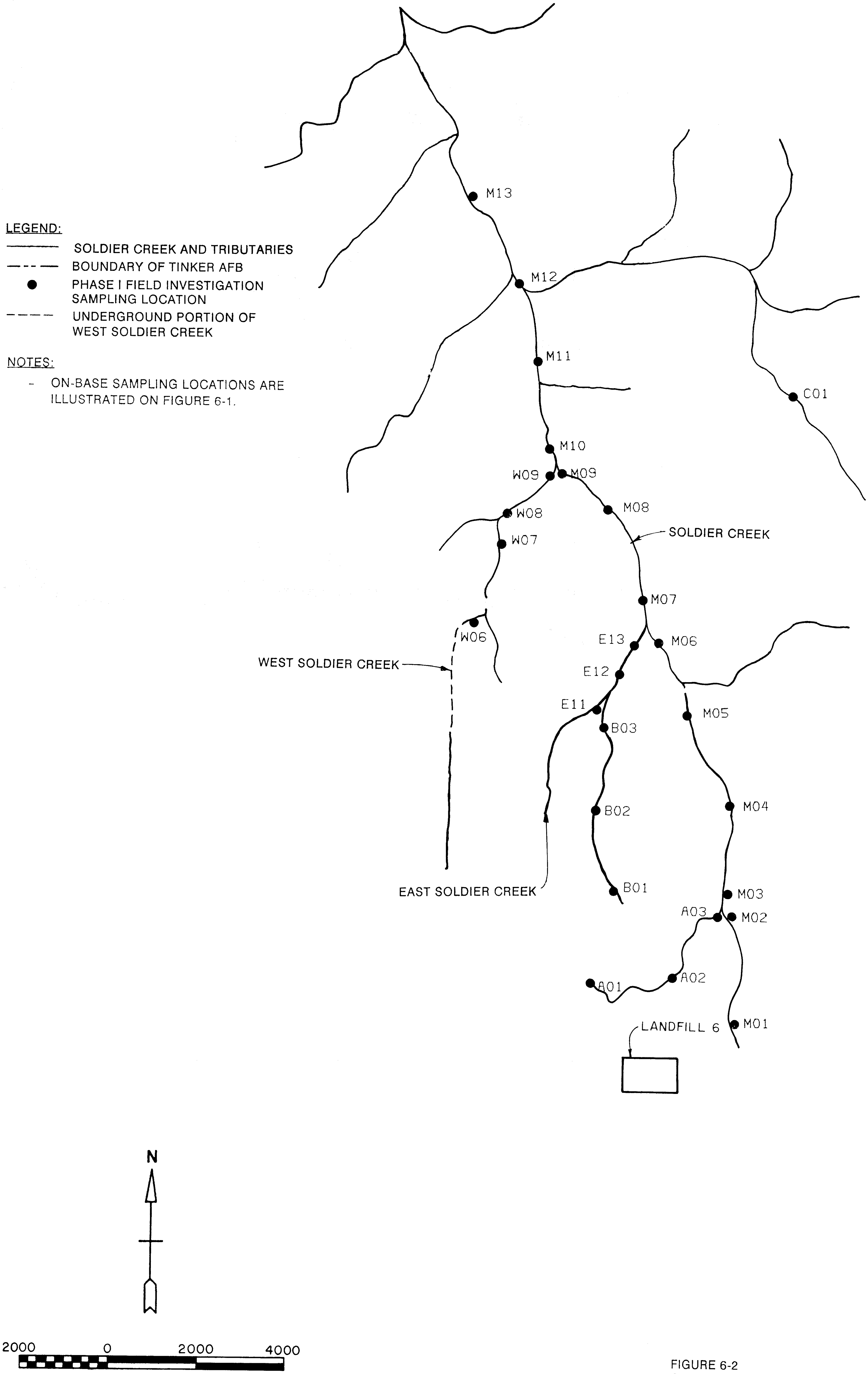


FIGURE 6-2
OFF-BASE SAMPLING LOCATIONS

One sediment background sample will be taken off-base on a major tributary of Soldier Creek. Due to the location of potential sources of contamination with regard to the creek, the sediment background sample will be located on private property on an eastern branch. The background sediment sample will be collected in the same manner and analyzed for the same chemical parameters as the sediment samples discussed previously.

For quality assurance (QA)/quality control (QC) purposes, one duplicate sediment sample will be obtained at each of the two depth intervals for ten percent of the sampling locations. These duplicate samples will be analyzed for the same chemical and physical parameters as the sediment samples.

In addition to the duplicate sediment samples, a minimum of one equipment rinsate blank will be prepared for each sampling method used in collecting the sediment samples. This blank sample will be collected and analyzed for the same chemical parameters as the sediment samples to determine the extent to which field procedures contribute to sample contamination.

For approximately five percent of the sediment samples collected, additional sample volume will be collected in order for the laboratory to prepare matrix spike and matrix spike duplicate samples for QA/QC protocol.

In addition to the chemical and physical analyses, all sediment samples will be scanned with an HNU photoionization detector or organic vapor analyzer (OVA) for a field qualitative assessment of volatile organic content.

6.1.4 Surface Water

This subtask includes all activities associated with the sampling of surface water from Soldier Creek. The Phase I field investigation surface water sampling locations will be the same as the sediment sampling locations shown on Figures 6-1 and 6-2. Approximately 42 surface water samples will be submitted for chemical analysis, not including the quality control samples. Approximately eight additional surface water samples will be submitted for water quality analyses.

Composite samples across a transect at each sampling location will be collected. The composite samples will be analyzed for BNA extractables, metals, and cyanide on the TCL and TAL using RAS procedures and detection limits. In addition, the following SAS additional analyses will be conducted on 20 percent of the surface water samples:

- Alkalinity.
- Hardness.
- Chemical oxygen demand (COD).
- Total suspended solids (TSS).
- Five-day biochemical oxygen demand (BOD_5).
- TOC.
- Oil and grease.
- Nitrates.

Composite surface water samples will be collected in accordance with methods described in the National Handbook of Recommended Methods for Water-Data Acquisition (USGS, 1980) and the accompanying SAP. The composite samples will be collected using the EWI method, therefore the number of aliquots used to form the composite samples will be dependent upon the width of the stream at each sampling location.

One grab sample will be collected at each location and analyzed for volatile organics on the TCL using RAS procedures and detection limits. This grab sample will be obtained along the transect at the location which is most likely to contain volatile organic contamination based upon stream morphology and visual observations. The procedure for determining the grab sample locations are outlined in Subsection 6.2.1 of the SAP.

One surface water background sample will be taken off-base at the same location as the off-base sediment background sample. The background sample will be collected in the same manner and analyzed for the same chemical parameters as the surface water samples discussed previously.

For QA/QC purposes, one duplicate surface water sample will be obtained at ten percent of the sampling locations. These duplicate samples will be analyzed for the same chemical and water quality parameters as the surface water samples.

In addition to the duplicate surface water samples, a minimum of one equipment rinsate blank will be prepared for each sampling method used in collecting the surface water samples. This blank sample will be collected and analyzed for the same chemical and water quality parameters as the surface water samples to determine the extent to which field procedures contribute to sample contamination.

A trip blank will be included in each shipping container which contains surface water samples to be analyzed for volatile organics. This trip blank will be analyzed for volatile organics to aid in determining if cross-contamination occurred during shipping. The trip blank will be prepared by the laboratory using analyte-free deionized water and shipped to the site with empty sample containers. The trip blanks will be stored at the field office, unopened until they are included in the shipments which contain samples to be analyzed for volatile organics.

For approximately five percent of the surface water samples collected, additional sample volume will be collected in order for the laboratory to prepare matrix spike and matrix spike duplicate samples for QA/QC protocol.

Water quality parameters will be measured in the field and include pH, dissolved oxygen (DO), specific conductivity, and temperature. In addition, all surface water samples will be scanned with an HNU photoionization detector or OVA for a qualitative assessment of volatile organic content.

Additional field measurements will include determination of the stream velocity at the time of sample collection. The profile of the stream bed along the transect at each sampling location will be determined during the field survey as discussed in Subsection 6.1.6.

6.1.5 <u>Groundwater</u>

This subtask includes all activities associated with sampling of groundwater from existing residential wells for chemical analysis. Soldier Creek Phase I groundwater sampling will be completed to aid in determining the extent of off-base groundwater contamination attributable to the Soldier Creek site.

Groundwater level measurements and groundwater samples will be collected at existing off-base private wells located within the Soldier Creek drainage system. Wells to be sampled shall be selected based on: (1) depth to screened interval; (2) proximity to Soldier Creek; and (3) ability of the Tulsa COE to obtain private property access for sampling. Locations of proposed wells to be sampled are illustrated in Figure 6-3. Eight groundwater samples will be submitted for chemical analysis, not including the quality control samples. The analytical data obtained from groundwater sampling will be evaluated based on available well information pertaining to well depth, screened depth, and water depth.

Discrete groundwater samples will be taken from each private well. All unfiltered groundwater samples will be analyzed for volatile organics, BNA extractables and metals (total) using SAS procedures and detection limits. The samples will be analyzed for cyanide using RAS procedures and detection limits. At three wells, an additional metals analysis will be performed on filtered groundwater samples to determine the fraction of total metals adsorbed onto soil particles and the fraction in the dissolved phase. The total (unfiltered) metals analysis is required for comparison of detected metals concentrations to drinking water standards. The dissolved (filtered) metals analysis is required to evaluate the data with regard to the implementation and effectiveness of specific treatment technologies.

For QA/QC purposes, one duplicate groundwater sample will be obtained. This duplicate sample will be analyzed for the same chemical parameters as the groundwater samples.

LEGEND:

——— SOLDIER CREEK AND TRIBUTARIES

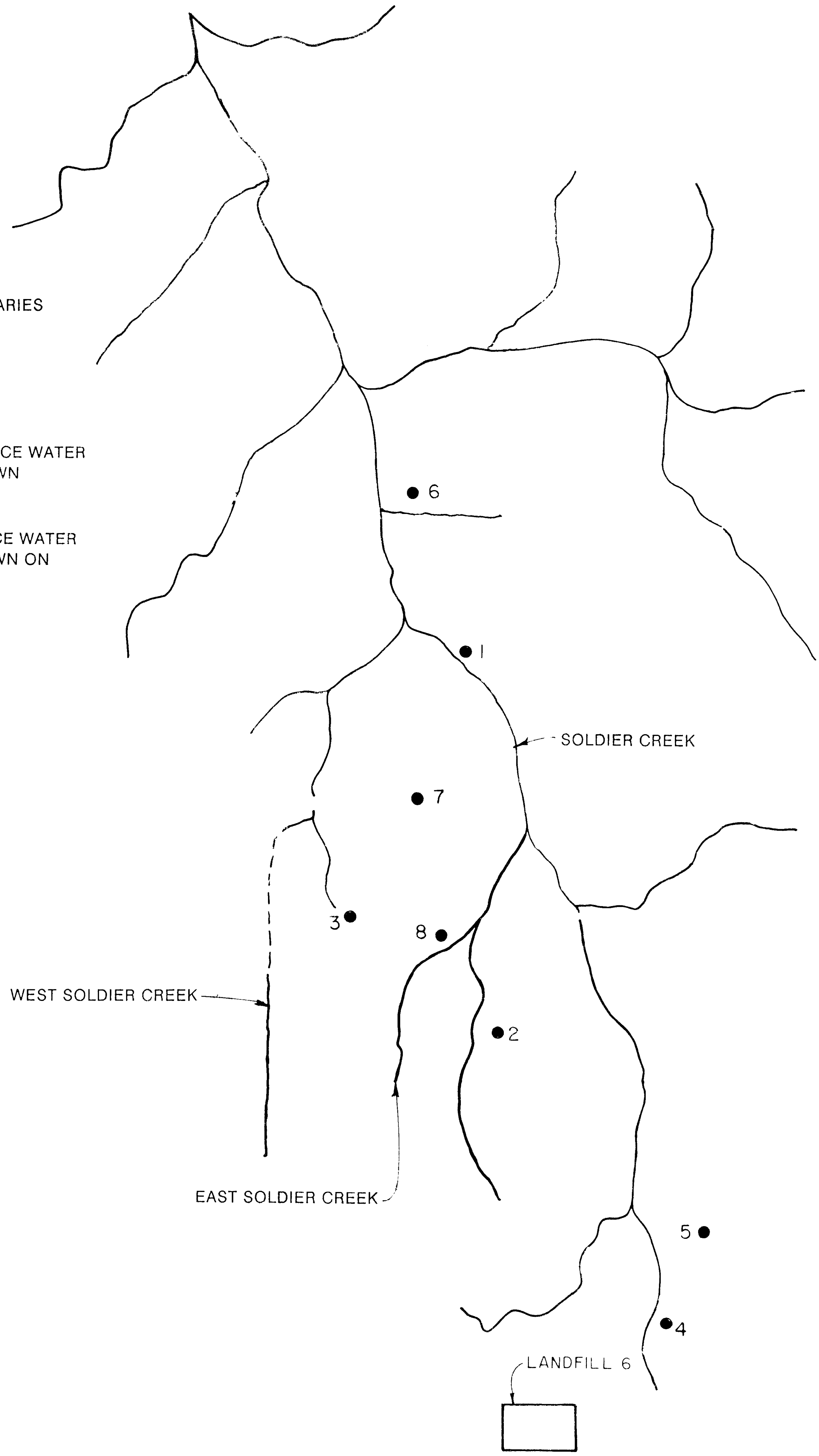
– – – – UNDERGROUND PORTION OF WEST SOLDIER CREEK

● SAMPLING LOCATION

NOTES:

- OFF-BASE SEDIMENT AND SURFACE WATER SAMPLING LOCATIONS ARE SHOWN ON FIGURE 6-2.

- ON-BASE SEDIMENT AND SURFACE WATER SAMPLING LOCATIONS ARE SHOWN ON FIGURE 6-1



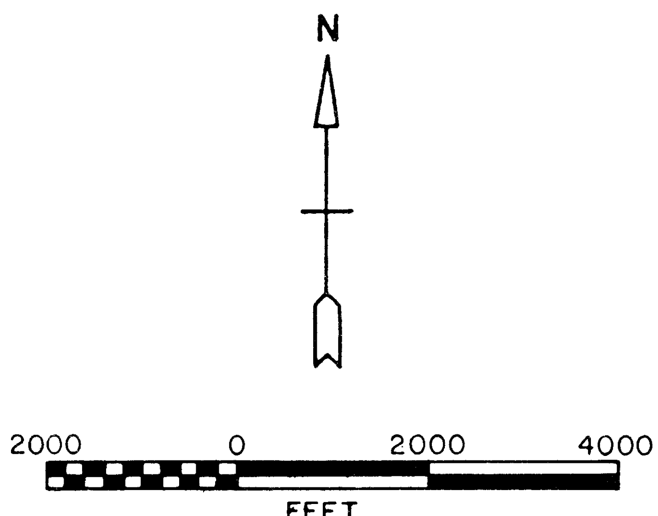


FIGURE 6-3
OFF-BASE GROUNDWATER SAMPLING LOCATIONS
TINKER AFB - SOLDIER CREEK RI/FS
RI WORKPLAN

In addition to the duplicate groundwater samples, a minimum of one equipment rinsate blank will be prepared for each sampling method used in collecting the groundwater samples. This blank sample will be collected and analyzed for the same chemical parameters as the groundwater samples to determine the extent to which field procedures contribute to sample contamination.

A trip blank will be shipped with each shipping container containing groundwater samples to be analyzed for volatile organics. This trip blank will be analyzed for volatile organics to aid in determining if cross-contamination occurred during shipping. The trip blank will be prepared by the laboratory using the same materials and procedures as for the surface water.

For approximately five percent of the groundwater samples collected, additional sample volume will be collected in order for the laboratory to prepare matrix spike and matrix spike duplicate samples for QA/QC protocol.

Water quality parameters will be measured in the field and include pH, specific conductivity, and temperature. In addition, all samples will be scanned with an HNU photoionization detector or OVA for a qualitative assessment of volatile organic content.

Each well sampled will be sounded to verify the depth of the well and establish the aquifer zone from which the well withdraws water, if possible.

If time permits during the Phase I field investigation, a comparison of local addresses to the municipal water billing list will be done in an attempt to locate additional off-base groundwater wells. If appropriate, these additional wells may be sampled during the Phase II field investigation.

6.1.6 Field Survey

Field personnel will perform a field ground survey after the sediment and surface water sampling which will include the following activities:

- Establish the stream bed profile at each sampling location and each 100 foot station along the length of Soldier Creek from East Reno Avenue upstream to the headwaters and along each tributary where sampling will be conducted.
- Establish the location and physical dimensions of outfalls and storm drains discharging into Soldier Creek within the study area.
- Visually inspect Soldier Creek to identify off-base outfalls and storm drains.
- Measure velocity of the water in Soldier Creek at each 500 foot station along the length of the stream. Velocity measurements will be used to determine the rate and volume of flow along each segment of Soldier Creek.
- Note surrounding land use and topographical characteristics for future reference in identifying potential impacts on Soldier Creek by area residents and industry.

The survey will have a third order accuracy and will be conducted by field personnel experienced in conducting third order surveys.

Established USGS bench marks will serve as the horizontal and vertical control points from which all other coordinates are established. The coordinates will be established in accordance with the state plane coordinate system.

Technicians will use the survey data to locate sampling locations on the base maps developed for the Soldier Creek site and draw profiles of the stream bed. Flow rates and volumes will be used to determine gaining and losing portions of the stream.

6.1.7 RI-Derived Waste Disposal

Field investigation activities will result in the production of contaminated materials that must be properly managed. Management of the hazardous wastes generated during the investigation requires compliance with federal and state requirements for generation, storage, transportation, and disposal. Contaminated materials generated during the field investigation will include excess sediment from sampling activities, decontamination solutions, personal decontamination station fluids, and personal protective clothing.

All RI-derived wastes will be containerized in DOT-approved 55 gallon drums and these drums will be staged at a designated on-base location. Tinker AFB is the generator of RI-derived waste and Tinker AFB personnel will sign manifests for its transport and disposal. All DOT-approved 55 gallon drums used to store the RI-derived waste will be labelled as to the contents of the drums. An itemized list of DOT-approved 55 gallon drum contents will be recorded in a field logbook. Following receipt of sample results, the disposal location for each type of RI-derived waste will be determined. Tinker AFB will select the disposal method and location. The contracting mechanism for transport and disposal of the RI-derived wastes generated during the Phase I field investigation will be selected upon determination of the disposal location for each type of waste.

Wastes produced by the field operations are divided into four categories:

- Sediment from Sampling Activities. This is any excess sediment generated during the sampling activities. The procedure for handling this excess sediment will be to containerize the excess sediment in DOT-approved 55 gallon drums.

- Personal Decontamination Station Liquids. These liquids include the wash water from the boot wash and the hand and face wash containers. Contaminants typically found in these liquids result from activities which bring personnel in contact with soil. The water will be containerized and stored for disposal.

- Personal Protective Clothing. This category includes the disposable work clothing such as booties, gloves, and paper coveralls worn by field personnel during the Phase I field investigation. The procedure for handling disposable personal protective clothing will be to place such articles in DOT-approved 55 gallon drums which will be stored on-base until the completion of the Phase I field investigation.

- o Decontamination Fluids. Decontamination fluids include wash waters used to decontaminate the sampling equipment. The wash waters will be containerized in 55 gallon DOT-approved drums, labelled, and stored on-base until completion of the Phase I field investigation.

Efforts will be made to segregate types of wastes by activity to allow different disposal options based on sampling results. For example, if chemical analyses indicates no organic contaminants or no levels of inorganic contaminants above background in a sediment sample, then the excess sediment from that sample may be disposed as non-hazardous material. These specific decisions will be made by Tinker AFB at the conclusion of the Phase I field investigation.

6.2 PHASE I SAMPLE AND DATA ANALYSIS

6.2.1 Sample and Data Management

Project personnel will package all samples for shipment via overnight carrier and will coordinate sample transportation and analysis with a CLP analytical laboratory. A sample tracking system will be used to monitor the movement of samples from the time of collection through laboratory analysis, data validation, and review of analytical results.

Project personnel will develop and manage the Tinker AFB-Soldier Creek analytical database to accommodate the analytical information obtained through the field investigation. The database will be developed using IBM-compatible hardware and software. In addition, chemical analytical results from surface water and groundwater sampling will be entered into EPA's database, STORET. This database is used by EPA and states to store and analyze water quality data. Data management will include: data entry, QC review of entered data, data manipulation, and initial data reporting. Further, more detailed data manipulation and reporting activities will be completed under the Data Reduction and Validation (Subsection 6.2.2) and Data Evaluation (Subsection 6.2.3) subtasks.

6.2.2 Data Validation and Reduction

Analytical data generated through the Phase I field investigation will be reviewed within the context of prescribed laboratory and site-specific quality assurance/quality control protocol to determine whether the data meets the standards and objectives presented in the CLP analytical laboratory's QA program plan and the accompanying QAPP. Data validation will be conducted by project personnel according to procedures defined in "Laboratory Data Validation, Function Guidelines for Evaluation" (two separate volumes: Inorganic Analyses and Organic Analyses)(EPA, 1988d and 1988e).

Data from each analyzed sample fraction will be reviewed and considered either acceptable, acceptable given qualifications noted, or unacceptable based on review of analytical detection limits and QA/QC blank sample analytical data. Rationale for data qualification or unacceptability will be completely documented. Additionally, any statistical measures used to define data quality will be explicitly stated. At the completion of all data validation activity, data will be compiled and entered into the Tinker AFB-Soldier Creek analytical database.

6.2.3 Data Evaluation

The physical and chemical data generated during the RI will be evaluated, interpreted, and summarized by medium as the project progresses to determine additional data needs. This may allow the field team to collect additional necessary data while they are still on-site and aid in avoiding costly remobilization efforts.

Data evaluation will involve performance of statistical analyses as well as extensive preparation of tables and plotting of data on maps and graphs. In general terms, this evaluation will include the following:

- Summarizing data in the following categories:
  - Sediment chemical analyses results
  - Sediment physical analyses results
  - Surface water chemical analyses results
  - Surface water quality results
  - Groundwater chemical analyses results
  - Field survey results.

- Reducing data for the RI report.

- Determining additional data needs.

Specifically, six types of data gathered during the Phase I field investigation will be evaluated: sediment chemical and physical data, surface water chemical and water quality data, groundwater chemical quality data, and field survey data.

The evaluation of each of these is discussed below:

- Sediment Chemical Analyses Results. Chemical analyses of sediment samples from Soldier Creek will be used to evaluate the nature and extent of contamination in Soldier Creek. In addition, statistical analyses will be performed to determine if a statistically significant correlation exists between the presence of metals and BNAs by sample depth. The results of sediment chemical analyses evaluation will be used to determine the scope of work for the Phase II field investigation. Chemical characteristics of the sediment will also be used to assess the effectiveness and implementability of remedial alternatives during the feasibility study.

- Sediment Physical Analyses Results. Physical analyses of sediment samples will be used to assess the transport mechanisms associated with contaminants adsorbed onto sediment particles. The physical results will be compared to the chemical analyses results to determine if a correlation exists. Physical characteristics of the sediment will also be used to assess the effectiveness and implementability of remedial alternatives during the feasibility study.

- Surface Water Chemical Analyses Results. The chemical analyses of surface water will be used to determine contaminant levels in Soldier Creek attributable to on-base and off-base sources. The results will be used to determine the scope of work for the Phase II field investigation. Chemical characteristics of the surface water will also be used to assess the effectiveness and implementability of remedial alternatives during the feasibility study.

- Surface Water Quality Results. Water quality characteristics of the surface water, including those measured in the field, will be used to assess the effectiveness and implementability of remedial alternatives during the feasibility study.

- <u>Groundwater Chemical Analyses Results</u>. The chemical analyses results for the groundwater samples will be used to evaluate the contaminant concentrations in off-base wells which could potentially be attributed to contaminant migration from and/or to Soldier Creek. The results will also be used to determine the scope of work for the Phase II field investigation. Groundwater analytical results and field-measured water quality characteristics will be used to assess the effectiveness and implementability of remedial alternatives during the feasibility study.

- <u>Field Survey Results</u>. Stream profile information and water velocity measurements will be used collectively to determine the flow volume and rates through a given segment of Soldier Creek. Comparing the flow volumes and rates for the various segments may aid in determining which portions of Soldier Creek are hydraulically connected to the underlying groundwater systems.

6.3 PHASE II FIELD INVESTIGATION

A brief overview of the scope of work for the Phase II field investigation is presented in this section. The scope of work for each Phase II field investigation task is presented in summary form only, since the actual tasks to be conducted and their associated scope of work cannot be established until after the completion of the Phase I field investigation and sample/data analysis. Therefore, certain assumptions were made with regard to the scope of the Phase II investigation. These assumptions are presented by task in the following subsections.

It should be noted that the necessity for and focus of treatment studies to evaluate identified remedial alternatives can only be assessed following Phase I - sample/data analysis and the technology screening step of the feasibility study. Such treatment studies and accompanying data collection activities necessary to allow evaluation of remedial alternatives during the feasibility study will be identified during scoping of the Phase II Field Investigation and implemented as necessary.

6.3.1 <u>Remedial Investigation Plans</u>

The remedial investigation plans, including the RI Workplan, SAP, QAPP, and HSP and DQO Report will be revised and expanded as needed to provide a detailed description of the activities to be conducted during the Phase II field investigation.

6.3.2 Easements and Permits

This task will be a continuation of the activities described in Subsection 6.1.1.

6.3.3 Support

This task will be a continuation of the activities described in Subsection 6.1.2 for the Phase I field investigation.

6.3.4 Sediment

It is assumed that additional sediment sampling may be required to define the horizontal, vertical and downstream extent of contamination within Soldier Creek and to support the FS activities. In particular, it is assumed that such samples will be required at sampling locations where contamination was identified during the Phase I field investigation and in locations identified as areas requiring a more focused investigation based on the Phase I results. It is assumed that composite and grab samples will be obtained at two depth intervals as described in Subsection 6.1.3. Analyses to be conducted on each sample will be determined based on the Phase I results. If a statistically significant correlation between the presence of metals and BNAs by sample depth can be established during the Phase I field investigation, chemical analytical protocols will not include analyses for BNAs during the Phase II field investigation. Until such a correlation can be demonstrated, it is assumed that the analyses will be the same as described for the Phase I investigation (Subsection 6.1.3). For cost estimating purposes, it is assumed that a total of 125 sediment samples will be submitted for chemical analyses. This estimate does not include duplicates and blanks.

Based on the analytical results from Phase I, additional physical and chemical analyses may be required to characterize the nature of the sediment. These actual analyses to be performed will be determined after review of the Phase I analytical results and further refinement of the treatment technologies which may be applicable to the site.

If significant contamination is detected in the 6 to 12 inch interval at a specific sampling location, then sampling will be conducted at the 6 to 12 inch interval and at a deeper interval at that location. The scope of work for the Phase II field investigation does not account for sampling at depths greater than 12 inches at this time.

6.3.5 Surface Water

It is assumed that additional surface water sampling may be required to adequately characterize the extent of contamination within Soldier Creek and to support FS activities. It is assumed that surface water samples will be obtained at the same locations as the Phase II sediment samples. It is assumed that composite and grab samples will be obtained as described in Subsection 6.1.4. Analyses to be conducted on each sample are assumed to be the same as the Phase I field investigation. For cost estimating purposes, it is assumed that a total of 64 surface water samples will be submitted for chemical analysis. This estimate does not include duplicates and blanks.

6.3.6 Groundwater

The scope of the Phase II groundwater investigation will be dependent upon the results of the Phase I investigation. It is assumed that the investigation will consist of the additional sampling of existing private or monitoring wells. No monitoring well installation activities are expected to occur. It is assumed that the wells sampled during Phase I will be resampled during Phase II according to the procedures outlined in Subsection 6.1.5. For cost estimating purposes, it is assumed that a total of 15 groundwater samples will be submitted for chemical analysis. This estimate does not include duplicates and blanks.

Groundwater quality parameters may need to be added to the analytical list during the Phase II field investigations if significant contamination is detected during Phase I. Water quality parameters may include, but not be limited to the following:

- o Alkalinity
- o Hardness
- o TSS
- o COD
- o TOC
- o Nitrates

The scope of the Phase II groundwater investigation does not include sampling for ground water quality parameters at this time.

6.3.7 Field Survey

It is assumed that additional surveying will be required if samples are obtained from locations not surveyed during the Phase I field investigation or if the area of investigation is extended. The field survey will be conducted as described in Subsection 6.1.6.

6.3.8 RI-Derived Waste Disposal

This task will be a continuation of activities described in Subsection 6.1.7 for the Phase I field investigation.

6.4 PHASE II SAMPLE AND DATA ANALYSIS

6.4.1 Sample and Data Management

This subtask will be the same as that described in Subsection 6.2.1.

6.4.2 Data Validation and Reduction

This subtask will be the same as that described in Subsection 6.2.2.

6.4.3 Data Evaluation

Seven types of data will be evaluated, including sediment chemical analyses results, sediment physical analyses, surface water chemical analyses results, surface water quality data, groundwater chemical analyses results, groundwater quality results, and field survey results. The evaluation of each of these is discussed below:

- o Sediment Chemical Data. Chemical analyses of the sediment samples will be used to evaluate the nature and extent of contamination in Soldier Creek. The data will also be used to assess the effectiveness and implementability of remedial alternatives during the feasibility study.

- <u>Sediment Physical Data</u>. Physical analysis of sediment samples used to evaluate the transport mechanisms associated with contaminants adsorbed onto sediment particles. The physical results will be compared to the chemical analyses results to determine if a correlation exists. Physical characteristics of the sediment will also be used to assess the effectiveness and implementability of remedial alternatives during the feasibility study.

- <u>Surface Water Chemical Data</u>. The chemical analyses of surface water will be used to determine contaminant levels in Soldier Creek attributable to on-base and off-base sources. Chemical characteristics of the surface water will also be used to assess the effectiveness and implementability of remedial alternatives during the feasibility study.

- <u>Surface Water Quality Data</u>. Water quality data for the surface water will be used to evaluate the effectiveness and implementability of remedial alternatives during the FS.

- <u>Groundwater Chemical Data</u>. The chemical analyses data will be used to evaluate the contaminant concentrations in off-base wells which may be attributable to contaminant migration from and/or to Soldier Creek.

- <u>Groundwater Quality Data</u>. Water quality data for groundwater will be used to evaluate the effectiveness and implementability of remedial alternatives during the FS.

- <u>Field Survey Data</u>. Stream profile information and water velocity measurements will be used collectively to determine the flow volume and rate through a given segment of Soldier Creek. Comparing the flow volumes and rates for the various segments may aid in determining which portions of Soldier Creek are hydraulically connected to the underlying groundwater systems.

6.5 ASSESSMENT OF RISKS

A risk assessment (RA) will be prepared after the data validation subtask has been completed. The Draft RA will be submitted separately from the Draft RI Report for review purposes. The Draft Final and Final RA will be submitted as a portion of the Draft Final and Final RI Reports, respectively.

The risk assessment will address the potential human health effects associated with the Soldier Creek site. This will be a site-specific, quantitative baseline risk assessment that evaluates the site and surrounding area in the absence of remediation. EPA has published guidance concerning the performance of risk assessments in the Superfund Public Health Evaluation Manual (SPHEM) (EPA, 1986) and Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Interim Final (EPA, 1989d). The main steps in such an assessment are outlined below.

- Select Compounds of Concern. The first step in the RA will be to review the results of the environmental sampling and other information developed during the RI, in order to identify chemicals of potential concern for detailed study in the RA. Key elements in this screening process are a comparison of site concentration to background levels of chemicals in appropriate media; that is, naturally occurring chemicals present at background concentrations will not be considered to be site-related and will not be evaluated in the assessment. In addition, chemicals present in blanks (i.e., laboratory or field contaminants) will be evaluated and may not be selected for the detailed analysis. The two most important factors used in selecting indicator chemicals will be concentration and toxicity. If further screening is needed, frequency, mobility, and persistence of the chemicals detected will be considered to complete the identification of chemicals of concern.

- Assess Exposure to Receptors. Actual or potential routes of exposure will be identified and the magnitude of exposure to receptors will be estimated by constructing exposure scenarios. Each exposure scenario will identify the source of contamination, the route of transport, possible receptors, and the likely routes of exposure (ingestion, inhalation, or direct contact). For each exposure scenario, concentrations in relevant environmental media (sediment, surface water, and groundwater) at the potential receptor locations will be estimated from sampling data or by modelling. Modelling may also be used to predict future concentrations.

  Chemical intakes for each exposure scenario will be estimated based on frequency and duration of exposure and rate of media intake (e.g., amount of water ingested or air breathed each day). The assumptions used in these estimates (e.g., activity patterns, consumption of groundwater, inhalation rates, adsorption factors) will be stated clearly and documented. The assumptions will be selected to present an "average exposure case" and a "plausible maximum case".

- <u>Access Toxicity</u>. In this step, critical toxicity values will be identified for each chemical of potential concern. These toxicity values will be combined with the intake values described above.

  Acceptable levels of contamination will be equal to criteria stated in chemical-specific ARARs. If ARARs are not available, the levels will be based on concentration levels which would yield exposures less than or equal to reference doses (RFDs) for noncarcinogens and potency factors for carcinogens.

  For humans, toxicity data will be presented: (1) for carcinogens, the carcinogenic potency factor, in the units $(mg/kg/day)^{-1}$ and (2) for noncarcinogens, the estimated RFD in the units mg/kg/day [formerly called acceptable daily intake (ADI)]. Additional guidance for employing RFDs and potency factors for calculating acceptable concentrations in environmental media is found in the SPHEM. Toxicity descriptions for substances for which RFDs and potency factors have not been developed can also be found in the SPHEM.

- <u>Assess Risks to Human Populations</u>. According to the procedures for risk assessments developed by EPA, the potential adverse effects on human health should be assessed where possible by comparing concentrations found at or near the site with ARARs that have been developed. However, it is anticipated that ARARs will not be available for all the chemicals of concern of for all environmental media that will be considered in this assessment.

  Therefore, in order to perform a quantitative risk assessment for contaminants of concern for which ARARs are not available, evaluation of the noncarcinogenic health risks associated with these contaminants will be based primarily on a comparison of the estimated daily intake of the indicator chemicals with appropriate critical toxicity values previously identified. For potential carcinogens, the estimated cancer risks associated with exposure will be calculated using EPA-derived cancer potency factors. Specifically, excess lifetime cancer risks are calculated by multiplying the cancer potency factor by the daily intake of the contaminant under consideration. This procedure is considered to be appropriate for low doses such as would potentially result from this site. The effects of exposure will be evaluated for the contaminants separately and as mixtures, if suitable data are available. As suggested in EPA guidance for evaluating mixtures, it may be useful to sum the excess cancer risks or to calculate hazard indices for chemical mixtures.

  Risk assessments will be conducted separately for each exposure pathway and for each source, when appropriate. Results will be presented separately for the "average case" and the "plausible maximum case" exposure assumptions. The risk assessment for each exposure pathway will include a discussion of the uncertainties in the estimates.

- <u>Qualitative Environmental Risk Assessment</u>. In addition to the assessment of risks to human populations, a qualitative environmental assessment will be conducted to determine potential risks to biota within the study area. Potential risks to sensitive populations will be identified. The qualitative risk assessment will be conducted in accordance with the Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual, Interim Final (EPA, 1989b).

6.6 CHEMICAL-SPECIFIC ARARS DEVELOPMENT

An Applicable or Relevant and Appropriate Requirements (ARARs) Report will be prepared which will include a general listing of federal and state chemical-specific ARARs. Those regulations, statutes, criteria or limitations which are determined to be either potentially applicable or relevant and appropriate to the Soldier Creek site will be discussed in detail. In addition, this report will include a discussion of other criteria to be considered (TBCs). The ARARs Report will be prepared in accordance with CERCLA Compliance with Other Laws Manual, Interim Final (EPA, 1988b) and CERCLA Compliance with Other Laws Manual: Part II. Clean Air Act and Other Environmental Statutes and State Requirements, Interim Final (EPA, 1989c).

6.7 REMEDIAL INVESTIGATION REPORT

The RI Report will include a discussion of the field investigations conducted at the Soldier Creek site, the nature and extent of contamination, contaminant fate and transport, and baseline risk assessment. The RI Report will be completed in accordance with the Guidance on Remedial Investigations under CERCLA (EPA, 1985b) and the Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (EPA, 1988c). The report will be presented in draft, draft final, and final versions.

6.7.1 <u>Draft RI Report</u>

The Draft RI Report will be submitted for review and comment. The report will include the following discussions:

- The site history.
- A site description.
- The activities performed during the Phase I field investigation.
- The physical characteristics of the Soldier Creek site.
- The nature and extent of contamination based on the analytical results from the Phase I field investigation.
- A discussion of contaminant fate and transport.
- Discussion of existing data gaps.

Appendices to the Draft RI Report will include a discussion of analytical methods used during the Phase I field investigation, the methods of data validation, and the validated data from the Phase I field investigation. Comments received on the Draft RI Report will be incorporated into the Draft Final RI Report.

6.7.2 Draft Final and Final RI Reports

The Draft Final RI Report will incorporate comments received on the Draft RI Report and results of the Phase II field investigation. Pertinent sections will be updated or modified based on the results of the Phase II investigation. The Draft Final Risk Assessment will also be included in the Draft Final RI Report. Comments received will be incorporated into the Final RI Report for final submission. The Final Risk Assessment will also be included in the Final RI Report.

6.8 MISCELLANEOUS ACTIVITIES

This task incorporates several activities which could potentially be required during the RI, but have not been fully defined at this time. These activities are outlined in the following subsections.

6.8.1 RI Secondary Reports

As a part of the RI, RI Secondary Reports may be necessary. The scope of these reports could include detailing any actions taken during the RI prior to completion of the Draft Final RI Report. The actual scope of these secondary reports will be defined as necessary during the course of the RI.

6.8.2 Review Conferences

It is anticipated that review conferences will be held during the progression of the RI activities. Review conferences are anticipated to occur after completion of the Draft and Draft Final RI Reports. Additional review conferences will be scheduled at the request of the Air Force.

6.8.3 Monthly Progress Reports

The Contractor's Project Manager shall prepare and transmit to the Tulsa COE Project Manager a monthly status report which will detail the following information:

- o Activities completed during the current reporting period.
- o Activities scheduled for completion during the next reporting period.
- o Outstanding information requests.
- o Percentage completion by task.
- o Problems encountered and corrective actions implemented.
- o Log of telephone conversations.

7.0 REMEDIAL INVESTIGATION SCHEDULE

The proposed schedule for completion of the RI for Tinker AFB-Soldier Creek RI/FS is presented on Figure 7-1. The RI schedule is plotted in number of weeks without specific dates, since the date for initiation of field activities has not been established. Figure 7-2 presents the proposed schedule of the Phase I field investigation, assuming the initiation of field activities in the middle of June 1990.

In preparing the schedule, it was assumed that normal weather patterns would prevail during field work activities. It was also assumed that the analytical results would be received from the CLP laboratory within four weeks of the date samples were submitted to the laboratory for analysis.

ACTIVITY	JUN 90	JUL 90	AUG 90	SEP 90	OCT 90	NOV 90	DEC 90	JAN 91	FEB 91	MAR 91	APR 91	MAY 91	JUN 91	JUL 91
MOBILIZATION														
PHASE I FIELD INVESTIGATION														
PHASE I SAMPLE/DATA ANALYSIS														
PHASE II FIELD INVESTIGATION														
PHASE II SAMPLE/DATA ANALYSIS														
DRAFT RI REPORT														
DRAFT ARARs REPORT *														
DRAFT RISK ASSESSMENT														
DRAFT FINAL RI REPORT **														
FINAL RI REPORT														
MISCELLANEOUS ACTIVITIES									#				#	

Notes:
- Schedule assumes Final Workplan is approved as of June 8, 1990
- * – Report includes only chemical-specific ARARs
- ** – Report contains Draft Final Risk Assessment
- # – Proposed Review Conferences

FIGURE 7-1
PROPOSED RI SCHEDULE
TINKER AFB-SOLDIER CREEK RI/FS
RI WORKPLAN

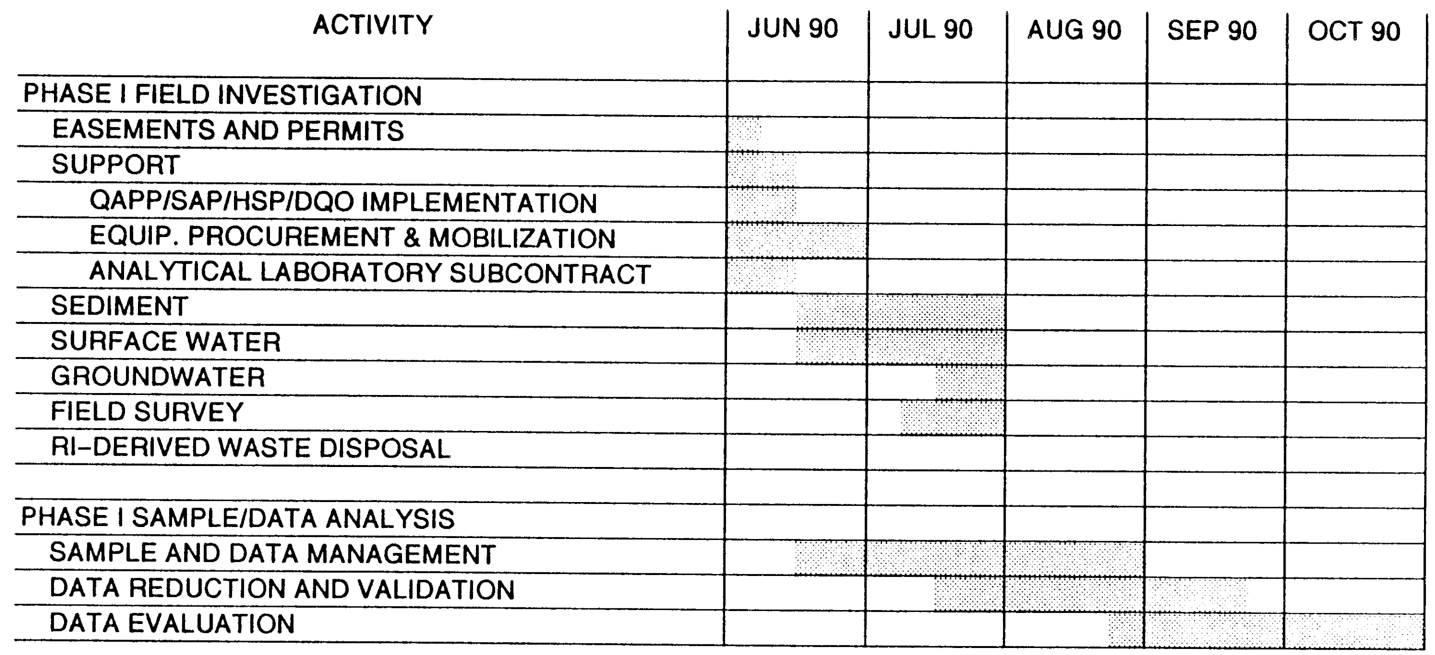


FIGURE 7-2
PROPOSED PHASE I FIELD INVESTIGATION SCHEDULE
TINKER AFB-SOLDIER CREEK RI/FS
RI WORKPLAN

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9.0 ABBREVIATIONS AND ACRONYMS

ADI	Acceptable daily intake
Ag	Silver
AFB	Air Force Base
As	Arsenic
ARAR	Applicable or Relevant and Appropriate Requirements
ATSDR	Agency for Toxic Substances and Disease Registry
AWS	American Weather Service
Ba	Barium
BOD_5	5-day biochemical oxygen demand
BNA	Acid, base/neutral extractables
BTX	Benzene, Toluene, and Xylene
BVWST	B&V Waste Science and Technology Corp.
CAS	Chemical Abstract Service
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
Cd	Cadmium
CFR	Code of Federal Regulations
CNS	Central nervous system
COD	Chemical oxygen demand
COE	U.S. Army Corps of Engineers
Cr	Chromium
Cu	Copper
DO	Dissolved oxygen
DQO	Data quality objectives
EKG	Electrocardiogram
EPA	U.S. Environmental Protection Agency
EWI	Equal-Width Increment
F	Degrees Fahrenheit
Fl	Fluoride
FS	Feasibility study
GAC	Granular activated carbon
Hg	Mercury
HHS	U.S. Department of Health and Human Services
HKS	Harry Keith & Sons, Inc.
HPLC	High-purity liquid chromatography water
HSM	Health and Safety Manager
HSP	Health and Safety Plan
IRP	Installation Restoration Program
IQ	Intelligence Quotient
IWTP	Industrial Waste Treatment Plant
Kg	Kilogram
l	Liter
LD50	Lethal dose to 50 percent of exposed population
m^3	Cubic meter
mg	Milligram
MGD	Million gallons per day

ml	Milliliter
mmole	Millimole
Mn	Manganese
mph	Miles per hour
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
Ni	Nickel
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
ONHI	Oklahoma Natural Heritage Inventory
O.S.	State of Oklahoma
OSDH	Oklahoma State Department of Health
OVA	Organic vapor analyzer
OWRB	Oklahoma Water Resources Board
Pb	Lead
PCB	Polychlorinated biphenyls
PCE	Tetrachloroethene
PM	Project Manager
POTW	Publicly-Owned Treatment Works
ppm	Parts per million
QAPP	Quality Assurance Project Plan
QA/QC	Quality assurance/quality control
RA	Risk assessment
RAS	Routine analytical services
RCRA	Resource Conservation and Recovery Act
RFD	Reference dose
RI	Remedial investigation
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SAS	Special analytical services
Se	Selenium
SPHEM	Superfund Public Health Evaluation Manual
STP	Sanitary Treatment Plant
TAL	Target Analyte List
TBC	To be considered
TCE	Trichloroethene
TCL	Target Compound List
t-1,2-DCE	Trans-1,2-dichloroethene
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TSS	Total Suspended Solids
USC	United States Code
USCS	Unified Soil Classification System
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UV	Ultra-violet
VOC	Volatile organic compounds
WQS	Water Quality Standards
Zn	Zinc