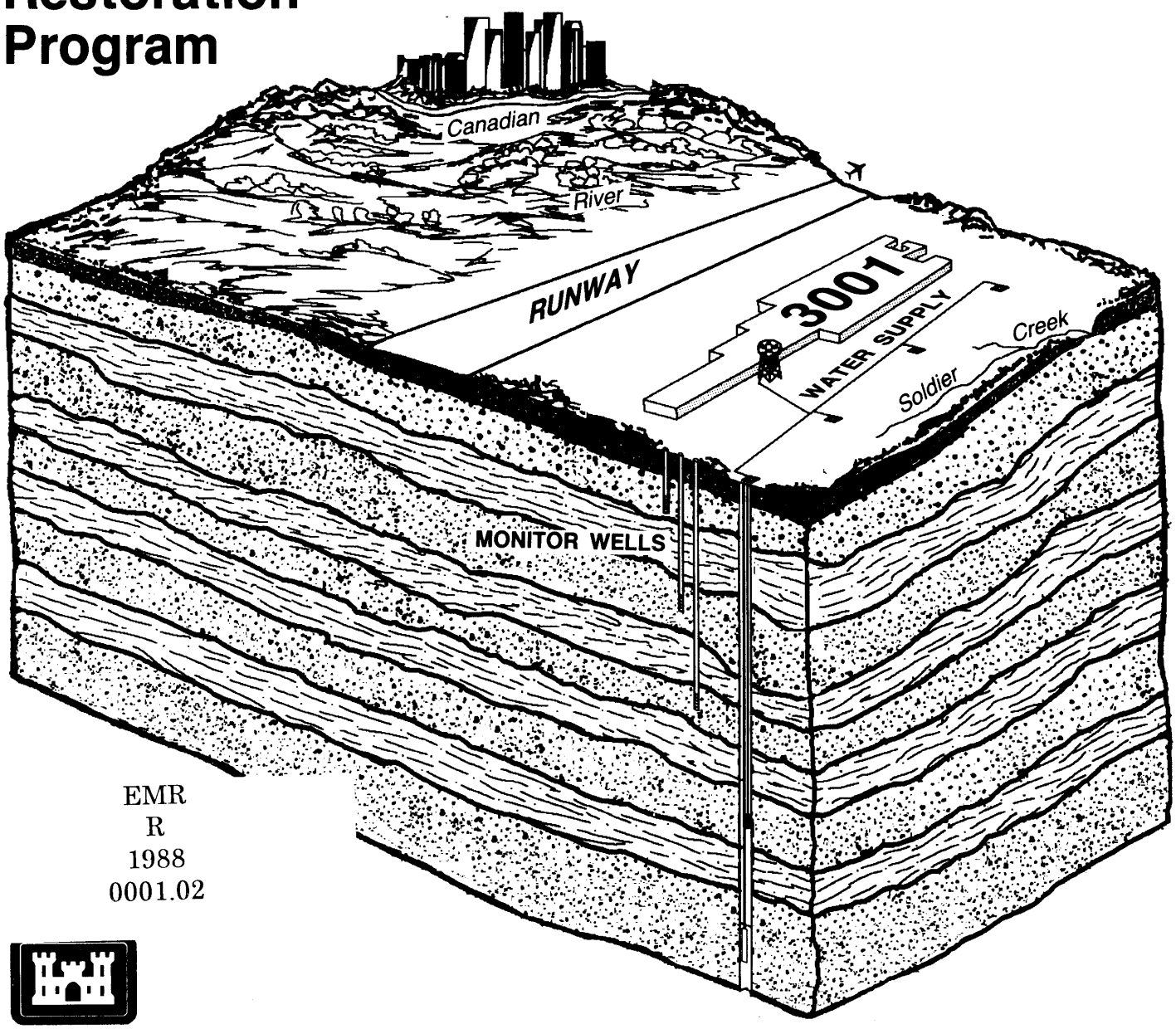
Building 3001
Remedial Investigations
Volume I - Report

TINKER AIR FORCE BASE
Installation
Restoration
Program



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US Army Corps of Engineers
Tulsa District

JANUARY 1988

BUILDING 3001
REMEDIAL INVESTIGATIONS

VOLUME I - REPORT

TINKER AIR FORCE BASE
INSTALLATION RESTORATION PROGRAM
PROJECT NO. WWYK86-311
SITE NO. TINKER 01

PREPARED FOR:
ENVIRONMENTAL MANAGEMENT DIRECTORATE
DEPARTMENT OF THE AIR FORCE
HEADQUARTERS OKLAHOMA CITY AIR LOGISTICS CENTER

PREPARED BY:
U.S. ARMY CORPS OF ENGINEERS
TULSA DISTRICT

JANUARY 1988

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TABLE OF FREQUENTLY USED ACRONYMS

Acronym	Meaning
ACOG	Association of Central Oklahoma Governments
AFB	Air Force Base
AFLC	Air Force Logistics Command
AFRCE	Air Force Regional Civil Engineer
CDC	Center for Disease Control
CE	Civil Engineering
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
COE	Corps of Engineers
EPA	Environmental Protection Agency
EM	Environmental Management
FS	Feasibility Study
IRP	Installation Restoration Program
NPL	National Priorities List
OGS	Oklahoma Geological Survey
OSDH	Oklahoma State Department of Health
OWRB	Oklahoma Water Resources Board
PHE	Public Health Evaluation
PPB	Parts Per Billion (equal to ug/l and ug/kg)
PPM	Parts Per Million (equal to mg/l and mg/kg)
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigations
SARA	Superfund Amendments and Reauthorization Act
TRC	Technical Review Committee
TWG	Technical Working Group
USGS	United States Geological Survey

TABLE OF FREQUENTLY USED CHEMICAL ABBREVIATIONS

Abbreviation	Meaning
Ba	Barium
Cd	Cadmium
Cr	Chromium
DCA	Dichloroethane
DCE	Dichloroethylene
Ni	Nickel
Pb	Lead
PCA	Tetrachloroethane
PCE	Tetrachloroethylene
TCA	Trichloroethane
TCE	Trichloroethylene

EXECUTIVE SUMMARY

Past industrial practices within and in the vicinity of Building 3001 have resulted in groundwater contamination of an underlying perched aquifer and upper zones of the Garber-Wellington Aquifer. The Environmental Protection Agency has placed the site on the Federal Facilities National Priorities List of hazardous waste sites. Remedial investigations have been conducted as part of the U.S. Air Force Installation Restoration Program (IRP) in order to define the extent and magnitude of contamination. This report presents the results of the remedial investigations.

Building 3001, located in the northeast portion of Tinker Air Force Base, Oklahoma, houses a large industrial complex where aircraft and jet engines are serviced, repaired, and/or upgraded. The primary contaminants are trichloroethylene (TCE) and chromium (Cr) although other organic compounds and trace metals are present. The maximum area of contaminated groundwater covers approximately 220 acres beneath the site and extends to a maximum depth of approximately 175 feet. The highest contaminant concentrations exist beneath the building in the perched aquifer, where 330,000 ug/l of TCE and 80,000 ug/l of Cr were detected. Two underground storage tank areas, referred to as the north and southwest tank areas, were included in the remedial investigations. Fuel product was found floating on the perched groundwater at the north tank area and both tank areas contain benzene, toluene, and xylene contamination in the perched groundwater.

The remedial investigations included records searching, investigating abandoned solvent pits within the building, investigating the hydrogeological site conditions, installing a groundwater monitoring well network, sampling water supply wells and monitoring wells, and conducting aquifer tests. As a corrective action, two water supply wells were permanently plugged during the course of the investigations. Data was analyzed in order to define the hydrogeologic conditions and extent of contamination. A groundwater and contaminant transport model was developed to simulate contaminant migration within the aquifer system.

The groundwater contamination is primarily a result of past industrial operations and storage practices which have now been corrected. Contamination probably entered the perched aquifer by vertical migration from solvent pits inside the building, storm drains, West Soldier Creek, and underground storage tanks.

The hydrologic and hydrogeologic systems at the site are complex and interdependent. Runoff is carried to East and West Soldier Creeks by surface drainage and storm drains. Both West Soldier Creek and the storm drain system apparently recharge a perched aquifer beneath the site. In the past, contaminants were discharged into storm drains and later detected in both East and West Soldier Creeks. The contaminants are also present in the perched aquifer. Hydrogeologic investigations indicate that the perched aquifer (beneath the east portion of the building) discharges into East Soldier Creek, providing the potential of contaminants being discharged into East Soldier Creek. The TCE and Cr plumes were modeled to simulate contaminant migration over time without any remedial actions to collect water or control the plumes. The highest concentrations of TCE and Cr beneath the building in the perched zone would decrease by an order of magnitude in the first 25 years of simulated time. The TCE and Cr plumes move about 20 feet per year toward the west and 15 feet per

year toward the east in the perched aquifer. As the eastward moving plume nears East Soldier Creek, the rate of migration increases to about 50 feet per year. Over 50 years of simulation (beginning with the present plume shape), the plumes remain within the Base property boundaries except where the plumes discharge to East Soldier Creek and are allowed to flow off-Base. TCE concentrations greater than 100 ug/l are predicted to reach the creek within 10 years. The perched aquifer and East Soldier Creek are sources of contamination to the regional aquifer.

The regional aquifer is contaminated in the upper two more permeable zones, referred to as the top of regional and regional zones. The geologic formations are characterized by very low vertical permeabilities and therefore limited vertical migration has occurred compared to horizontal migration. The horizontal spread has extended beyond water supply well locations within Tinker AFB and has allowed migration of contaminants down the sides of poorly sealed wells. Two wells have been plugged (wells 18 and 19) and two wells (wells 15 and 16) currently contain trace levels of organic compounds.

TCE and Cr Plumes in the regional aquifer are moving toward the west at a maximum rate of approximately 20 feet per year. Over 50 years of simulation, the plumes remain within the Base property boundaries. The water supply wells on Base produce from zones of approximately 250 feet to 700 feet. The pumpage of these wells have no apparent effect on the upper contaminated groundwater zones. The primary concern is from vertical migration down the well shafts.

The contaminated groundwater and the presence of 2 fuel contaminated sites are primary public health and environmental concerns. A feasibility study has been initiated to develop remedial actions for the site. All monitoring wells at the site will be resampled annually and selected monitoring wells and water supply wells near the building will be sampled quarterly prior to implementation of remedial actions.

CHAPTER 1

INTRODUCTION

1.1 Purpose and Scope. Past activities within and in the vicinity of Building 3001 have resulted in contamination of the upper groundwater zones with industrial solvents, metals, and fuel products. The primary contaminants are trichloroethylene (TCE) and chromium (Cr). Building 3001, located in the northeast portion of Tinker Air Force Base (AFB), houses a large industrial complex where aircraft and jet engines are serviced, repaired, and/or upgraded. The Environmental Protection Agency (EPA) has placed the site on the National Priorities List of hazardous waste sites. Remedial investigations have been conducted at the site by the Tulsa District Corps of Engineers (COE) in order to define and characterize the sources, extent, and magnitude of the contamination. The investigations are part of the U.S. Air Force Installation Restoration Program (IRP). This report presents the data, conclusions, and recommendations from these remedial investigations. All work to date has been reviewed and discussed by the Technical Working Group (TWG), which consists of members from Tinker AFB, Tulsa District COE, Region VI of the EPA, Oklahoma State Department of Health (OSDH), Oklahoma Water Resources Board (OWRB), Garber-Wellington Association, Air Force Regional Civil Engineer (AFRCE), and others. Investigations and interim actions have been approved by the Technical Review Committee (TRC), consisting of Colonel Ray Reaves, Tinker AFB, Robert Hanneschlager, Region VI EPA, and Marc Coleman, OSDH. The minutes of the TRC and TWG meetings are contained in Appendix A.

1.2 Location . Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan complex, in Oklahoma County. The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. Building 3001 is located in the northeast portion of the Base, east of the north-south runway. Figure 1-1 shows the location of the Base.

1.3 Site Description. The Building 3001 site (as referred to in this report) includes the building complex (covering 50 acres), two adjacent underground storage tanks areas, and the surrounding areas encompassed by the lateral extent of the contaminant plume. The site is located near the northeast boundary of the Base and covers an area of approximately 220 acres. A site map is shown in figure 1-2. The underground storage tank areas include one site immediately north of the building and one site southwest of the building, immediately southwest of Building 3108. This report refers to these sites as the north and southwest tank areas.

a. Building 3001 Complex. The building complex houses an aircraft overhaul and modification complex to support the mission of the Oklahoma City Air Logistics Center. The primary industrial activities conducted in the building (since operations began in the early to mid-1940's) are listed in Table 1.1. Some industrial processes use or generate solutions containing solvents and metals similar to contaminants found in the underlying groundwater. Organic solvents were used for cleaning and degreasing metal engine parts. Trichloroethylene (TCE) was the predominant solvent used from the 1940's until

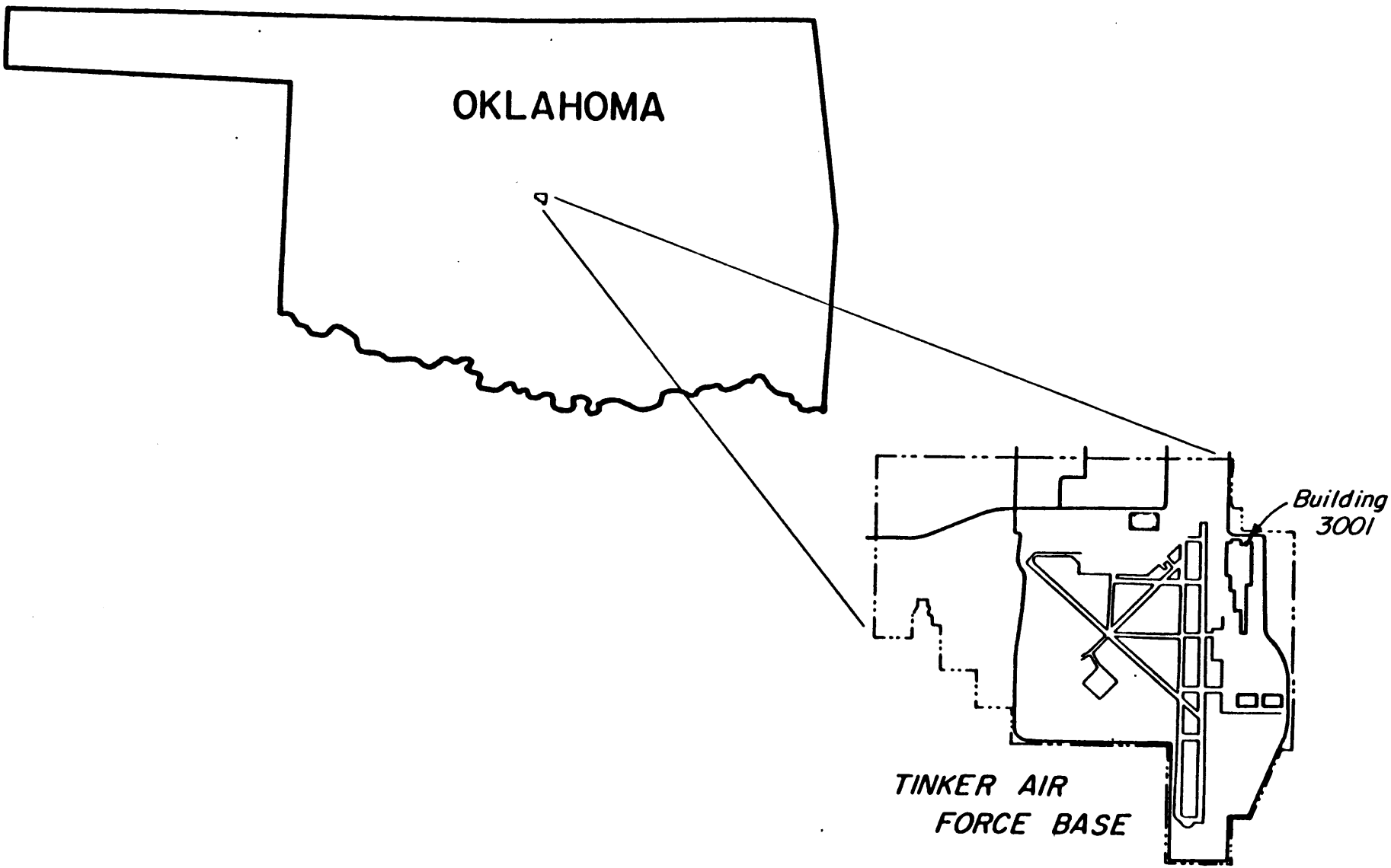


Figure 1-1. Location of Tinker Air Force Base within Oklahoma.

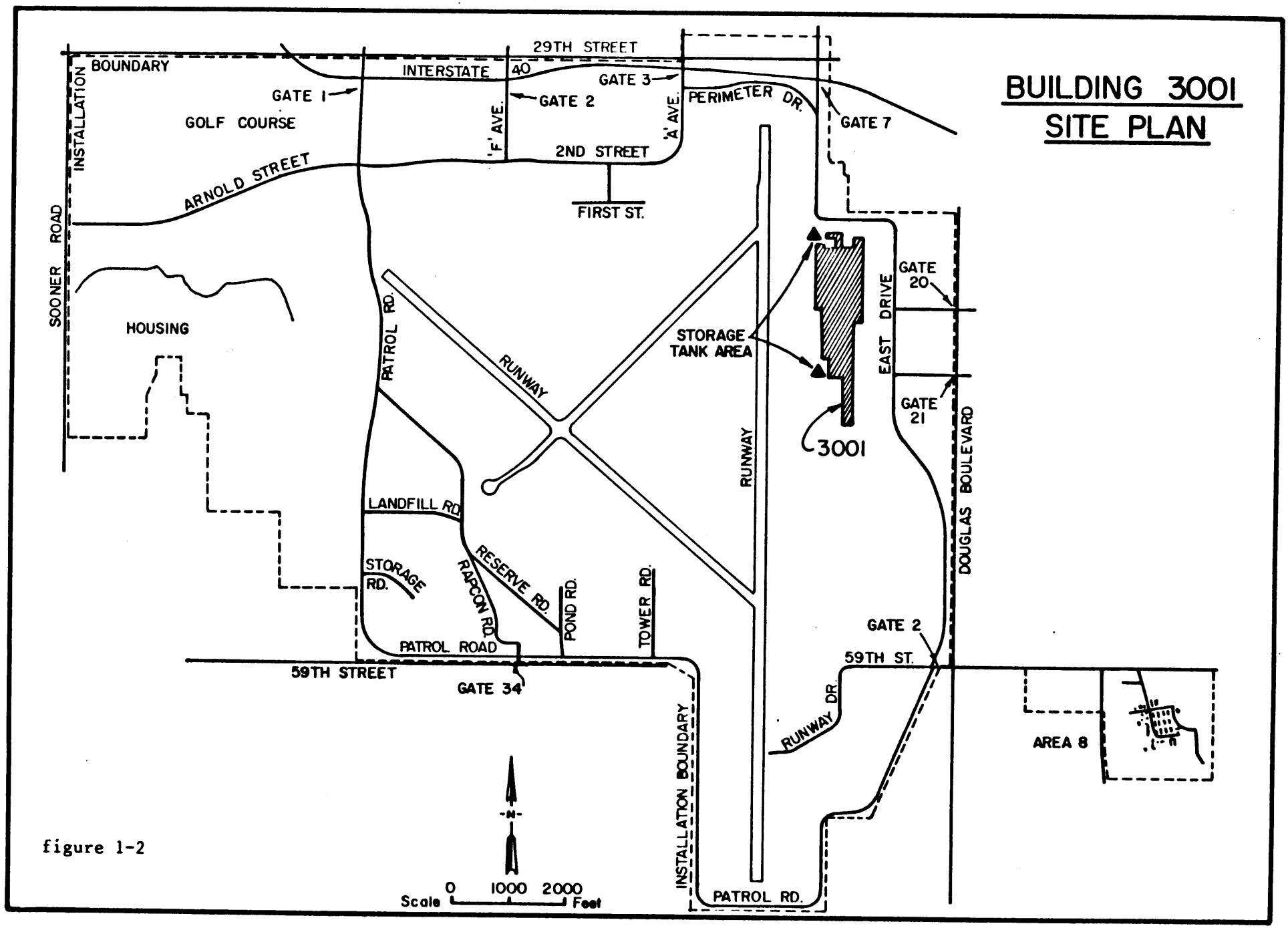

BUILDING 3001
SITE PLAN
29TH STREET
INTERSTATE 40
BOUNDARY
INSTALLATION
GATE 1
GOLF COURSE
GATE 2
'F' AVE.
GATE 3
'A' AVE.
PERIMETER DR.
GATE 7
2ND STREET
ARNOLD STREET
FIRST ST.
SOONER ROAD
HOUSING
PATROL RD.
RUNWAY
STORAGE TANK AREA
3001
EAST DRIVE
GATE 20
GATE 21
DOUGLAS BOULEVARD
LANDFILL RD.
STORAGE RD.
RAPCON RD.
RESERVE RD.
POND RD.
TOWER RD.
PATROL ROAD
59TH STREET
GATE 34
GATE 2
59TH ST.
RUNWAY DR.
AREA 8
INSTALLATION BOUNDARY
PATROL RD.
N
0 1000 2000
Scale Feet

figure 1-2

the 1970's. The degreasing operations were conducted in tanks set below the floor level in concrete pits. In the early 1970's, tetrachloroethylene (PCE) began to replace TCE and also pits were replaced with degreasing equipment, where the entire system (pit, piping, pumps, etc.) is above ground. The subsurface pits were abandoned typically by backfilling with sand and capping with concrete. Cleaning operations may have included paint stripping in which the stripper and the wastewaters produced contained high concentrations of metals (particularly chromium). Waste materials generated from plating, painting, and heat treating activities contain both solvents and metals. Subsurface contamination occurred by leakage from trenches and pits, erroneous discharging of solvents or wastewaters into storm drains, accidental spills, and/or improper connections between wastewaters and storm drains.

Table 1.1
Industrial Activities Within Building 3001

1. Disassembly, degreasing, cleaning, and inspection of aircraft and engine parts and components;

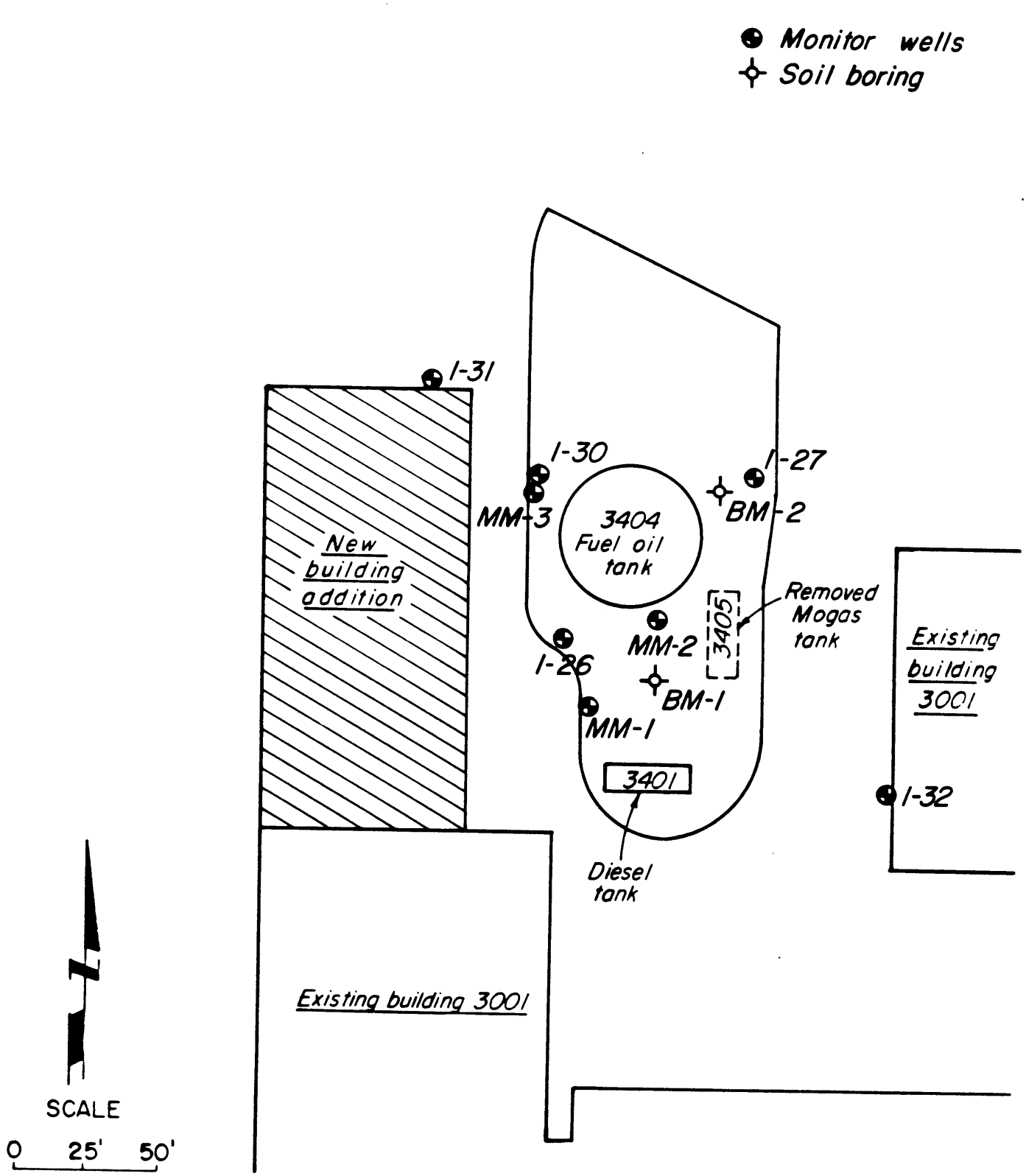
2. Plating, painting, heat treating, and testing of metal parts and components;

3. Assembly and repair shops for accessories including electrical, valve and governor, gear box, tubing and cable, fuel controls, nozzles, pumps, and bearings;

4. Assembly, testing, and packaging of aircraft and aircraft components.

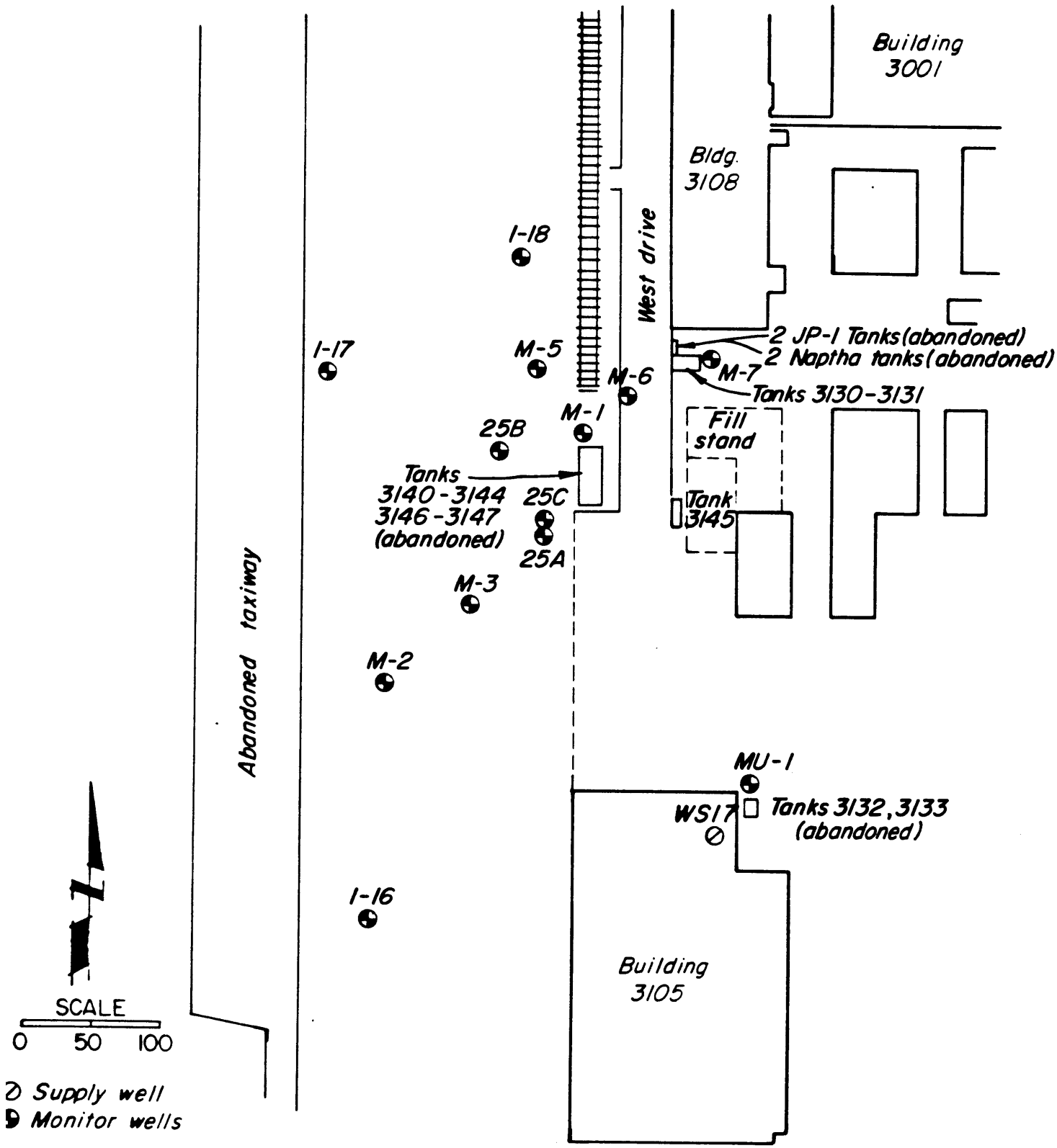
b. North Tank Area. The north tank area contains an active underground fuel oil tank (tank number 3404, approximately 235,000 gallons) and an active underground diesel tank (tank number 3401, approximately 20,000 gallons). An abandoned gasoline tank (tank number 3405, approximately 13,000 gallons) was removed from the site in 1985. The site, shown in figure 1-3, is a small grassed area covering approximately 16,400 square feet. The soil and groundwater have become contaminated with fuel product, benzene, toluene, and xylene, due to leaking tanks and/or possible fuel spills. Also, some metals and organic solvents are present in the groundwater, which may be a result of leaking utility lines in the area.

c. Southwest Tank Area. The southwest tank area contains both abandoned fuel tanks and abandoned solvent tanks. The tanks and their original contents are listed in Table 1.2. Also, two active 12,000 gallon solvent tanks, containing PD680 Solvent, are located south of Building 3108 (tank numbers 3130 and 3131). The site location, which covers approximately 2.5 acres, is shown in figure 1-4. The groundwater in this area is contaminated with toluene, benzene, and xylene, which likely occurred from past leaking tanks and/or possible spills. Also some metals and solvents, probably originating from inside Building 3001, are present in the groundwater.



SITE PLAN
NORTH TANK AREA

FIGURE 1-3



SITE PLAN
SOUTHWEST TANK AREA

FIGURE 1-4

Table 1.2
Southwest Tank Area Abandoned Tanks and Original Contents

Tank* No	Size (gal)	Original Contents	Remarks	Information Source
3140	20,000	Gasoline	Abandoned in 1972	Dwg 3130-3150-F-4 and Ref. 7
3141	20,000	Gasoline	"	"
3142	20,000	Gasoline	"	"
3143	20,000	Gasoline	"	"
3144	20,000	Gasoline	"	"
3145	10,000	Lubricating Oil	Converted to solvent storage in late 1960's Abandoned in 1972	"
3146	9,000	Gasoline Dump	Abandoned in 1972	"
3147	9,000	Oil Dump	"	"
3132	3,800	Naptha	"	Dwg 3130-3150-F-17-18
3133	3,800	Solvent Stoddard	"	"
—	1,000	JP-1	"	Ref. 7
—	1,000	JP-1	"	"
—	1,000	Naphtha	"	"
—	1,000	Naphtha	"	"

*See figure 1-4 for tank locations.

1.4 Nature and Extent of the Problem. The past activities within Building 3001 have resulted in gross contamination of the groundwater with chlorinated solvents and heavy metals to a maximum depth of approximately 175 feet. The primary contaminants are TCE and Cr, where their composite plumes extend laterally across an area of approximately 220 acres in the groundwater, all of which is located within 1800 feet of Building 3001 and beneath the boundaries of Tinker AFB. Chemical tests of the valency states of the Cr indicate that most of it is hexavalent chromium (Cr^{+6}). Other contaminants exist at the site including fuel product at the north storage tank area and benzene, toluene, and xylene at both the southwest and north storage tank areas.

Contaminants exist in the soil near the surface and in the perched aquifer and upper portions of the regional aquifer. These contaminants have been identified by an extensive monitoring well network, which is shown on drawing 1. Monitoring wells typically monitor the perched water table, from 15 to 30 feet, the top of the regional aquifer, which is the first major water bearing unit of the Garber-Wellington Formation at depths of 50 to 80 feet, and the regional zone, which is deeper into the Garber-Wellington aquifer at depths of 110 to 175 feet. More detailed discussion of groundwater zones is found in section 8.2.

a. Contamination Sources. During the period from the 1940's to the 1970's, industrial solvents and wastewaters inside Building 3001 were contained in subsurface pits and trenches (some were steel-lined and some were concrete-lined), some of which leaked and allowed percolation and downward subsurface migration. Also, some solvents and wastewaters were drained to the storm drain system in the building. The storm drains discharged to the east and west sides of the building into tributaries of Soldier Creek, commonly referred to as East and West Soldier Creek. Some contaminants were carried into the creeks (ref's. 1, 15, and 20), however, some leakage from storm drain pipes probably occurred, allowing downward migration into the perched aquifer. Some of the discharge to storm drains occurred from improper tie-in connections between industrial waste lines and storm drains. In the early 1970's, solvent pits began to be replaced with above ground pits. Most of the subsurface pits were backfilled with sand and covered with a concrete cap. Based on investigations within the building for abandoned pits still containing contaminants, (conducted in the north portion of the building in 1985 and south portion in 1986) only seven were found to contain any significant contamination. The contents were removed from three of these pits during a reconstruction period in the fire-damaged portion of the building (see appendix B for detailed report). The other four pits are recommended for removal. Three of these pits contain low concentrations of solvents (TCE, 1,1,1-trichloroethane, and xylenes) and one pit contains high concentrations of metals (cadmium and lead). Tinker AFB personnel are evaluating and correcting the industrial waste piping errors to ensure that industrial waste is no longer discharged into storm drains (ref. 16 and 19).

Underground tanks within the north and southwest tank storage areas allowed leakage into the soils and groundwater. The southwest tank area contains both active and abandoned tanks. Two active fuel tanks are present in the north tank area. Fuel product sampled in the soil and groundwater in the north tank area was identified as fuel oil which is contained in one of the tanks (tank number 3404, approximately 235,000 gallons). The fuel product is evidently the result of leaks in the tank, although some contamination may have resulted from spills.

b. Soil Contamination. The soil is contaminated in localized areas beneath the building and in the north tank area. The soils and bedrock (above the perched water table) became contaminated in areas beneath the building as contaminant migration occurred. Concentrations of TCE, 1,2-dichloroethylene (DCE), PCE, methylene chloride, benzene, 1,1,1-trichloroethane (TCA), chlorobenzene, and methyl ethyl ketone were all detected in localized areas beneath the building. Concentration levels are low except in two locations, where high concentrations of TCE (120 and 11 mg/kg in two locations) are present. Cr, lead (Pb), barium (Ba), and cadmium (Cd) are also present in areas. Although most contamination sources have been eliminated, the soils beneath the building will continue to flush contaminants into the perched aquifer for a number of years.

The upper soils at the north tank area contain fuel contamination, primarily fuel oil. Significant contamination was not observed in the upper soils at the southwest tank area.

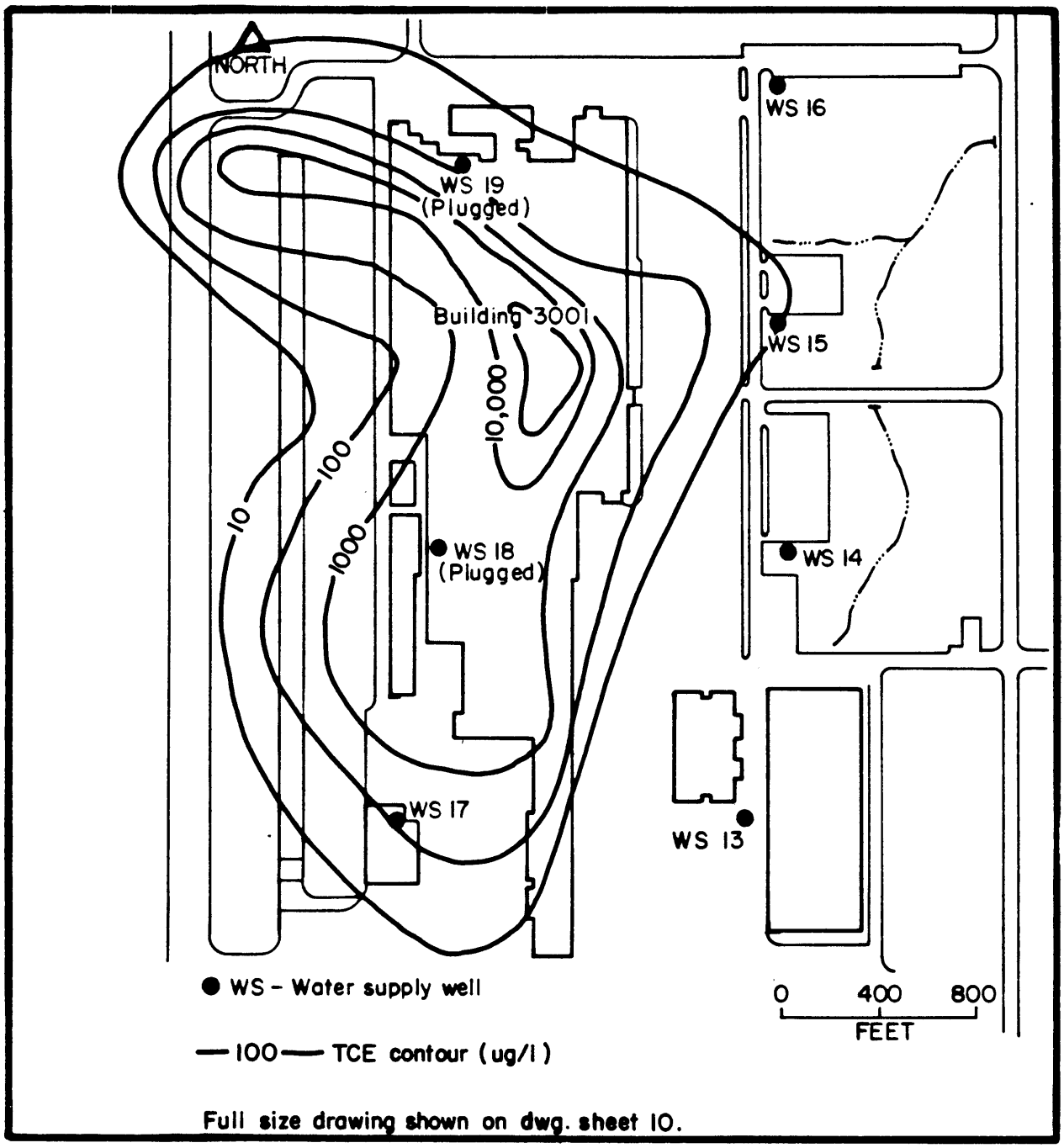
c. Perched Aquifer. Perched groundwater exists beneath the site, overlying the regional aquifer. The highest concentrations of contaminants are contained in this zone. Contamination occurred from percolation of liquids laden with solvents, metals, and fuel products. TCE is spread beneath the site with concentrations ranging from 330,000 ug/l beneath the building to less than 5 ug/l at the limits of the plume. The TCE plume, which covers approximately 140 acres, is shown in figure 1-5. 1,2-DCE is present with a similar shaped plume and the highest concentrations (4600 ug/l detected) located west of the building. PCE exists primarily beneath the building with the highest concentration of 260 ug/l located beneath the building. Plumes of 1,2-DCE and PCE cover approximately 78 and 17 acres respectively. Toluene, benzene, and xylene are found at the north and southwest tank area and fuel product (approximately 6,000 - 12,000 gallons is estimated) is found floating above the groundwater at the north tank area. The maximum concentrations of toluene, benzene, and xylene were 47000, 1535, and 780 ug/l, respectively. Cr, Pb, and Ba, at levels in excess of primary drinking water standards, are present in the perched zone also. Cr is present beneath the site with concentrations ranging from 80,000 ug/l beneath the building to less than 10 ug/l. The Cr plume, which covers approximately 220 acres, is shown in figure 1-6. Pb and Ba have similar shaped plumes with the highest concentrations detected as 570 and 28,000 ug/l for Pb and Ba, respectively.

The perched water is not used as a water supply source on-Base or off-Base. Yields within this zone are very low and the quality is generally poor, with high concentrations of chlorides and sulfates (background averages for chlorides and sulfates are 297 and 83 mg/l respectively). Discontinuities in underlying shales which support the perched water allow migration of groundwater between the perched zone and regional aquifer and therefore, percolation of contamination into the regional zone (reference paragraph 1.4d).

d. Regional Aquifer. Regional groundwater exists in the Garber-Wellington formation under both water table and confining conditions, depending on the presence of overlying shale beds. The upper, non-producing portion of the aquifer has been divided conceptually into two zones, the top of the regional zone and the regional zone. Below these zones, at depths of 250 to 700 feet, groundwater is pumped by Tinker AFB and is referred to as the producing zone. These zones are discussed below.

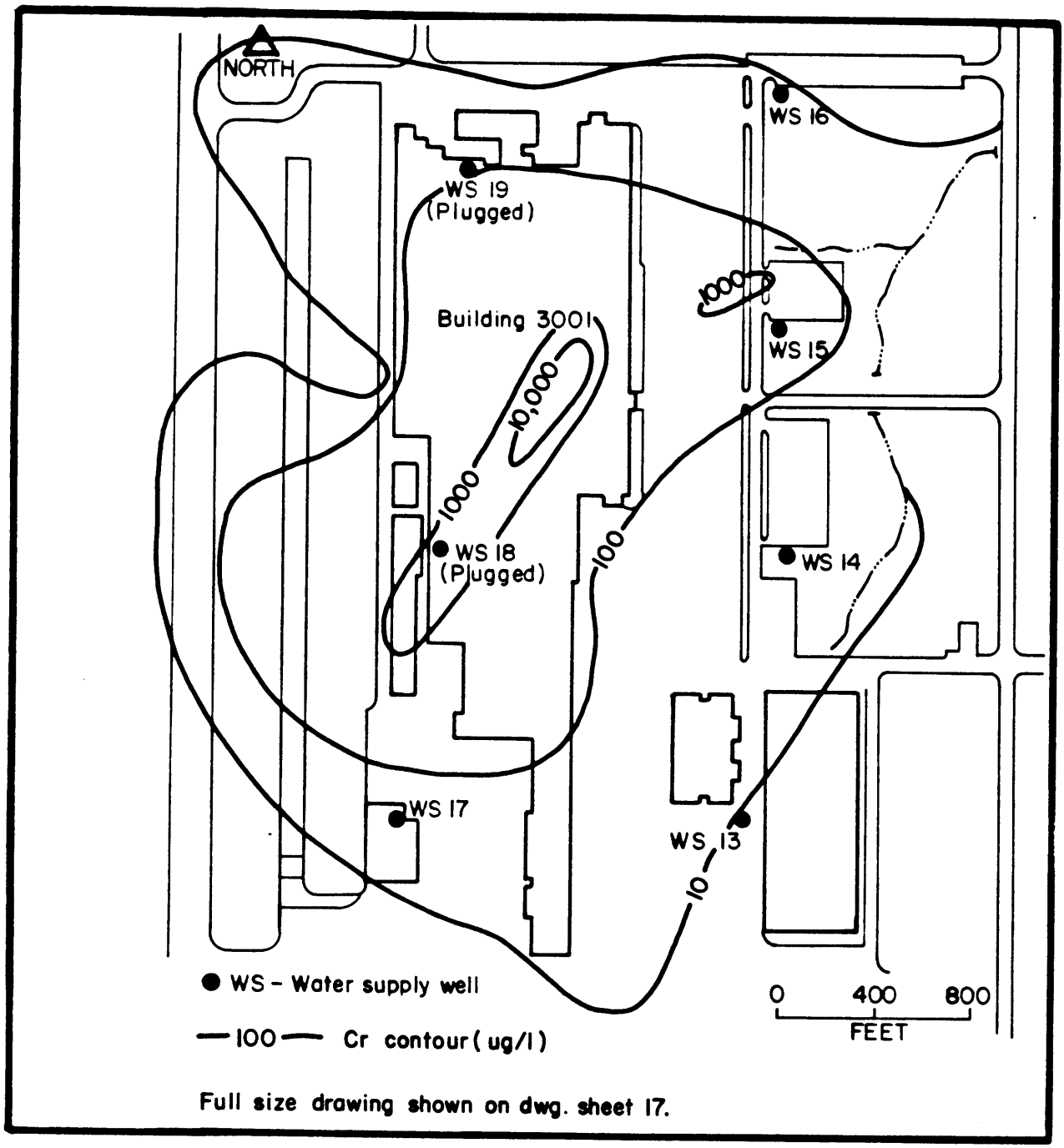
1) Top of the Regional Zone. TCE, 1,2-DCE, Cr, Pb, and Ba are all present in the aquifer in concentrations generally lower than in the perched zone. Concentrations of PCE are slightly higher in this zone. TCE and Cr, the primary contaminants, were detected with maximum concentrations beneath the building of 30,000 ug/l for TCE and 1700 ug/l of Cr. The contaminant plumes of TCE and Cr cover approximately 181 and 153 acres respectively and are shown in figures 1-7 and 1-8. The highest concentration of 1,2-DCE was 1400 ug/l in an area northeast of the building. The plume shape is similar to the TCE plume. PCE is present primarily beneath the building with the highest concentration detected at 1200 ug/l. Ba and Pb exist in plumes with similar shapes as Cr. The maximum concentration of Ba was 24,000 ug/l and the maximum concentration of Pb was 410 ug/l.

One area northeast of the building contains higher concentrations of TCE, 1,2-DCE, PCE, and Cr and also contains high concentrations of chlorobenzene and vinyl chloride, which were not detected in significant concentrations throughout

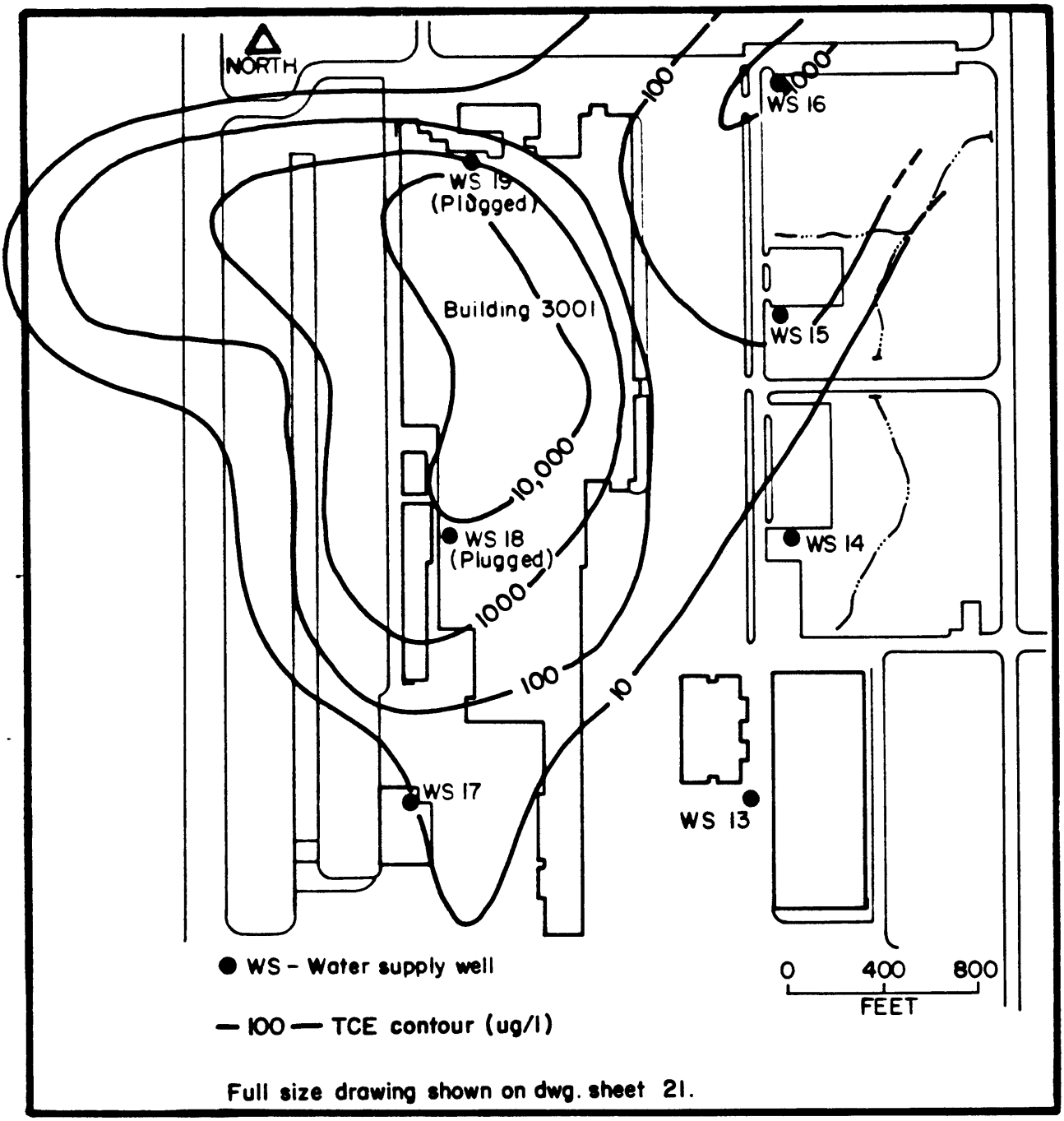


TCE PLUME IN PERCHED AQUIFER

FIGURE 1-5

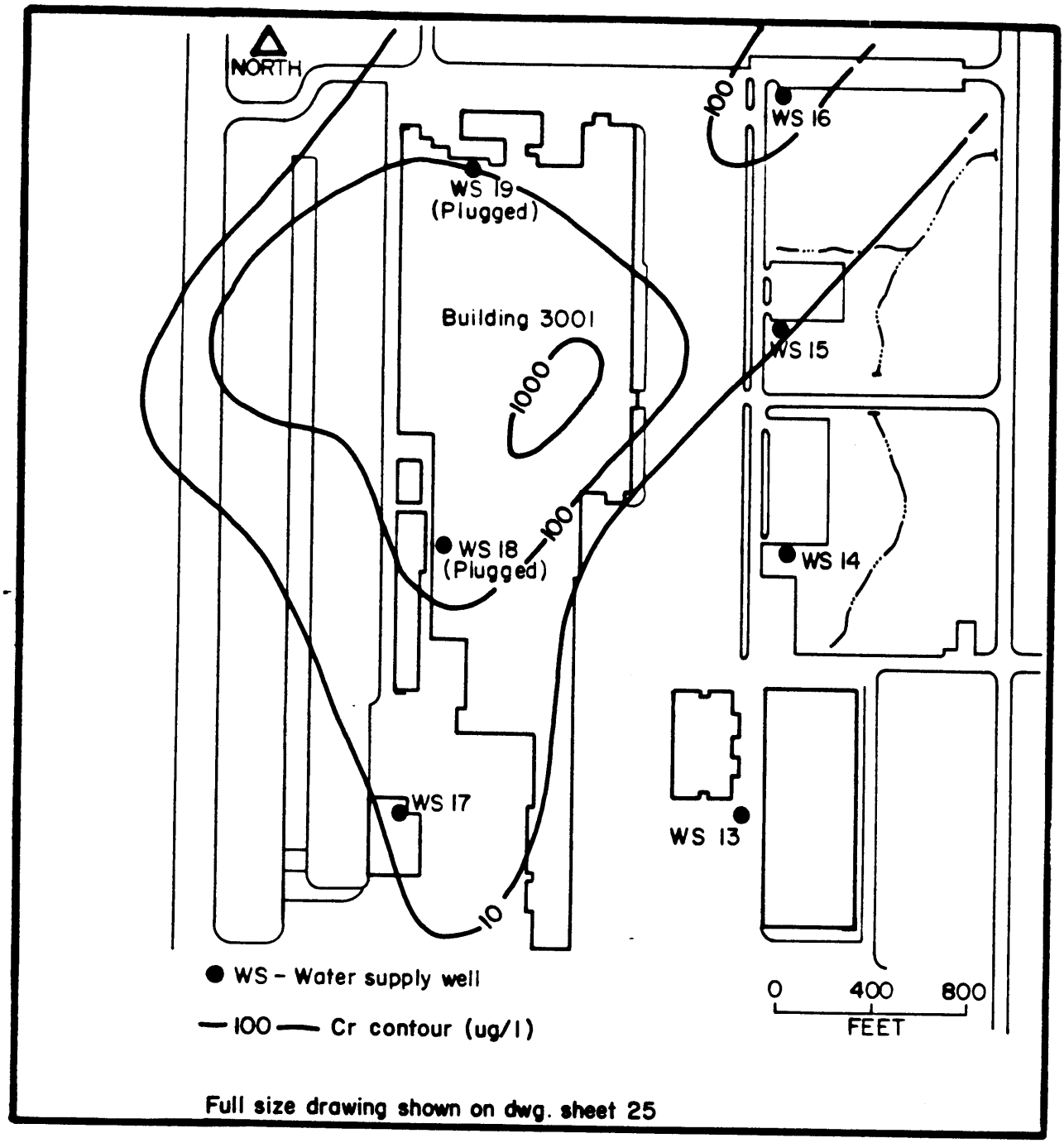


CR PLUME IN PERCHED AQUIFER
FIGURE 1-6



TCE PLUME IN TOP OF REGIONAL ZONE

FIGURE 1-7



CR PLUME IN TOP OF REGIONAL ZONE

FIGURE 1-8

the rest of the site. This area is upgradient from the site and the contaminants have evidently migrated from a different source, perhaps off-Base.

2) Regional Zone. The significant organic compounds found in this zone are TCE and 1,2-DCE, with concentrations much lower than in the top of the regional zone. The maximum concentrations of TCE and 1,2-DCE were 1000 and 46 ug/l, respectively. The extent to which contaminants have migrated in the regional zone is significantly less than in the top of the regional zone. Contaminants are concentrated primarily beneath the building. The TCE plume covers approximately 78 acres. Cr is also present with a maximum concentration of 1200 ug/l beneath the building. The plume covers approximately 145 acres. The regional zone is not used as a water supply source on-Base. The producing zone begins at approximately 100 feet below the bottom of this layer.

3) Producing Zone. There are 25 existing water supply wells on-Base which pump groundwater from this zone. Seven water supply wells were located in the vicinity of Building 3001 (well numbers 13-19). These well locations are shown on drawing 1. Wells 18 and 19 contained TCE and PCE and were taken out of operation in 1984 and recently plugged (as described in paragraph 2.4). These wells were within the horizontal limits of the TCE and PCE plumes and the poor condition of the wells allowed for vertical migration. Wells 15 and 16 contain trace levels of TCE and well 16 also contains trace levels of 1,2-DCE and PCE. Well 17, which is near the southwest corner of the building, is likely to contain these compounds also, but has not been tested because it is out of service.

e. Soldier Creek. Past discharges into East and West Soldier Creeks have resulted in contamination of creek waters and sediments. Storm water sewers draining into the creeks have carried discharges of industrial wastes due to improper connections between industrial wastewater lines and storm drains, and the washing down or possible dumping of waste liquids or solvents into drains. Geotechnical investigations have shown that the perched aquifer beneath the east portion of Building 3001 partially discharges towards East Soldier Creek. The potential for contaminant migration into the creek exists, although contaminant concentrations are low in the perched groundwater near the creek.

Past sampling of sediments in East Soldier Creek have shown the presence of heavy metals, and volatile organic compounds (ref's. 11, 14, 15, and 18). A cleanup operation was conducted in early 1986 to remove the contaminated sediments. Sampling of sediments and creek waters is continuing.

1.5 Summary of Remedial Investigations. The remedial investigations were conducted in order to properly assess the subsurface conditions and implement a remedial action plan. The field and laboratory work required to accomplish this objective included investigating abandoned solvent pits within the building, investigating the geological site conditions, installing a groundwater monitoring well network, sampling water supply wells and monitoring wells, and conducting aquifer tests. As a corrective action, water supply wells 18 and 19 were plugged during the course of the investigations. All of the field and laboratory work was conducted in accordance with a Quality Assurance/Quality Control Plan (attached in Appendix H). The collected data was analyzed in order to define the contamination problem at the site. A groundwater and contaminant transport model

was developed (Appendix K) to simulate the contaminant movements within the aquifer systems.

1.6 Overview of Report. The remainder of the report presents background information, site features, and the details, results, and conclusions of the investigations conducted at the site. Chapter 2 presents a summary of background events which preceeded or occurred during the remedial investigations. The general site features are discussed in chapter 3 and chapter 4 contains the data and results of the investigations of wastes found on-site. Chapter 5 discusses the affected surface waters and summarizes past surface water investigations conducted in the affected areas. Air quality at the site is discussed in chapter 6. Chapter 7 identifies the affected flora and fauna in the area. The hydrogeology is discussed in chapter 8 including summaries of the investigations, data collected, and investigation results. The public health and environmental concerns of the contamination problem are presented in chapter 9 and the conclusions of the investigations are presented in chapter 10. Also several appendices are attached which contains pertinent data and reports that are too lengthy to include in the text.

CHAPTER 2

BACKGROUND INFORMATION

2.1 Previous IRP Investigations. The previous IRP work conducted at the site consisted of records search, field evaluation, and confirmation/quantification investigations. The Records Search, conducted by Engineering Science in 1982 (ref. 7), reviewed current and past waste management practices in an effort to identify areas with a potential for contaminant migration. The Field Evaluation, conducted by Radian Corporation in 1984 (ref. 17), investigated the site to determine if contamination had resulted from past waste disposal practices. The Field Evaluation included pumping water supply well 18 (for 16 hours) where volatile organics including TCE and PCE had previously been found, and periodically collecting samples for volatile organic testing. TCE concentrations ranged from 4600 to 1800 ug/l during the pumping period and PCE remained below detection limits. The Quantification/Confirmation report, prepared by Radian Corporation in 1984 (ref. 18), determined that contamination existed at the site and recommended that additional investigations be performed to define the site conditions. Monitoring wells were installed at seven locations around the building (well numbers 19A, 20A, 21A, 22A, 23A, 24A, and 25A) during these investigations. TCE concentrations of 642 and 102 ug/l were found in wells 19A and 20A, respectively. Other substances such as chlorobenzene and trans-1,2-DCE were detected in relatively high concentrations at some locations. The conclusions drawn from the previous IRP reports were that any abandoned pits and tanks beneath Building 3001 should be sampled and analyzed for the presence of chlorinated solvents, the area of contamination should be defined, and a remedial action plan should be initiated for the contaminated groundwater.

2.2 Investigations Within Fire-Damaged Area. In November of 1984, the roof of the north portion of Building 3001 north of column-line 81 was extensively damaged by fire. During May through August 1985, the Tulsa District COE conducted IRP investigations within this fire-damaged area as reconstruction was in progress. The work consisted of investigating abandoned pits, conducting groundwater investigations, and installing monitoring wells. Sixty-four pits were located and investigated. One pit (located near column-row E105) contained high TCE concentrations (120 mg/kg were detected in the soil adjacent to the pit). Two other pits (near column-rows V85 and LM 107) contained high concentrations of metals. The pit near V85 contained 25,600 mg/kg of lead and the pit near LM 107 contained 106 mg/kg of lead. The contents of the three pits were removed and disposed of in a hazardous waste landfill. The groundwater investigations revealed an upper perched aquifer overlying the regional Garber-Wellington aquifer. TCE contamination was present in both the perched zone and the top of the regional aquifer. Groundwater monitoring well clusters were installed at four locations within the fire-damaged area so that quality monitoring could be continued. Each well cluster consisted of three wells, one located in the perched aquifer, one in the top of the regional aquifer, and one approximately 75 feet into the regional aquifer. Appendix B discusses the investigations within the fire-damaged area. The columns and rows refer to the internal grid system at Building 3001 and are shown, along with the pits investigated, in plate 4 of Appendix B.

2.3 Underground Storage Tank (UST) Investigations. An investigation of abandoned and active underground storage tanks at Tinker AFB was conducted by A.L. Burke Engineers, Inc., in 1985 (ref. 3). The investigations included locating underground tanks and analyzing samples of soil, groundwater, and hydrocarbons from areas adjacent to tanks to determine if subsurface contamination existed from leaking tanks. Two contaminated storage tank areas (north tank area and southwest tank area) were identified during the investigations. The north tank area (figure 1-3) contains an active fuel oil tank (tank number 3404) and an active diesel tank (tank number 3401). An abandoned gasoline tank (tank number 3405) was removed during the course of the investigation (1985). Three monitoring wells (MM-1, MM-2, and MM-3) were installed adjacent to the tanks. Free fuel product was observed in two of the wells (MM-1 and MM-3). The southwest tank area (figure 1-4) contains both abandoned fuel tanks and abandoned solvent tanks. Seven monitoring wells were installed adjacent and downgradient of the tanks during the investigations (wells M-1 through M-7). Minor amounts of fuel product were observed, but groundwater samples contained concentrations of benzene, toluene, and xylenes. Both tank areas are included in the Building 3001 Remedial Investigations conducted by the COE.

2.4 Plugging of Wells 18 and 19. In late 1983 routine Air Force testing indicated the presence of both TCE and PCE in water wells 18 and 19. The wells were taken out of service, and a contract was awarded with Engineering Enterprises (ref. 17) that next year to make a study of the wells. They conducted pump tests, took water samples, and performed a television log. In 1986, Dansby and Associates (ref. 18) cleaned the wells, conducted geophysical logging and televising operations, set packers and took stratified water samples, and did an environmental assessment on possible interim actions (ref. 19). The results of these investigations showed that the casings in both wells were highly corroded and that the cement bond was not very good in well 18. Channeling and downward movement of water was indicated by noise and spinner logs. TCE in well 18 was as high as 2400 ug/l, and in well 19, it was as high as 9 ug/l. These studies concluded that contaminants were entering both wells through corrosion holes in the upper zones, and traveling downward through the casing as well as through the annular space between the casing and the formation. They recommended that the wells be plugged as soon as possible. Both of the wells were plugged in September, 1986. A report on the well plugging procedures is given in Appendix C.

CHAPTER 3

SITE FEATURES

3.1 Demography. Building 3001 is a large industrial complex which operates around the clock. Approximately 8,000 people are employed at the complex. Building 3001 is located near the northeast boundary of Tinker AFB and is in Oklahoma County. Approximately 20,000 people work on Tinker AFB. The Base accommodates 530 family housing units and 7 dormitories. Oklahoma County has a population of 628,600, in which the highest population is in the community of Oklahoma City. Tinker AFB is located in the Oklahoma City limits and adjacent to Midwest City and Del City which have populations of 406,800, 58,000 and 33,400 respectively.

3.2 Land Use. Building 3001 is primarily an industrial site with a mission to support the Air Logistics Center. The Base is bordered on the north and northeast by urban communities (Midwest City/Del City) and the south boundary area is adjacent to the General Motors Plant, an industrial complex. Lake Stanley Draper is located southeast of the base. The remaining areas to the south and east are primarily agricultural.

3.3 Climatology. The climate of Tinker AFB is characterized by long hot summers (sometimes droughts of varying duration occur). The average annual temperature is approximately 60-62 degrees F. The maximum precipitation generally occurs in May. Precipitation then decreases in June, setting the stage for hot and dry summers. Fall is the second wettest season but again tapers off with January being a dry month. Average annual precipitation for the area is 32 inches and the average evaporation rate is approximately 50 inches.

3.4 General Geohydrology. Tinker Air Force Base is located in the Interior Lowlands physiographic province on gently westward dipping Permian redbeds. The geology, which is shown on figure 3-1, is discussed below. Figure 3-2 is a geologic section along the east perimeter through Building 3001. Bedrock units encountered at Tinker include the Garber-Wellington Formation and the overlying Hennessey Formation. These units are discussed below.

a. Garber-Wellington Formation.

1) Geology. The Garber-Wellington Formation outcrops in Central Oklahoma, as shown on figures 3-1 and 3-2, and supplies much of the drinking water for residents of Oklahoma and Cleveland counties. The recharge area covers the eastern half of Oklahoma County including TAFB, and the formation dips to the west about 15 feet per mile. The Garber Sandstone and Wellington Formations are hydrologically interconnected formations which are not easily distinguished from each other based on rock type, key beds, fossils, or hydrologic properties. The Garber-Wellington is about 900 feet thick in the Tinker area, and consists of lenticular and interbedded sandstone, shale, and siltstone. Sandstone is orange-red to reddish-brown, fine-grained, and poorly cemented. The grains are sub-angular to sub-rounded and composed of quartz. Shale is reddish-brown and silty. Although present beneath all of Tinker AFB, the Garber-Wellington is overlain by The Hennessey Formation over the southern half of the Base, as shown on the geologic map of the Tinker AFB area, figure 3-3. Sediments of the Garber-

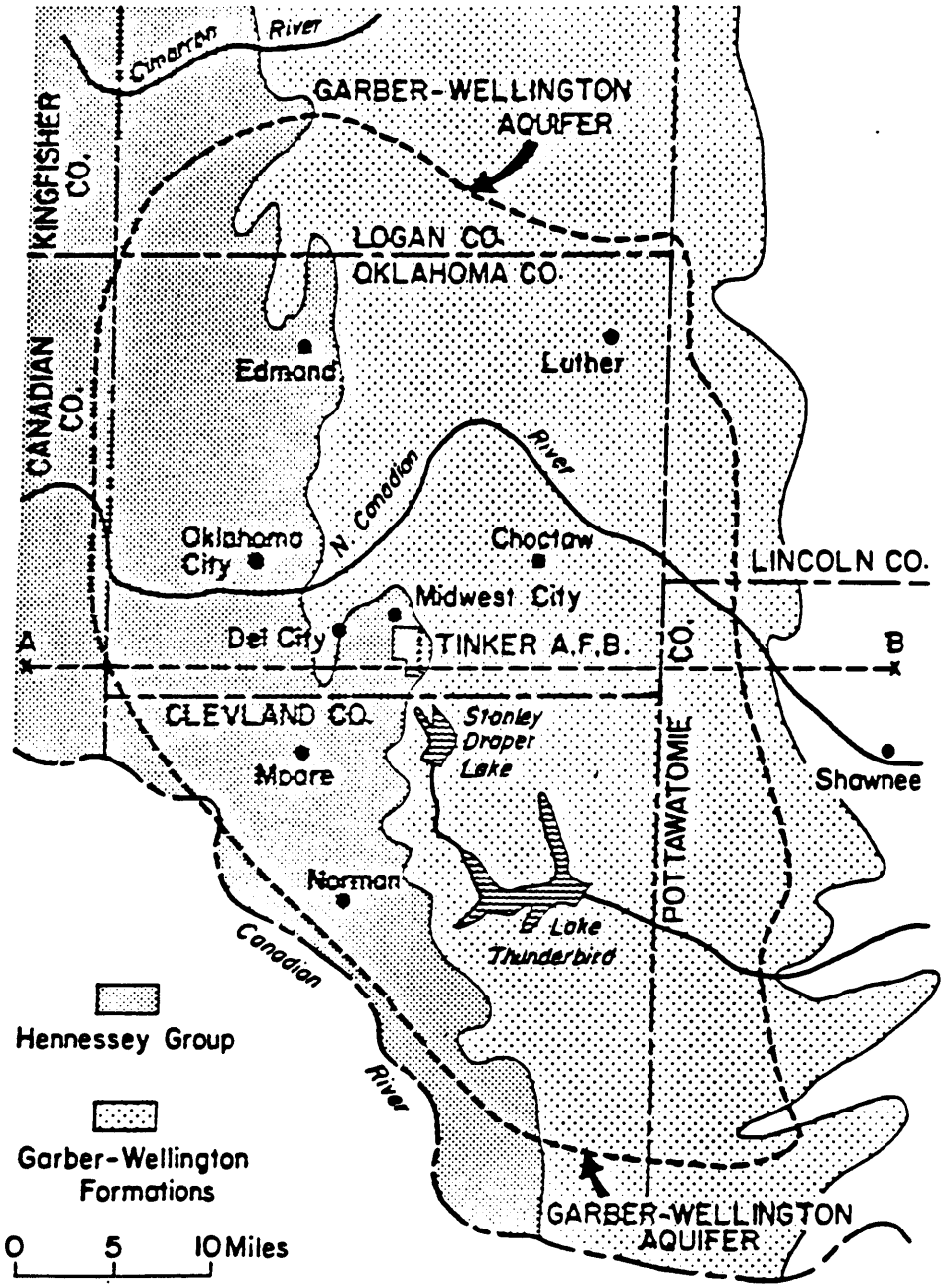


FIGURE 3-1. Generalized geologic map showing the outcrop area of the Garber-Wellington and Hennessey formations. The area inside the dashed line is the area where the Garber-Wellington is a major groundwater resource.

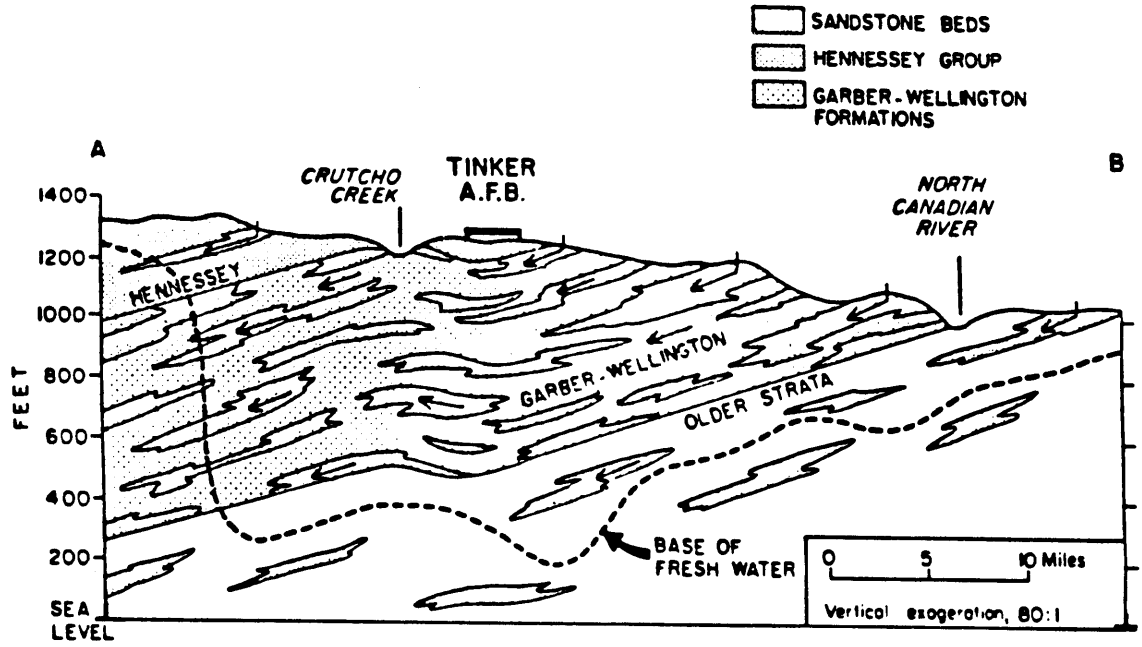


FIGURE 3-2. Generalized geologic section across portions of Canadian, Oklahoma, and Lincoln Counties showing the Garber-Wellington formation.

Wellington are overlain by the Hennessey Formation over the southern half of the Base, as shown on figure 3-3. Sediments of the Garber-Wellington are deltaic in origin. Stream-deposited sands interfinger with marine shales, and individual beds vary from a few feet to about 40 feet in thickness. Sandstone averages about 65% of the formation, as determined from borings drilled at the Base. Because of shifting channels and changing currents during deposition, detailed correlation of lithologic units is only possible over short distances. A north-south geologic section, through Tinker AFB, figure 3-4, is comprised of borings from Building 3001, water supply wells, and other IRP borings. It shows that the Hennessey does not extend as far north as Building 3001. It also shows that the major sandstone and shale beds can be correlated over this distance.

(2) Groundwater. Groundwater exists in the Garber-Wellington under both water table and confining conditions, depending on the presence of overlying shale beds and flows to the southwest. Midwest City and Del City pump from a depth of about 550 feet with rates of approximately 250 gallons per minute per well. Midwest City, just north of the Base, has 28 wells in their system, and although they do not all operate simultaneously, the well system pumps about 1 million gallons per day. Residential usage is generally shallower than 200 feet, and pump rates average about 35 gallons per minute. There are currently 25 water supply wells located on Tinker AFB. These wells, which were drilled in the 1940's and are shown on figure 3-5, provide 4 to 6 million gallons per day for use by the Base, making Tinker the greatest user of groundwater in the area. These wells average about 217 gallons per minute and consist of multiple screens from a depth of 250 feet to a depth of about 700 feet. This zone, where most of the water for industrial and commercial use is pumped, is relatively permeable, and pump tests from wells in the towns of Norman and Edmond yield permeabilities

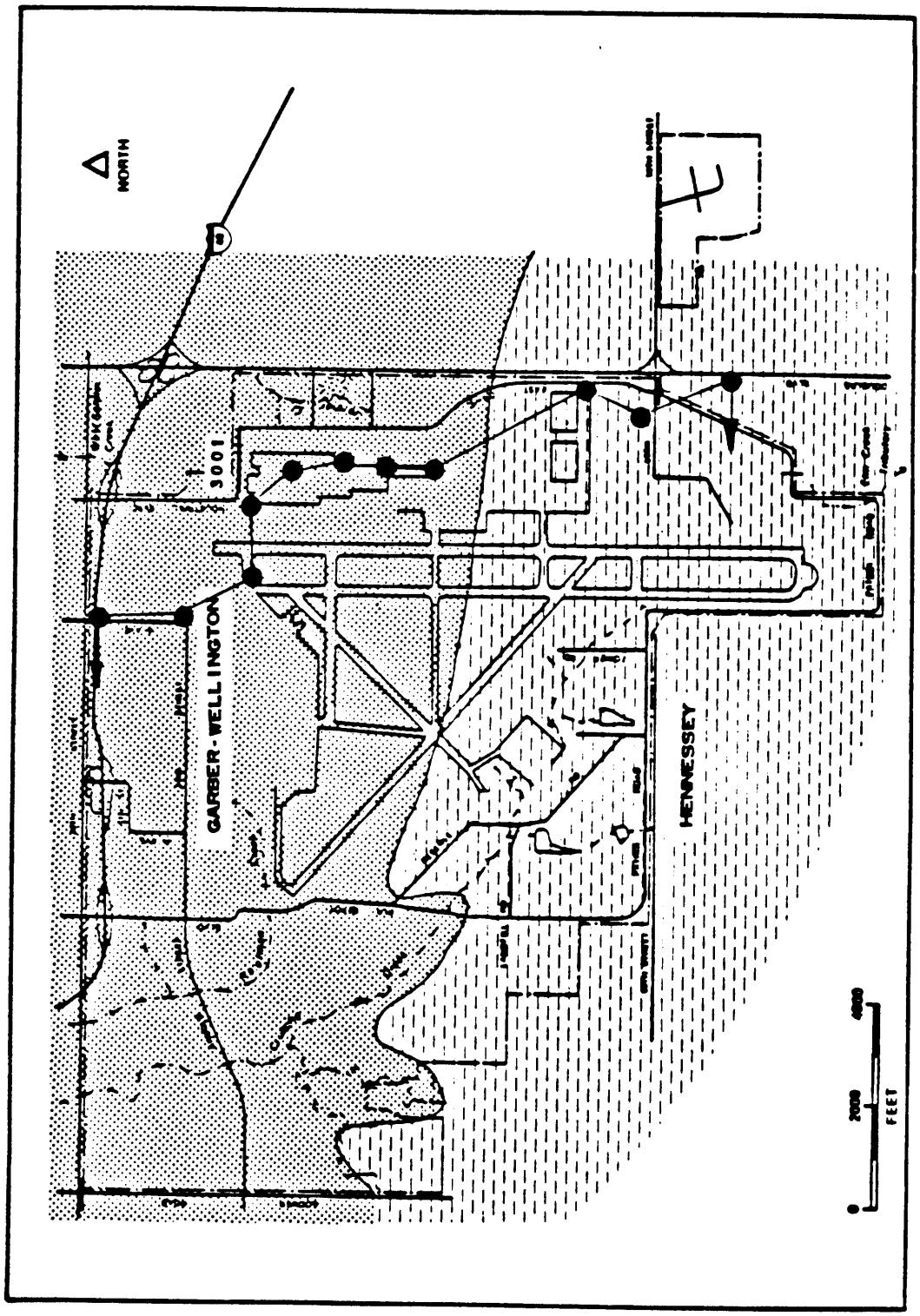


FIGURE 3-3. Surface geology at Tinker Air Force Base. Location of North-South geologic section, figure 3-4, is shown.

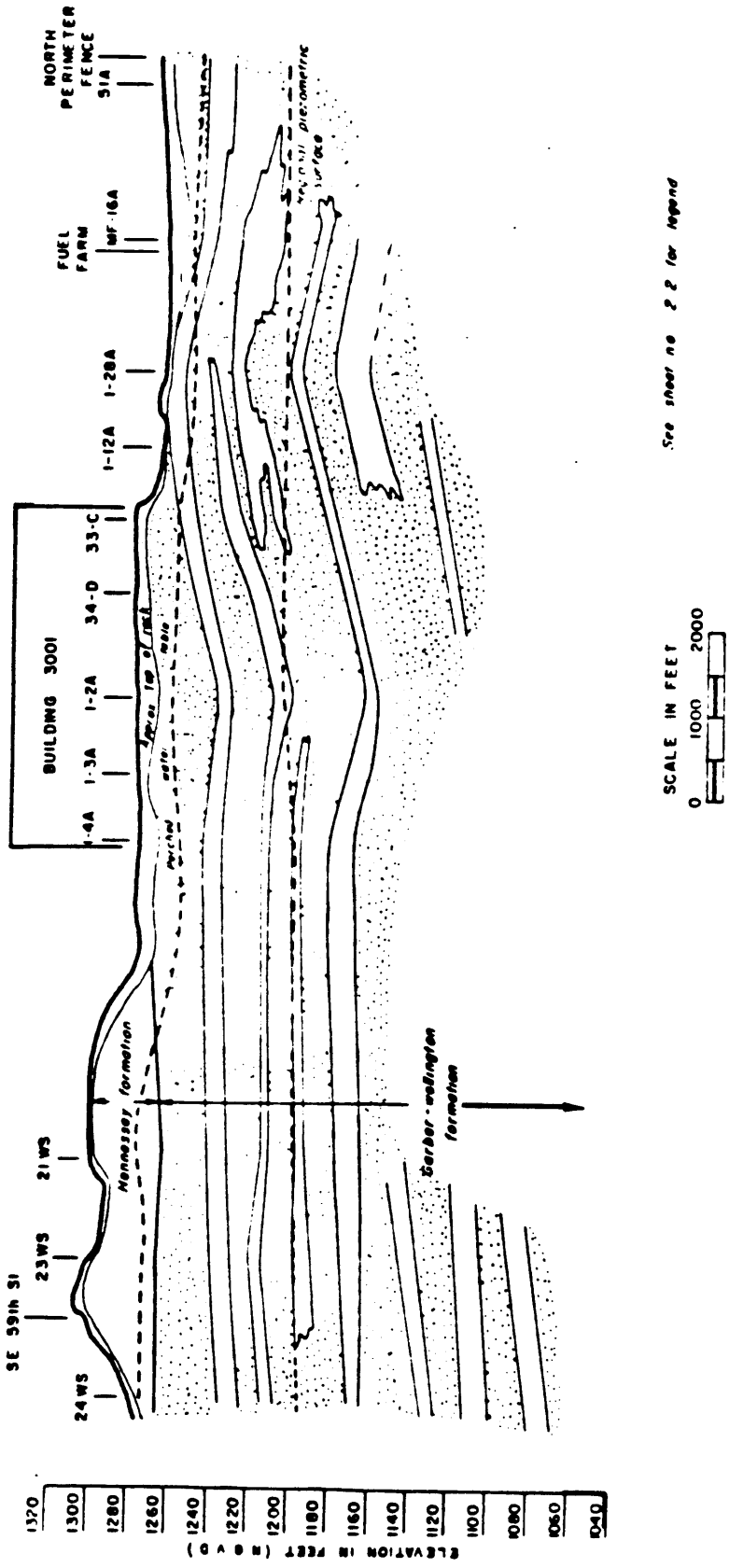


FIGURE 3-4. North-South geologic section through eastern portion of TAFB.

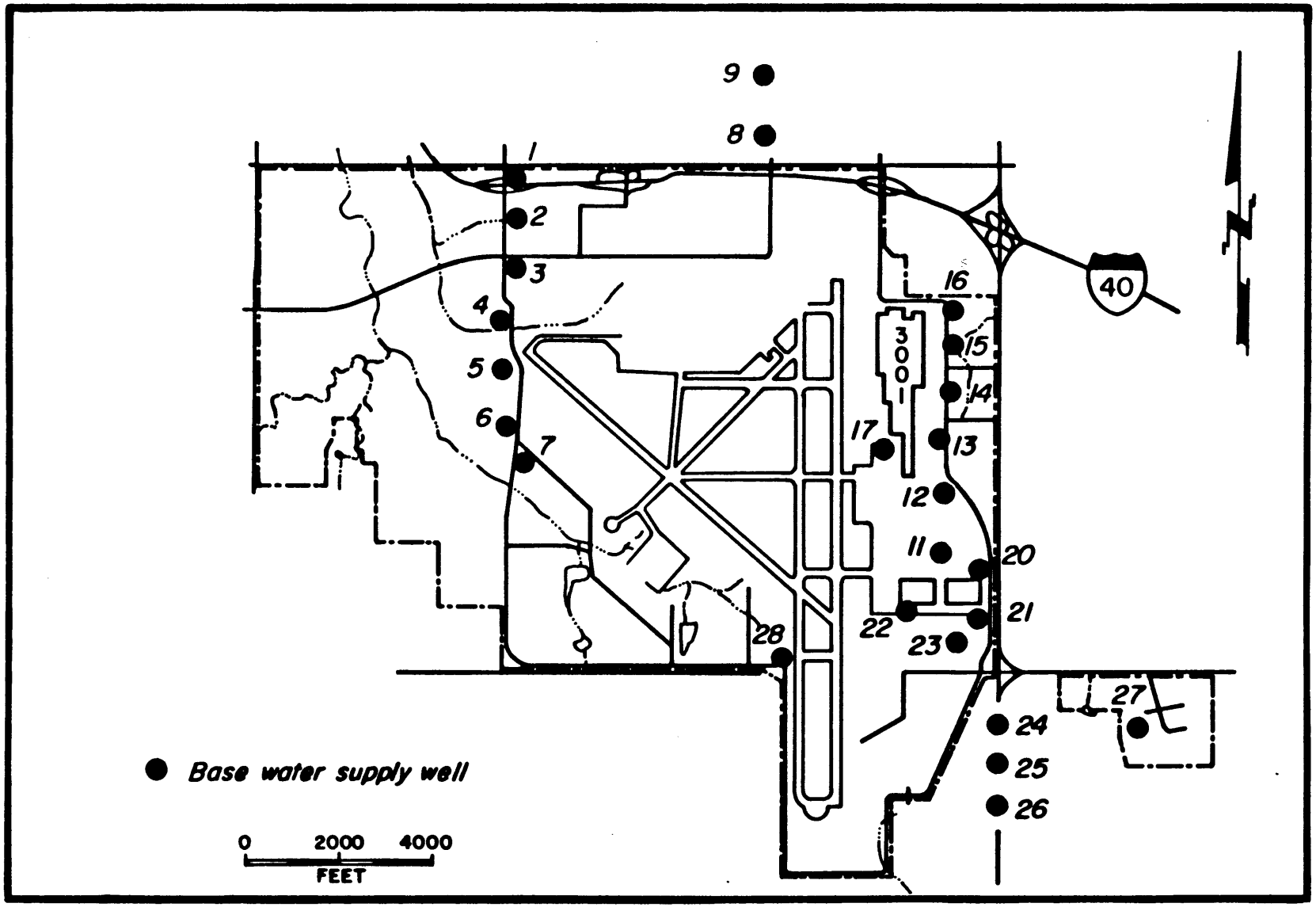


Figure 3-5. Water supply wells on Tinker Air Force Base.

about 10^{-3} cm/sec. The average depth to water in the producing zone is about 250 feet, which is about 200 feet lower than the regional water table. Thus, a vertical component of groundwater flow also exists. The water becomes salty near the base of the formation, and wells drilled through the fresh water zone have to be partially backfilled to be usable. Background water quality at Tinker is best in the deeper strata. In general, heavy metals such as barium, cadmium, chromium, mercury, and silver are at or below detection limits. Arsenic is about 0.002 mg/l, lead about 0.04 mg/l, and selenium 0.002 mg/l. Overpumpage tends to increase the values of some of these metals, especially arsenic, selenium, and chromium. Chlorides, sulfates, and conductivities seem to be the lowest in the deeper strata, and highest in groundwater under water table conditions.

b. Hennessey Formation. The Hennessey Formation outcrops over the southern half of Tinker AFB as shown on figures 3-3 and 3-4. The Hennessey thins to the north and pinches out just south of Building 3001. It consists of reddish-brown shale with beds of siltstone and silty sandstone. Where present, the Hennessey separates the regional water table in the Garber-Wellington from overlying perched water. There are several wells in the area producing minor amounts of water from the Hennessey which are developed from one of the thin sandstone beds or from joints and fractures in the shale.

c. Quaternary Alluvium. Most of the streams at Tinker have some alluvial deposits unless their channels have been modified, such as East Soldier Creek. These deposits consist of unconsolidated sediments of sand, silt, and clay. The thickness of these deposits have not been determined at Tinker. The alluvial deposits are water-bearing and are hydrologically connected to a perched water table which is found over most of the Base.

3.5 Natural Resources. The primary natural resource at the site is groundwater. The underlying Garber-Wellington aquifer is the single most important source of potable groundwater in the Oklahoma City area. Five water supply wells (well numbers 13 through 17) are located in the vicinity of the site (figure 3-5). These wells draw water from the producing zone at depths of approximately 250 to 700 feet. Two of the wells contain trace levels of chlorinated solvents (wells 15 and 16) and one well (well 17) has not been sampled (because it is currently out of service). Wells 15 and 16 contain 0.7 and 1.9 ug/l of TCE and well 16 also contains 1.9 ug/l of 1,2-DCE and 0.7 ug/l of PCE.

CHAPTER 4

HAZARDOUS SUBSTANCES INVESTIGATIONS

4.1 Abandoned Pit Investigations. During the course of the remedial investigations, a survey of abandoned pits was conducted inside Building 3001, south of column-line 81. Pit investigations were previously conducted north of column-line 81 in 1985 (discussed in paragraph 2.2 and Appendix B). The purpose of the investigation was to identify any remaining sources which are potentially contaminating the groundwater. Twenty-three pits were located, sampled, and tested. Three pits contained TCE (pit numbers MN36, Q51, and U51) and one pit contained a high concentration of 1,1,1-trichloroethane (TCA) (pit number P75). The contents of these pits should be removed. Several of the pits contained trace levels of other volatile organics and metals. The complete test results and summary of the investigations and findings are contained in Appendix D.

4.2 Wastes Generated and Stored at the Site. Organic solvents, heavy metals, and fuel products, present in the upper groundwater zones at the site, are the result of migrating solvents, wastes, and fuels from operating and storage areas within and in the vicinity of the building. Many hazardous wastes were and still continue to be generated at the site, primarily in the industrial shops. During a records search conducted in 1982 (ref. 4), the wastes generated in Building 3001 were identified. Table 4.1 contains this list including the approximate quantity of wastes generated and the methods of disposal of the wastes. The north tank area contains stored fuel oil (235,000 gallon tank) and diesel (20,000 gallon tank). The southwest tank area contains two 12,000 gallon tanks which store PD 680 Solvent. Since efforts to correct improper tie-ins to storm drains and remove subsurface solvent pits are being made, most contaminating sources should be eliminated. Table 4.2 lists the contaminants present in the groundwater along with some of their chemical and physical properties. The potential sources of these contaminants are listed in Table 4.3.

Table 4.1
Hazardous Wastes Generated in Building 3001 Shops [1]

Shop Areas	Waste	Quantity [3]	Disposal
Directorate of Maintenance Petroleum waste, consolidated for all shops. [2]	Reclaimable Waste Oil	22,000 gal/yr	IWP[5] (1946-1965) then DPDO
	Reclaimable Waste Fuel	30,000 gal/yr	" "
	Waste fuels and fluids	250,000 gal/yr	" "
	Waste calibration fluid	140,000 gal/yr	" "
	Chlorinated Solvents	15,000 gal/yr	" "
Aircraft Division-all shops [2]	Paint stripper, phenolic	400 gal/day	Storm Sewer (1940's-1965) then IWTP[6]
	Methyl ethyl Ketone	55 gal/day	IWP(1940's-1965)then disposal contract
	Paint stripper sludges	150 gal/day	" "
Propulsion-electroplating	Chrome plating wastes	30,000 gal/yr	IWP(1940's-1965)then IWTP or disposal Contract
	Alkaline-cyanide wastes	37,300 gal/yr	" "
	Mixed waste acids	77,000 gal/yr	" "
	Various plating solutions	2,000 gal/yr	IWP(1940's-1965)the disposal contractor
	Perchloroethylene/Wax	7,300 gal/yr	" "
	Contaminated vat rim hoods	150 drums/yr	Landfills (1950-1980)then disposal contractor
Cleaning Areas	Carbon remover	18,900 gal/yr	IWP (1955-1965)then disposal contractor
	Alkaline Cleaners	22,400 gal/yr	IWP(1940's-1965)then disposal contractor
	Chromic/phosphoric acid	3,500 gal/yr	IWP(1940's-1965)then disposal contractor
	Rubber remover	1,100 gal/yr	Disposal Contractor (1970's-1980's)
	Phosphoric Acid	45,000 gal/yr	IWP(1940's-1960's)then disposal contractor
	Hot tank stripper	5,000 gal/yr	" "
	Emulsion Cleaner	5,000 gal/yr	Disposal Contractor (1970's-1980's)
	Nitric/hydrofluoric acid	1,000 gal/yr	IWP(1940's-1960's)then disposal contractor
	Trichloroethylene Wastes[4]	7,300 gal/yr	IWP(1940's-1960's)then disposal contractor (1960's-1970's)
	Perchloroethylene Wastes[4]	7,300 gal/yr	Disposal Contractor (1970's-1980's)
Non-destructive Inspection	Penetrant	1,800 gal/yr	IWP (1955-1960's)then disposal contractor
	Developer	1,500 gal/yr	" "
	Emulsifier	16,300 gal/yr	IWP(1955-1960's)then IWTP or disposal contractor

Table 4.1 (CONT)
Hazardous Wastes Generated in Building 3001 Shops [1]

Shop Areas	Waste	Quantity [3]	Disposal
Paint Areas	Thinners	1,700 gal/yr	IWP(1940's-1960's)then disposal contractor
	Waste Paints	7,000 gal/yr	" "
	Acetone	1,375 gal/yr	" "
Machine Shop Areas	Coolant Oil	80,000 gal/yr	IWP(1940's-1960's)then disposal contractor
	Magnesium thorium	600 lb/yr	Nevada AEC disposal site (1964-1975)
Assesories - all shops [2]	Carbon remover	2,100 gal/yr	IWP(1940'2-1960's) then IWTP or disposal contractor.
	Alkaline Cleaner	5,600 gal/yr	" "
	Perchloroethylne	included above	IWP(1940's-1960's)then disposal contractor
	Trichloroethane	"	" "
	Freon	"	" "
	Paint Wastes	"	" "
	Thinners	"	" "
	Strippers, phenolic	"	" "
	Coolant Oil	"	" "

1 Ref 4
2 Also includes shops in buildings other than 3001
3 Based on current rates and past rates estimated from 40 to 70 percent of current rate
4 Ref 7
5 IWP - Industrial Waste Pit
6 IWTP - Industrial Waste Treatment Plant

Table 4.2
Chemical and Physical Characteristics of Contaminants

Contaminant	Molecular Weight (g/mole)	Solubility[1] (mg/l)	Specific Gravity	Vapor Pressure (mm Hg)	Henry's Law Constant (atm-m^3/mol.)	Mobility in Water	Degree of Adsorption in Soil
Acetone	58	1,000,000	0.790	270	2.06E-05	high	low
Barium	137			0	NA		
Bis(2-ethylhexyl)phthalate	391	14[2]					
Benzene	78	1,750	0.879	95	5.59E-03	moderate	moderate
Chlorobenzene	113	466	1.106	12	3.72E-03	moderate	mod. high
Cadmium	112			0	NA		
Chromium	52			0	NA		
1,1-dichloroethylene	97	2,250	1.218	600	3.40E-02	mod. high	moderate
1,2-dichloroethylene(trans)	97	6,300	1.260	324	6.56E-03	high	low
Di-n-butyl phthalate	391	13[2]					
1,2-dichloroethane	99	8,520	1.250	64	9.78E-04	high	low
Lead	207			0	NA		
Methylene Chloride	50	6,500	1.326	4310	4.40E-02	high	low
Nickel	59			0	NA		
Phenol	94	9,300	1.070	0341	4.54E-07	high	low
1,1,2,2-Tetrachloroethane	168	2,900	1.338	5.0	3.81E-04	mod. high	moderate
Tetrachloroethylene	166	150	1.623	17.8	2.59E-02	low	high
Toluene	92	535	0.866	28.1	6.37E-03	moderate	mod. high
1,1,2-Trichloroethane	133	1,500	1.338	123	1.44E-02	moderate	mod. high
Trichloroethylene	131	1,100	1.464	58	9.10E-03	moderate	mod. high
Vinyl Chloride	63	2,670	0.912	2660	8.19E-02	mod. high	moderate
Xylene -o	106	130	0.864	10		low	high
Xylene -m	106	198	0.880	10		low	high
xylene -p	106	198	0.861	10		low	high

[1] At 20 degrees C
[2] At 25 degrees C

TABLE 4.3
Potential Sources of Contaminants

Contaminant	Potential Source
Acetone	Painting Operations
Barium	Unknown (probable natural geologic process)
Bis(2-ethylhexyl)phthalate	Unknown (possibly aircraft division)
Benzene	Fuel storage at Tank Areas
Chlorobenzene	Degreasing and Cleaning
Cadmium	Plating, Cleaning, and Stripping
Chromium	Plating, Cleaning, and Stripping
1,1-dichloroethylene	Unknown (possibly biotransformation)
1,2-dichloroethylene	Biotransformation of TCE or PCE
Di-n-butyl phthalate	Cleaning Areas
1,2-dichloroethane	Unknown (possibly accessories shops)
Lead	Cleaning, degreasing, or stripping
Methylene Chloride	Cleaning and paint removing
Nickel	Plating and cleaning
Phenol	Plating or stripping
Tetrachloroethane	Accessories shop
Tetrachloroethylene	Degreasing and cleaning
Vinyl Chloride	Biotransformation of TCE or PCE
Xylenes	Fuel storage at tank areas
Toluene	Fuel storage at tank areas
Trichloroethane	Accessories Shops
Trichloroethylene	Degreasing and cleaning

CHAPTER 5

SURFACE WATER INVESTIGATIONS

Tinker AFB is drained primarily by three watersheds, Crutcho Creek, Khulman Creek and Soldier Creek, which ultimately flow to the North Canadian River. The Building 3001 site is drained by two tributaries to Soldier Creek. One tributary drains the west side of the building (West Soldier Creek) and the other tributary drains the east side of Building 3001 (East Soldier Creek). The tributaries flow to Soldier Creek which is a tributary to Crutcho Creek.

5.1 West Soldier Creek. West Soldier Creek is primarily a drainage ditch which receives surface runoff and cooling waters from the south end of the building (ref. 14). Storm drain pipes extend to the creek from Building 3001. An inspection in 1985 by OWRB indicates that the two northern most pipes may now have no discharge. Drawing 7A shows the creek, surface topography, and storm drain lines. Perched groundwater contours, which will be discussed in section 8.2, are also shown on drawing 7A. The groundwater contours are elevated (mounded) in the vicinity of West Soldier Creek, which indicates that the creek is in a source of recharge to the perched groundwater. Past chemical analyses of grab samples (taken by the OWRB in 1984 and 1985) have identified Cr, PCE, TCE and 1,2-DCE in the creek (ref. 14, 15, and 19), which probably originated from within Building 3001.

5.2 East Soldier Creek. The east side of Building 3001 drains to East Soldier Creek. This creek is fed by surface runoff, storm drains, and some perched groundwater. Drawing 7A shows the relationships between perched groundwater, the creek, surface topography, and storm drains. Hydrogeologic investigations indicate that perched groundwater discharges to East Soldier Creek and the creek potentially recharges the top of the regional aquifer (section 6.2). In the past, water quality testing of streamwaters (USGS-1963, OU-1968, TAFB-1985) has revealed the presence of Cr, Ni, Cd, and Mn at varying concentrations (ref. 11). Unpermitted discharges from storm drains that receive contaminated runoff and uncontrolled dumping of liquid wastes (paints, solvents, etc.) were discovered in 1984 (ref. 14). Storm drain discharges were also found which carried industrial waste because of erroneous connections between the storm system and industrial waste system (ref. 7, 14, and 16). In 1985, the top 5 inches of sediments were sampled in East Soldier Creek at several locations (ref. 11). Also deeper sediments (24 inches) were inspected for odor and visual contamination. The laboratory analysis indicated that sediments contained heavy metals and volatile organic compounds. Sediments were removed to the depth of visibly contaminated material (which varied in depth), and disposed of in a hazardous waste landfill (ref. 19). Follow up sampling and visual inspection indicates that some contaminants may still be present.

5.3 Soldier Creek as an NPL Site. In July of 1987, Soldier Creek (both the east and west tributaries) was placed on the National Priority List of federal facility sites. Therefore, the creek site will undergo a complete remedial investigations/feasibility study (RI/FS) process as required by CERCLA. The RI/FS is being conducted separately from the Building 3001 RI/FS and is therefore not a part of this report.

CHAPTER 6

AIR INVESTIGATIONS

6.1 Air Investigations. Air is not monitored either inside or outside of Building 3001 at the present time. The building is equipped with exhaust systems for areas where hazardous materials are used in industrial processes. Approximately 168 toxic and/or hazardous air emission sources exist within the building. Twenty-five sources require state operating permits for particulates emmitted. For the air quality management zone that Tinker Air Force Base and Building 3001 are in, carbon monoxide is the only non-attainment parameter.

The present subsurface conditions have little effect on the air quality, since few contaminants are being emitted to the atmosphere. Some vapors may be released from the shallow fuel contaminated soils at the North Tank Area during excavations or other disturbances. Organic volatilization may occur in contaminated streams. However, data from past investigations have indicated that concentrations of organics in streams are relatively low (ref. 11, 14, and 15).

CHAPTER 7

BIOTA INVESTIGATIONS

7.1 Biota Investigations. The Building 3001 site has little effect on the flora and fauna environment at Tinker AFB. The primary effects occur because storm drains and the perched groundwater discharge contaminated waters into East and West Soldier Creeks that are harmful to aquatic life. West Soldier Creek is a small tributary fed by surface drainage and cooling waters. East Soldier Creek is fed by surface drainage, storm drains, and the perched groundwater. Discharges to the creeks in the past from improperly connected storm drains have caused demarcation of shorelines with oil and caused waters to be void of aquatic life (ref. 11). Groundwater contaminant plumes in the perched aquifer indicate TCE and Cr could discharge low concentrations of contaminants into East Soldier Creek with additional plume migration toward the east. With the implementation of a remedial action to control and collect contaminated groundwater and corrections of improper tie-ins between storm drains and industrial waste, aquatic life and vegetation should revive in East and West Soldier Creeks. The general flora and fauna at Tinker AFB are discussed in Appendix M.

CHAPTER 8

HYDROGEOLOGIC INVESTIGATIONS

8.1 Site Investigations. Current investigations were conducted both inside and outside Building 3001 to determine the type, magnitude and extent of contamination in the groundwater as well as stratigraphy and aquifer characteristics. Previous investigations, such as those conducted by A.L. Burke, Radian Corp., J.W. Dansby, and the Corps of Engineers, established that operations in and near the building caused groundwater contamination. Borings and monitoring wells drilled during these previous investigations were supplemented in 1986 and 1987 with the installation of 34 well clusters totalling 73 wells and three core borings. Each cluster consists of 1 to 4 wells, with screens set at varying depths. Drawing 1 is a map showing the locations of the borings at the site, and Appendix E contains the geologic logs. Geophysical logs of these borings are available from TAFB Environmental Management Directorate.

a. Core Borings. Three core holes (borings 1-7C, 1-8C, and 1-11C) were drilled near the building to a depth of 150 feet to establish the relationship between the materials and the geophysical logs which were run in each boring. These logs included gamma ray, single point resistivity, and spontaneous potential logs. The purpose of comparing the cores and logs is to determine the stratigraphy in the monitoring wells, where samples at depth were not taken. In addition, undisturbed samples were taken in each boring and analyzed in the laboratory to determine Atterberg limits, gradation, dry density, moisture content, specific gravity, and permeability. This information is shown on the geologic sections.

b. Monitoring Well Installations. Each boring was begun by augering through the overburden into shallow bedrock, generally to refusal. Disturbed samples were taken from the auger for physical descriptions. Borings were then deepened with a rock bit to total depth, using clean water (water from Base supply system) as a drilling fluid. Drilling mud was formed as cuttings mixed with clean water. The deepest well in each cluster was drilled first and logged geophysically. Borings penetrating contaminated water zones were drilled only with drilling mud or casing to prevent cross contamination. Wells were installed in the borings as soon as possible and were pumped to clean and develop the well and remove contamination resulting from the installation. Placement of well screens and filter sand for each well in the cluster was determined from the geophysical log. Most of the well clusters contain 2 or 3 wells and are placed in the perched aquifer, the top of the regional aquifer, and deeper into the regional aquifer. Well 34D was drilled 250 feet deep inside the building to establish the total depth of contamination. A typical well cluster is shown in figure 8-1. Well schematics are given in Appendix F. Each boring was flushed with clear water upon completion and schedule 40 PVC casings and screens were installed (schedule 10 stainless steel 316 casings and screens were used inside the building). Screens are 0.01 and 0.02 inches in slot thickness, and are generally 10 feet in length, but several 5-foot screens were used. Several wells have more than one screen. Screen depths and water levels are given in table 8.1. The annulus between the well casing and the boring is filled with a coarse Arkansas River sand through the entire water bearing interval. A gradation and mineralogic composition of this sand is given in table 8.2. Above the filter

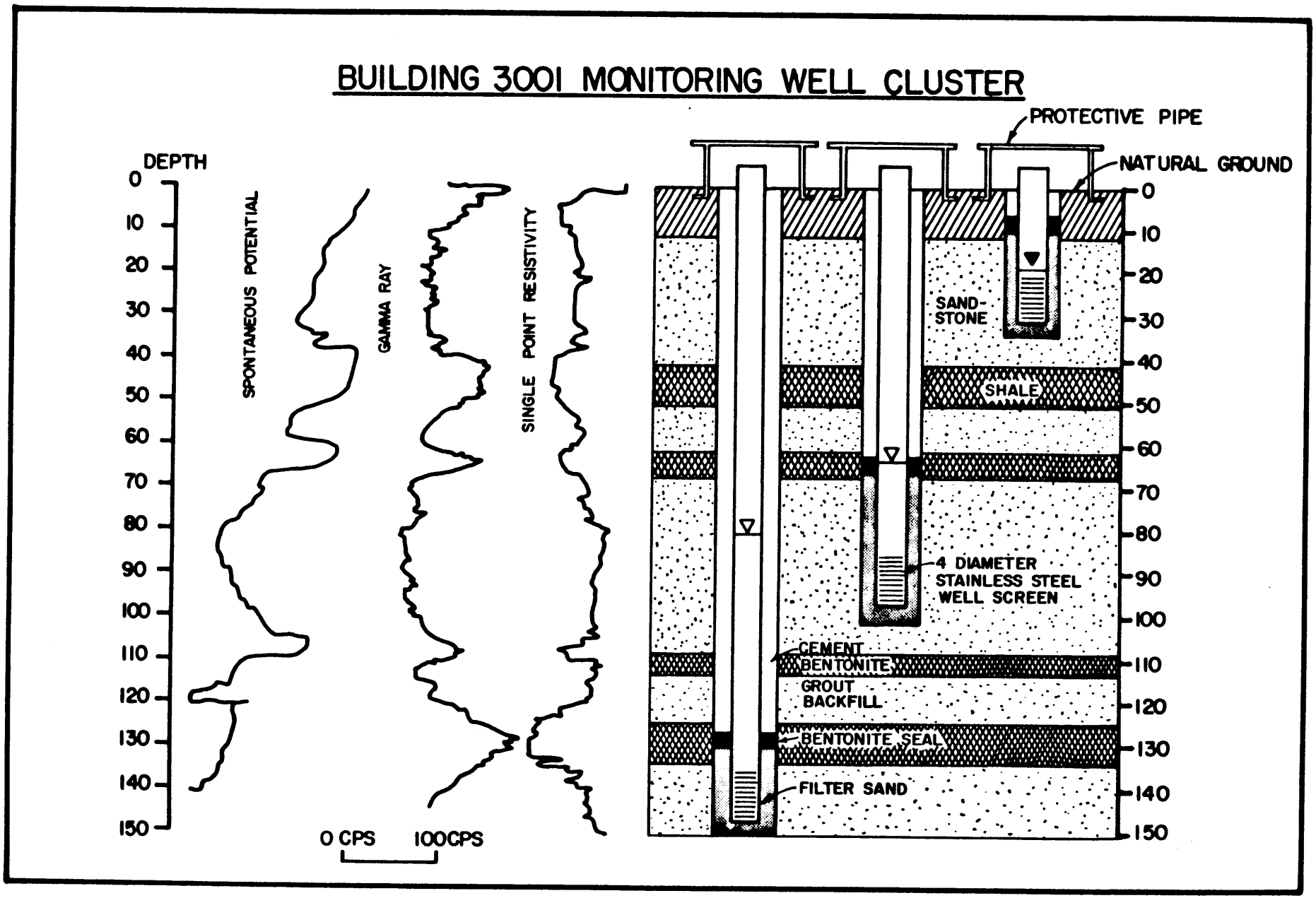

BUILDING 3001 MONITORING WELL CLUSTER
DEPTH
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
SPONTANEOUS POTENTIAL
GAMMA RAY
SINGLE POINT RESISTIVITY
0 CPS
100CPS
PROTECTIVE PIPE
NATURAL GROUND
SAND-
STONE
SHALE
4 DIAMETER
STAINLESS STEEL
WELL SCREEN
CEMENT
BENTONITE
GROUT
BACKFILL
BENTONITE SEAL
FILTER SAND

FIGURE 8-1

TABLE 8.1
Monitoring Wells at Building 3001

Well No.	Depth Feet	Screen Depths Feet	Water Level Feet	Date Recorded	Water Level Elev
			PERCHED AQUIFER		
1-1B	35.0	23.0-33.0	16.8	07-29-86	1256.5
1-2B	35.0	23.0-33.0	20.5	07-29-86	1255.2
1-3B	35.0	23.0-33.0	19.8	07-29-86	1256.8
1-4B	35.0	22.8-32.8	20.5	07-29-86	1255.2
1-5B	35.0	22.4-32.4	18.7	07-29-86	1257.3
1-6B	35.0	21.8-31.9	19.0	07-29-86	1256.2
1-7B	35.0	21.8-31.8	15.6	07-29-86	1257.0
1-8B	35.0	26.9-31.5	17.0	07-29-86	1256.7
1-9B	35.0	23.0-33.0	16.2	07-29-86	1255.0
1-10B	35.5	23.5-33.5	15.4	07-29-86	1253.5
1-11B	35.5	23.5-33.5	14.7	07-29-86	1253.5
1-12B	40.0	27.0-37.0	14.8	09-09-86	1247.8
1-13B	30.0	17.1-27.1	11.5	09-10-86	1253.9
1-14B	35.0	28.0-33.0	13.4	09-11-86	1253.3
1-15B	30.0	17.0-27.0	20.6	09-11-86	1253.9
1-16	25.0	15.0-25.0	18.8	12-03-86	1252.5
1-17	19.0	7.0-17.0	11.7	12-03-86	1256.3
1-18	25.0	9.9-19.9	17.6	12-03-86	1257.1
19B	35.5	23.5-33.5	18.6	07-29-86	1249.1
20B	35.0	23.0-33.0	dry	07-29-86	-
21B	35.4	23.4-33.4	15.6	07-29-86	1253.4
22B	35.5	23.5-33.5	26.7	07-29-86	1225.8
23B	35.0	23.0-33.0	20.8	07-29-86	1246.7
24B	35.0	23.0-33.0	dry	07-29-86	-
25B	30.0	15.0-25.0	18.0	07-29-86	1257.2
1-26	17.0	6.8-16.8	12.8	01-22-87	1259.2
1-27	24.0	13.8-23.8	14.8	01-07-87	1258.2
1-28B	30.0	20.0-30.0	14.0	01-08-87	1245.5
1-29	30.0	20.0-30.0	12.6	01-08-87	1245.3
1-30	35.8	18.0-28.0	14.6**	03-10-87	1257.4
			15.9	03-10-87	1256.1
1-31	20.5	10.1-20.1	16.9**	03-10-87	1259.8
			18.7	03-10-87	1259.7
1-32	15.0	5.0-15.0	14.7	03-10-87	1259.5
1-39	17.9	14.9-17.9	14.4	07-03-87	1225.6
1-40	12.3	9.3-12.3	9.2	07-03-87	1226.8
1-41	23.2	20.2-23.2	19.2	07-03-87	1227.8
1-42	26.7	23.7-26.7	24.6	07-03-87	1225.4
1-43A	30.7	25.7-30.7	24.3	07-03-87	1240.0
1-43B	12.2	7.2-12.2	12.1	07-03-87	1253.0
1-44B	21.8	16.8-21.8	19.8	07-03-87	1242.0
32A	34.6	20.6-31.6	20.1	07-28-86	1255.9
33A	36.8	20.1-31.1	20.4	07-28-86	1255.6
34A	35.0	20.1-31.1	20.7	07-28-86	1255.3
35A	35.0	20.2-30.2	20.4	07-28-86	1255.6

TABLE 8.1 (Cont)
Monitoring Wells at Building 3001

Well No.	Depth Feet	Screen Depths Feet	Water Level Feet	Date Recorded	Water Level Elev
M-1	20.0	10.0-20.0	19.5	10-24-85	1255.5
M-2	20.0	10.0-20.0	13.8	07-29-86	1255.5
M-3	30.0	15.0-25.0	17.7	10-25-85	1257.0
M-4	30.0	15.0-25.0	17.3	07-29-86	1257.5
M-5	30.0	10.0-20.0	17.1	10-25-86	1257.7
M-6	34.0	17.0-27.0	18.5	10-30-85	1258.1
M-7	25.0	15.0-25.0	17.8	10-28-85	1258.2
MM-1	23.0	13.0-23.0	18.4**	01-21-87	1254.2
			19.5	01-21-87	1253.0
MM-2	25.0	15.0-25.0	15.6**	01-21-87	1257.6
			25.5	01-21-87	1247.7
MM-3	26.5	16.5-26.5	17.0**	01-21-87	1255.2
			29.2	01-21-87	1243.0
MU-1	30.0	15.0-25.0	18.8	10-25-85	1256.2

M, MM, and MU series wells installed by A.L. Burke for underground storage tank investigations.
** fuel level

TOP OF REGIONAL AQUIFER

1-1A	100.9	88.0-98.0	68.8	07-29-86	1204.5
1-2A	102.5	90.5-100.5	75.5	07-29-86	1200.2
1-3A	120.0	108.0-118.0	77.3	07-29-86	1198.9
1-4A	120.0	106.7-116.7	80.7	07-29-86	1194.8
1-5A	130.0	106.4-116.4	78.4	07-29-86	1197.7
1-6A	120.0	106.3-116.3	79.3	07-29-86	1195.4
1-7A	120.0	97.0-107.0	76.4	07-29-86	1196.3
1-9A	122.0	110.0-120.0	73.4	07-29-86	1197.8
1-10A	100.5	88.0-98.0	64.6	07-29-86	1204.3
1-11A	100.0	88.0-98.0	60.6	07-29-86	1207.6
1-12A	100.0	87.3-97.3	63.7	09-09-86	1199.3
1-13A	80.0	67.0-77.0	69.5	09-10-86	1196.0
1-14A	99.4	98.0-99.0	74.7	09-11-86	1192.0
1-15A	100.0	87.0-97.0	72.2	09-11-86	1202-3
19A	82.0	72.0-82.0	54.8	07-29-86	1214.4
20A	90.0	80.0-90.0	60.1	07-29-86	1208.5
21A	90.0	80.0-90.0	63.8	07-29-86	1205.2
22A	57.0	47.0-57.0	23.8	07-29-86	1223.7
23A	115.0	105.0-115.0	57.3	07-29-86	1211.2
24A	102.0	92.0-102.0	79.5	07-29-86	1205.5
25A	90.0	80.0-90.0	82.2	07-29-86	1195.0
1-28A	100.0	55.0-65.0	62.9	07-29-86	1196.6
		75.0-85.0			
1-36	57.5	54.4-57.5	51.0	07-03-87	1215.0
1-38	39.4	36.4-39.4	34.3	07-03-87	1217.0

Table 8.1 (CONT)

Well No.	Depth Feet	Screen Depths Feet	Water Level Feet	Date Recorded	Water Level Elev
1-44A	41.4	36.4-41.4	29.5	07-03-87	1212.0
32B	95.5	80.6-91.6	77.2	07-28-86	1198.8
33B	96.8	80.1-91.1	75.5	07-28-86	1200.5
34B	95.0	80.6-90.6	74.7	07-28-86	1201.3
35B	95.0	80.2-90.2	74.2	07-28-86	1201.8

Wells 19A through 25A drilled by Radian Corp. for earlier phases of IRP.

REGIONAL AQUIFER

1-8A	130.0	106.2-116.2	78.5	07-29-86	1195.0
1-10C	151.3	112.6-122.1 133.1-142.1	69.4	04-01-87	1199.5
1-12C	155.0	143.0-153.0	68.1	09-09-86	1194.7
1-13C	150.0	137.1-147.1	71.9	09-10-86	1193.4
1-14C	149.5	121.1-140.1	73.2	09-11-86	1193.5
1-15C	150.0	137.0-147.0	73.5	07-25-86	1202.9
25C	149.6	123.0-132.0 138.0-147.0	80.1	07-29-86	1194.9
32C	149.0	130.2-141.2	80.8	07-28-86	1195.2
33C	149.6	130.1-141.1	77.8	07-28-86	1198.2
34C	146.0	130.2-140.2	76.4	07-28-86	1199.6
34D	258.3	218.0-228.0 243.1-253.1	155.2	08-11-86	1120.8
35C	139.3	120.2-130.2	74.3	07-28-86	1201.7

Table 8.2
Specifications for Filter Sand

Mineralogy		Gradation (% passing each sieve)	
quartz	80.7%	#4	98
feldspar	15.7	#8	85
granite	2.7	#16	58
chert	0.6	#30	27
sandstone	0.2	#50	9
magnitite	0.1	#100	0.5
shale	tr		
limestone	tr		
volcanic rock	tr		

sand is a 2 to 5 feet bentonite seal, made up of bentonite pellets which were placed in the annulus and allowed time to hydrate and swell. This seal was placed adjacent to a shale bed as interpreted by the geophysical logs. Above the bentonite seal is a neat cement grout, which contains 10% (by volume) bentonite to retard shrinkage.

Drilling equipment was steam cleaned after installing each well cluster and spent drilling mud was transferred into industrial waste pits on-Base. The mud was sampled in the pits, determined to be uncontaminated, and properly disposed. Borings not used as monitoring wells were grouted with neat cement grout. Water levels from each well were checked to be certain they were indicative of the zone being monitored. Each well installation is in a separate boring, spaced about 10 feet apart.

c. Chemical Sampling Parameters. At the beginning of the sampling period, selected wells were sampled for an extensive list of parameters, including volatile and semivolatile compounds, pesticides, PCBs, radiometric parameters, metals, and indicator parameters, as listed in Table 8.3. This testing program was performed to be certain that no potential contaminants would be missed. After results were received, an abbreviated parameter list was established as given in table 8.4. Also, specific parameter lists were developed to evaluate the effectiveness of alternative control plans and other concerns, such as high pH values and the presence of fuel contamination. This list is shown in table 8.5. All of the wells were sampled during 1986 and 1987. Results of this sampling are given in Appendix G. Sampling and laboratory test procedures, EPA test methods, and QA/QC plans are given in Appendix H. The results of field (travel and equipment) blanks are given in Appendix Q. The results of duplicate and spiked laboratory analyses are contained in the original laboratory reports and are available from the Tinker AFB EM Directorate office.

Table 8.3
Parameters for Chemical Testing of Selected Wells
(Wells 32ABC, 33ABC, 34ABC, 35ABC)
(19A, 20A, 21A, 22A, 23A, 24A, 25A)

Total and Diss. Metals

arsenic
barium
cadmium
chromium
lead
mercury
nickel
selenium
silver
zinc

Radiometrics

gross alpha
gross beta
radium-226
radium-228

Semivolatiles

3,3'-dichlorobenzidene
butyl benzyl phthalate
pyrene
fluoranthene
di-n-butyl phthalate
2-methylnapthalene
hexachlorocyclopentadiene
2,4,6-trichlorophenol
2,4,5-trichlorophenol
2-chloronaphthalene
2-nitroaniline
dimethyl phthalate
acenaphthylene
2,4-dinitrophenol
4-nitrophenol
dibenzofuran
2,3-dinitrotoluene
2,6-dinitrotoluene
diethyl phthalate
4-chlorophenyl phenyl ether
fluorene
4-nitroaniline
4,6-dinitro-2-methylphenol
N-nitrosodiphenylamine

Semivolatiles (cont)

hexachlorobenzene
pentachlorophenol
phenanthrene
1,4-dichlorobenzene
benzyl alcohol
1,2-dichlorobenzene
2-methyl phenol
benzo(g,h,i)perlyene
dibenzo(a,h)anthracene
bis(2-chloroisopropyl)ether
4-methylphenol
N-nitrosodipropylamine
hexachloroethane
nitrobenzene
isophorone
2-nitrophenol
2,4-dimethylphenol
benzoic acid
bis(2-chloroethoxy)methane
2,4-dichlorophenol
1,2,4-trichlorobenzene
naphthalene
4-chloroaniline
hexachlorobutadiene
p-chloro-m-cresol
benzo(b)fluoranthene
benzo(k)fluoranthene
benzo(a)pyrene
indeno(1,2,3-c,d)pyrene
anthracene
chrysene
di-n-octyl phthalate
phenol
bis(2-chloroethyl)ether
2-chlorophenol
1,3-dichlorobenzene
bis(2-ethylhexyl)phthalate
benzo(a)anthracene
4,6-dinitro-2-methylphenol
N-nitrosodiphenylamine
4-bromophenol phenyl ether
hexachlorobenzene
pentachlorophenol
phenanthrene

Table 8.3 (Cont)
Parameters for Chemical Testing of Selected Wells
(Wells 32ABC, 33ABC, 34ABC, 35ABC)
(19A, 20A, 21A, 22A, 23A, 24A, 25A)

Volatiles

1,1,2-trichloroethane
benzene
cis-1,2-dichloropropene
2-chloroethylvinylether
bromoform
2-hexanone
4-methyl-2-pentanone
tetrachloroethene
1,1,2,2-tetrachloroethane
toluene
chlorobenzene
1,1,1-trichloroethane
2-butanone
1,2-dichloroethane
chloroform
trans-1,2-dichlorothene
1,1-dichloroethane
1,1-dichloroethene
carbon disulfide
acetone
methylene chloride
chloroethane
vinyl chloride
bromomethane
chloromethane
ethylbenzene
styrene
total xylenes
carbon tetrachloride
vinyl acetate
bromodichloromethane
1,2-dichloropropane
trans-1,3-dichloropropene
trichloroethene
dibromochloromethane

Pesticides and PCBs

dieldrin
aldrin
a-BHC
b-BHC
d-BHC
g-BHC
chlordane
4,4'-DDE
4,4'-DDT
4,4'-DDD
endosulfan I
endosulfan II
endosulfan sulfate
endrin
endrin aldehyde
heptachlor
heptachlor epoxide
toxaphene
PCB 1016
PCB 1221
PCB 1232
PCB 1242
PCB 1248
PCB 1254
PCB 1260

Misc and Indicators

chloride
sulfate
cyanide
oil and grease
total organic carbon
pH
conductivity

Table 8.4
Additional Parameters for Chemical Testing

Abbreviated Parameter List

Total Metals
Dissolved Metals
Indicator Parameters
Purgeable Organics

Table 8.5
Specific Parameter List

Alternatives Evaluation List	
Trivalent chromium	Total metals
hexavalent chromium	Dissolved metals
pH	Heterotropic plate count
Conductivity	
High pH Evaluation	
pH	Hardness as CaCO3
Conductivity	Carbonate
Common Cations	Bicarbonate
Fuel Contaminated Areas	
pH	Fe and Mn
Conductivity	Total Metals
Purgeable Organics	GC for Fuel types

d. Field Aquifer Tests. Field tests included individual well slug tests to estimate aquifer parameters and observations of pumping water supply wells to determine the influence between the producing aquifer zones and upper contaminated zones. Slug tests were performed in selected wells by inserting a known volume (slug) inside the well casings to displace a column of water and recording the falling head. This type of test is common for estimating the hydraulic conductivities (permeabilities) and transmissivities of the aquifer zone near the well. The test procedures and methods of analyzing the data are given in Appendix N. The values of hydraulic conductivity and transmissivity determined from the slug tests are shown in table 8.6.

Table 8.6
Slug Test Results

Well No.	Aquifer Zone	Aquifer Thickness (feet)	Hydraulic Conductivity[1] K (cm/sec)	Hydraulic Conductivity K (gpd/ft^2)	Transmissivity[2] T (gpd/ft)
1-6B	perched	6	$6x10^{-4}$	12	72
1-8B	"	24	$6x10^{-4}$	13	312
1-4B	"	11	$6x10^{-4}$	13	143
1-5B	"	19	$1x10^{-3}$	27	513
1-11B	"	12	$1x10^{-3}$	21	252
1-2A	top of regional	12	$6x10^{-4}$	14	168
1-4A	"	19	$9x10^{-4}$	19	361
19A	"	27	$6x10^{-4}$	12	324
1-7A	"	13	$7x10^{-4}$	15	195
25A	"	16	$7x10^{-4}$	16	256
1-1A	"	21	$6x10^{-4}$	12	252
23A	"	14	$2x10^{-3}$	31	434
21A	"	22	$9x10^{-4}$	19	418
1-11A	"	11	$1x10^{-3}$	21	231
25C	regional	13	$5x10^{-4}$	10	130
1-10C	"	16	$2x10^{-4}$	4	64

[1] Hvorslev method (ref. 10)
[2] T=K x aquifer thickness

Observations of the nearest operational water supply wells were made to determine the influence the aquifer producing zone might have on the perched and upper regional zones. Prior to the observations, water supply well 15 was shut down (for approximately 4 weeks due to repairs) and wells 14 and 16 were operating only during the day. Continuous water level recorders were placed on selected monitoring wells and water supply wells 14, 15, and 16 were allowed to run continuously for two weeks (beginning the day well 15 was restarted). A plot of the water levels versus time for the two week period is shown on drawing 2. As shown by the drawing, the producing wells seem to influence each other but very little influence was noted in the upper zones. Well 34D, which is the deepest observation well (screened at 218-228 and 243-253 feet), fluctuated (rose and fell) about 0.5 feet during the 2 week period. Some wells in the perched aquifer rose and fell slightly more than 1 foot, but changes did not seem attributable to the producing wells.

8.2 Site Conditions.

a. Geohydrology. Interbedded sandstone, siltstone, and shale of the Garber-Wellington underlie Building 3001. These beds support groundwater under a variety of conditions, varying from unconfined to confined. Groundwater flow at the site is very complex due to the highly variable geology. However, a conceptual model has been developed which divides the groundwater into vertical components, based roughly on depth. These water-bearing zones, from shallowest to deepest, are as follows: perched, top of regional, regional, and producing zone. The basic characteristics of each zone are listed in Table 8.7.

Table 8.7
Conceptualized Water-Bearing Zones

ZONE	Type Aquifer	Water Level Feet	Depth Water Encountered
Perched Water Table	unconfined	15-30	15-30
Top of Regional	semi and confined	30-80	50-80
Regional	confined	75-90	110-175
Producing Zone	confined	100-175	250-700

Four geologic sections (A-A through D-D), drawings 3 through 6, have been constructed to illustrate the geology and groundwater conditions at the site. Section A-A and B-B are east-west sections through the building and East Soldier Creek and West Soldier Creek, and sections C-C and D-D are north-south sections. The locations of these sections are shown on drawing 1. Drawings 7 through 9 are potentiometric surface contour maps of the perched aquifer, the top of the regional aquifer, and the regional aquifer. These drawings show the stratigraphy and the potentiometric surfaces, and their relationship to the surface drainages. East Soldier Creek is partially fed by perched water, and has little effect on any of the deeper water zones. Drawing 7A shows the perched groundwater contours overlain by the utility lines at the site. The perched water is slightly mounded under the building and west of the building from leaky storm drains and West Soldier Creek. The depth to this perched water is about 15 feet. The top of regional and regional zones are very similar to each other and flow to the west and southwest. The water-bearing zones of the Garber-Wellington are influenced by shale confining beds, and show a vertical downward gradient.

There is a head loss of a few feet from the top of regional to the regional zone, as shown on drawings 8 and 9. This head loss is indicative of the heterogeneity present in the Garber-Wellington. This suggests the potential for vertical migration of contaminated groundwater from upper to lower units. Contouring the potentiometric surface of the producing zone is not possible because there are few data points, and the configuration frequently changes depending on which wells are operational. The Garber-Wellington in the upper 150 feet is about 65% sandstone and the remainder is shale and siltstone. Samples were taken from the core holes (1-7C, 1-8C, and 1-11C) and auger holes at Soldier Creek (1-40 and 1-44) and were tested for engineering and physical properties. Results from these tests are listed in table 8.8. The shale is generally very sandy (25 to 40% or more sand grains) and lean (liquid limit 30 to 35%), and has a laboratory permeability (by falling head test) varying from 0.7 to 7.7 x 10^{-8} cm/sec. The permeability of the sandstone was determined by both a falling head test and a constant head test, and varied about 6 orders of magnitude, from 8 x 10^{-3} cm/sec to less than 10^{-9} cm/sec. This variation was probably due to the amount of shale and amount of cementation present although some variance can occur between samples due to sample handling and testing procedures. There was one falling head test on a sand siltstone and that value was 1 x 10^{-7} cm/sec.

In order to more thoroughly understand the nature of the sandstones and shales at the site, thin sections were prepared for microscopic study from undisturbed samples taken from borings 1-7C, 1-8C and 1-11C. Physical properties noted on the thin sections are described in table 8.9. The sandstones were comprised of subrounded to subangular quartz grains held in a largely open network. The grains are held together by compaction, calcite and hematite cementation, and clay. The presence of cementation and shale cause the variability in permeability found in the laboratory permeability tests.

Table 8.8
Physical Properties of Undisturbed and Disturbed Samples

Hole #	Depth Feet	Gradation gr sa fi	Atterbergs LL PL PI	% saturat.	Dry Density pcf	Poros %
			SANDSTONE			
1-40	0.0-11.3	0 80 20	NP NP NP			
1-7C	31.8-32.6			100.0	138	.17
	62.7-63.6			85.4	113	.32
	110.0-111.8			90.6	132	.21
	144.8-145.4			94.8	119	.29
	146.4-147.1			100.0	141	.15
1-8C	14.2-14.8	6 73 21		100.0	133	.20
	20.8-21.7			71.3	139	.17
	37.3-38.0			103.3	151	.09
	66.3-67.0			77.6	113	.33
	98.2-99.0			103.2	142	.15
	133.9-134.5			97.9	128	.23
1-11C	26.9-27.8			99.4	132	.21
	42.0-42.7			65.4	114	.32
	70.2-71.2			90.9	130	.21
	102.8-103.5	0 82 18	NP NP NP	95.8	112	.33
	134.6-135.5			100.0	145	.13
			SILTSTONE			
1-11c	67.9-68.8			97.9	131	.22
	138.4-139.4	0 35 65	NP NP NP	85.0	128	.23
			SHALE			
1-7C	24.3-25.0			93.5	129	.23
	40.6-41.3	0 41 59		100.0	147	.13
	41.3-42.3	0 38 62	32 17 15	66.1	134	.20
	107.4-108.3	0 50 50	30 13 17	80.3	129	.23
	126.1-126.9	0 24 76	26 14 12	93.8	132	.22
1-8C	24.6-25.5	0 2 98	36 15 21	100.0	134	.20
	45.0-46.0			94.4	129	.23
	71.0-72.0			97.7	132	.22
1-11C	25.8-26.9	0 16 84	27 14 13	91.8	129	.23
	30.7-31.7	0 25 75	30 14 16	94.5	126	.25
	50.8-51.6	1 43 56	33 13 20	78.5	128	.24
	128.9-129.6	0 18 72	31 14 17	80.0	133	.21
			EAST SOLDIER CREEK ALUVIUM			
1-44	0.0-30.0	1 52 47	25 14 11			

LL - Liquid Limit (%)
PL - Plastic Limit (%)
PI - Plasticity Index (%)
gr - percent gravel (% > No. 4 sieve)
sa - percent sand (% > No. 200 sieve)
fi - percent fines (% < No. 200 sieve)
pcf - pounds per cubic feet

Table 8.9
Description of Thin Section Samples from Selected Borings

Boring	Depth (feet)	Porosity n(%)	% of Pores open	% of Pores max	Pore Size (mm) ave	Pore Size (mm) max	Grain Size (mm) ave	Grain Size (mm) <0.1
			Sandstone					
1-7C	62.7-63.6	30	95	.4	.1	.5	.2	40
	114.8-145.4	20	85	.5	.1	.3	.2	30
1-8C	66.3-67.0	30	85	.5	.2	.6	.2	5
1-11A	42.0-42.7	25	90	.4	.1	.5	.2	50
	102.8-103.5	30	60	.3	.1	.3	.1	30
			Shale					
1-11A	30.7-31.7	12	60	.2	<.2	.2	<.1	90

8.3 Groundwater Quality.

a. Background. Background groundwater quality has been determined by sampling wells which are upgradient of Tinker AFB. These samples were taken from perimeter wells installed for the Base-wide groundwater assessment (ref. 20), Building 3001 wells on the upgradient side of the site, and Base water supply wells. Average background values have been calculated for the producing zone, top of regional zone and perched zone and are shown in Table 8.10. These values do not necessarily represent uncontaminated groundwater, but represent the groundwater quality thought to be uncontaminated by operations associated with Building 3001.

Table 8.10
Background Averages of Groundwater Quality[1]

	Producing Zone	Regional Aquifer	Perched WT
arsenic	0.002	0.002	0.010
barium	<0.500	0.663	1.11
cadmium	<0.0075	<0.0075	0.010
chromium	<0.010	<0.010	0.046
lead	0.033	0.048	0.057
mercury	<0.0004	<0.0004	<0.0004
selenium	0.0021	0.0005	0.0021
silver	<0.010	<0.010	0.010
nickel	0.019	0.033	0.101
zinc	0.44	0.12	0.11
chloride	4.9	42.1	297.4
sulfate	5.8	21.0	82.8
conductivity (umhos/cm)	442	718	684
pH (S.U)	7.17	9.80	7.10
TOC	2.2	5.3	3.9
oil and grease	<1.0	<1.0	<1.0
cyanide	<0.20	<0.20	<0.20
alpha (pc/l)	4.2	3.7	55.2
beta (pc/l)	9.0	9.3	106.8

[1] Concentrations in mg/l unless otherwise noted.

b. Contaminants in Groundwater. The chemical character of the groundwater in the vicinity of Building 3001 has been defined horizontally and vertically by laboratory analyses of samples from the monitoring wells at the site. The maximum contamination spread extends laterally beyond the limits of the building to the west approximately 1,750 feet, to the east approximately 1,100 feet, and to the southwest approximately 800 feet. The vertical extent of contamination is primarily in the upper 175 feet.

1) Perched Aquifer. Samples from the perched zone were from the monitoring wells listed in Table 8.1. The results of chemical analyses (Appendix G) indicated the zone is contaminated with organic solvents, trace metals, and fuel product. The highest areas of contamination are located beneath the building, the north tank area, and the southwest tank area. The compounds and metals detected in the perched zone are listed in Table 8.11. Two contaminants, TCE and Cr, can be considered the primary contaminants in the aquifer, because their maximum concentrations are higher than other contaminants and they are consistently detected over a larger area of the site. All other contaminants lie within the plumes of these two contaminants. Other organic compounds with significant plumes are 1,2-DCE, PCE, acetone, toluene, benzene, and xylene. Other metals with significant plumes are Pb, Ni, and Ba. A fuel product plume is present at the north tank area.

Table 8.11
Contaminants Detected in Perched Zone

Organic Compounds	Detected[1] Frequency	Concentration Range (ug/l)	Average[2] Conc (ug/l)	Max. Conc. Location
TCE	19/33	<5 - 330,000	12,125	34A
Toluene	10/39	<5 - 47,000	662	M-6
1,2-DCE	10/33	<5 - 4,600	376	1-12B
Acetone	11/33	<5 - 1,600	324	1-18
Benzene	10/39	<5 - 1,535	122	M-6
Xylene	6/39	<5 - 780	98	1-30
PCE	6/33	<5 - 260	102	35A

Total Metals	Detected Frequency	Concentration Range (mg/l)	Average Conc (mg/l)	Max. Conc. Location
Cr	27/33	<0.01 - 80	2.60	34A
Zn	33/33	<0.01 - 1.30	2.10	1-30
Ba	29/33	<0.05 - 28	3.6	1-18
Ni	33/33	.013 - 1.10	0.2	1-30
Pb	33/33	< .01 - .57	0.10	1-30
Cd	9/33	<.005 - .020	0.006	1-30

[1] Detected Frequency = Number of chemical detections/number of samples analyzed for parameter.

[2] Average Values were calculated assuming concentrations below detection limits are equal to half of detection limit.

[3] Fuel product was also present in the north tank area (well 1-30).

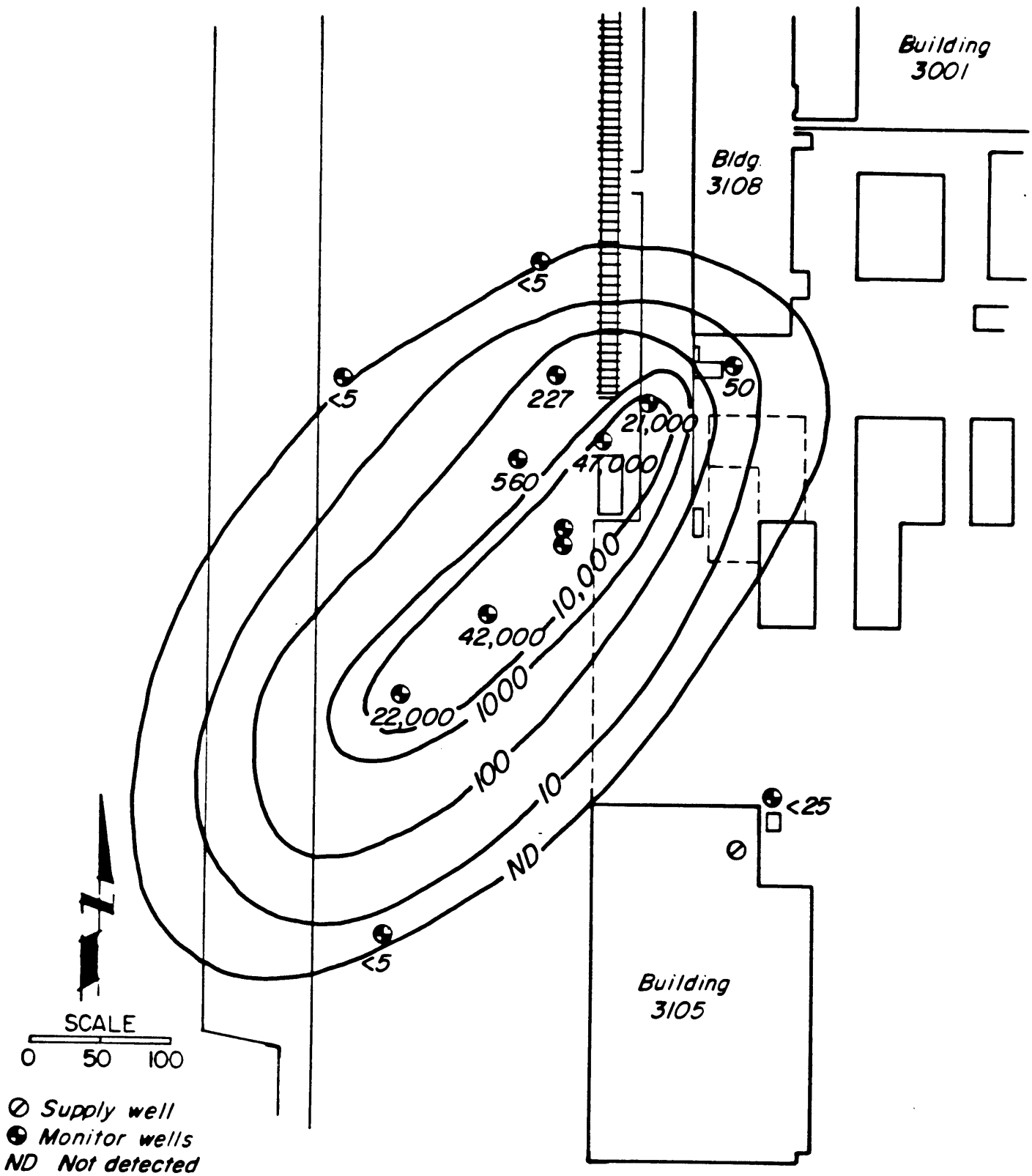
Table 8.12 lists the significant contaminants, the plume locations, approximate plume areas, approximate quantities of contaminants in the plumes, and the respective drawing number of each plume.

Table 8.12
Significant Contaminant Plumes in Perched Aquifer

Contaminant	Plume Location	Plume Area (acres)	Contaminant Quantity	Drawing
TCE	Entire Site	137	500 gal	10
1,2-DCE	Entire Site	78	138 gal	11
PCE	Entire Site	17	<1 gal	12
Toluene	N. and SW tank areas	5	20 gal	13
Benzene	N. and SW tank areas	9	2 gal	14
Xylene	N. and SW tank areas	3	<1 gal	15
Acetone	Entire Site	73	28 gal	16
Cr	Entire Site	221	825 lb	17
Pb	Entire Site	203	180 lb	18
Ba	Entire Site	176	7700 lb	19
Ni	Entire Site	96	220 lb	20

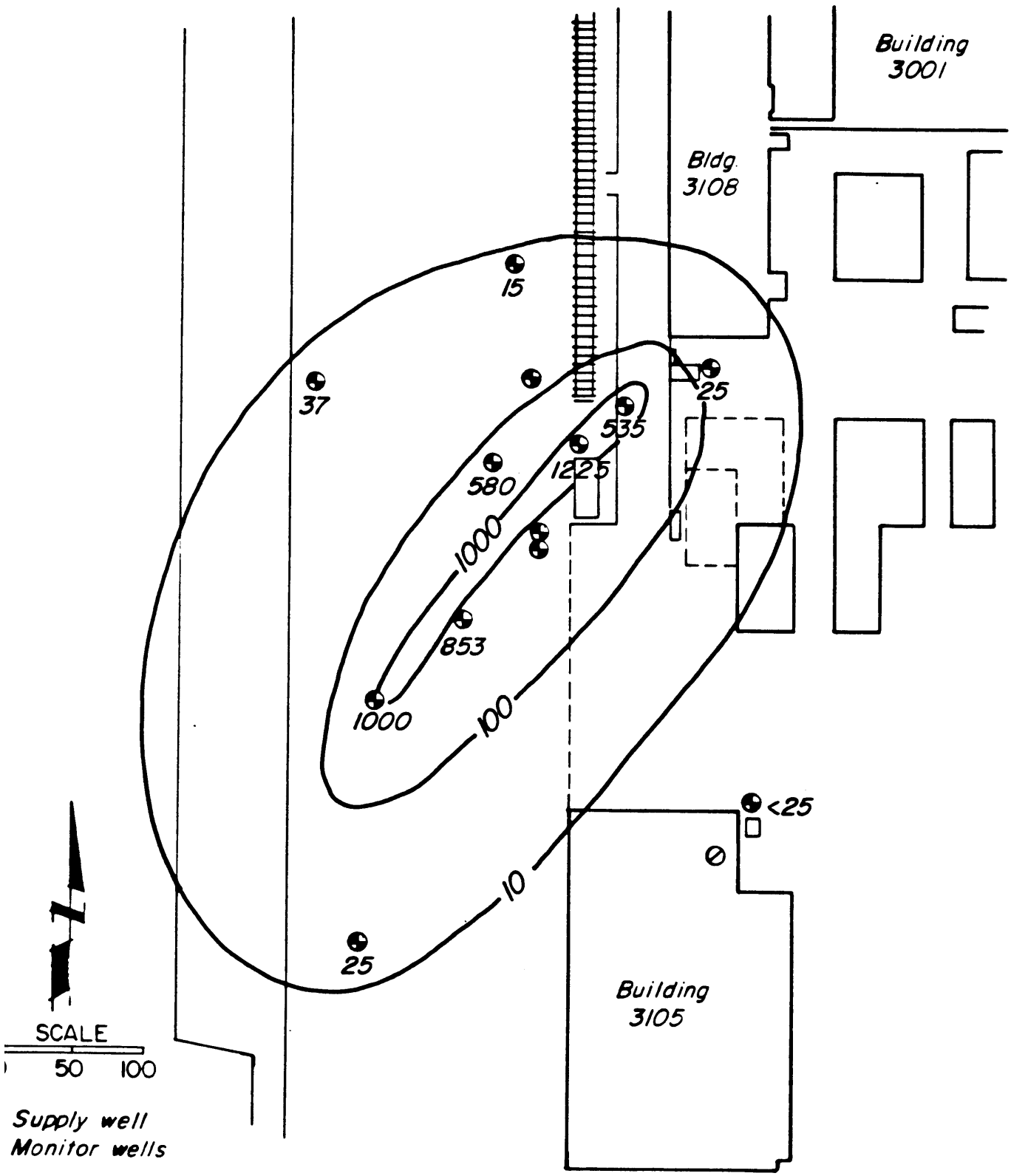
TCE concentrations ranged from 330,000 ug/l beneath the building (in well 34A) to less than 5 ug/l at the limits of the plume. The plume shape (drawing 10) indicates that the source was primarily beneath the building and migration is away from the building in the east, west, and southwest directions. This is the characteristic directions of the groundwater flow in this zone. Considerable quantities of 1,2-DCE are also present at the site. The plume has a similar shape (drawing 11) to the TCE with the highest concentrations detected beneath the building and west of the building. There are no records of 1,2-DCE being used at the building and some literature suggests that the compound is a result of anaerobic biotransformation of the TCE (ref. 1). PCE is also present primarily beneath the building with the highest concentration of 260 ug/l present at well 35A. Plume movement appears to be towards the east in the direction of East Soldier Creek. Total concentrations of Cr were detected throughout the site with the highest concentration detected at well 34A. The Cr plume has a similar shape to the TCE with movement away from the building in the east, west, and south directions. Pb is present with concentrations above the primary drinking water standard (.05 mg/l) and background concentrations (.057 mg/l). The plume (drawing 19) is concentrated primarily beneath the building with an apparent movement toward the southwest. Ba exists with a wide spread of concentrations above the primary drinking water standard (1.0 mg/l) and the background levels (1.11 mg/l). Cr, Pb, TCE, and 1,2-DCE contained elevated concentrations in the north fuel area. Also significant concentrations of nickel (Ni) and cadmium (Cd) are present in this area (wells 1-30 and 1-31). These metals and compounds are present due to migrations from operations within the building. As shown on the drawings, a storm drain line extends from the building, through this area, and discharges to West Soldier Creek. Therefore, it appears contaminants have migrated into storm drains in the building and leaked to the groundwater in this area.

a) Southwest Tank Area. Toluene, benzene, and xylene were found in high concentrations at the southwest tank area. Toluene ranged from 47,000 ug/l (well M-1) to less than 5 ug/l (well 1-16) during the sampling period. The plume is moving towards the southwest, which is the direction of groundwater flow in this area. Benzene ranged from 1535 ug/l (well M-6) to 15 ug/l in a similar shaped plume. Total xylenes concentrations ranged from 130 to 5 ug/l. Figures 8-2, 8-3 and 8-4 show this tank area in greater detail with the plumes of toluene, benzene, and xylene, respectively. The organics are the result of fuel leaks. As shown by the figures, the plume shapes indicate that the source is in the vicinity of the 7 abandoned fuel tanks (tank numbers 3140 - 3144, and 3146-3147). The plumes of toluene and benzene extend to the west beyond wells 1-16 and 1-17. An additional well cluster will be installed in the location shown (well 1-45) on drawing 1 to further define the extent of this contaminant spread.



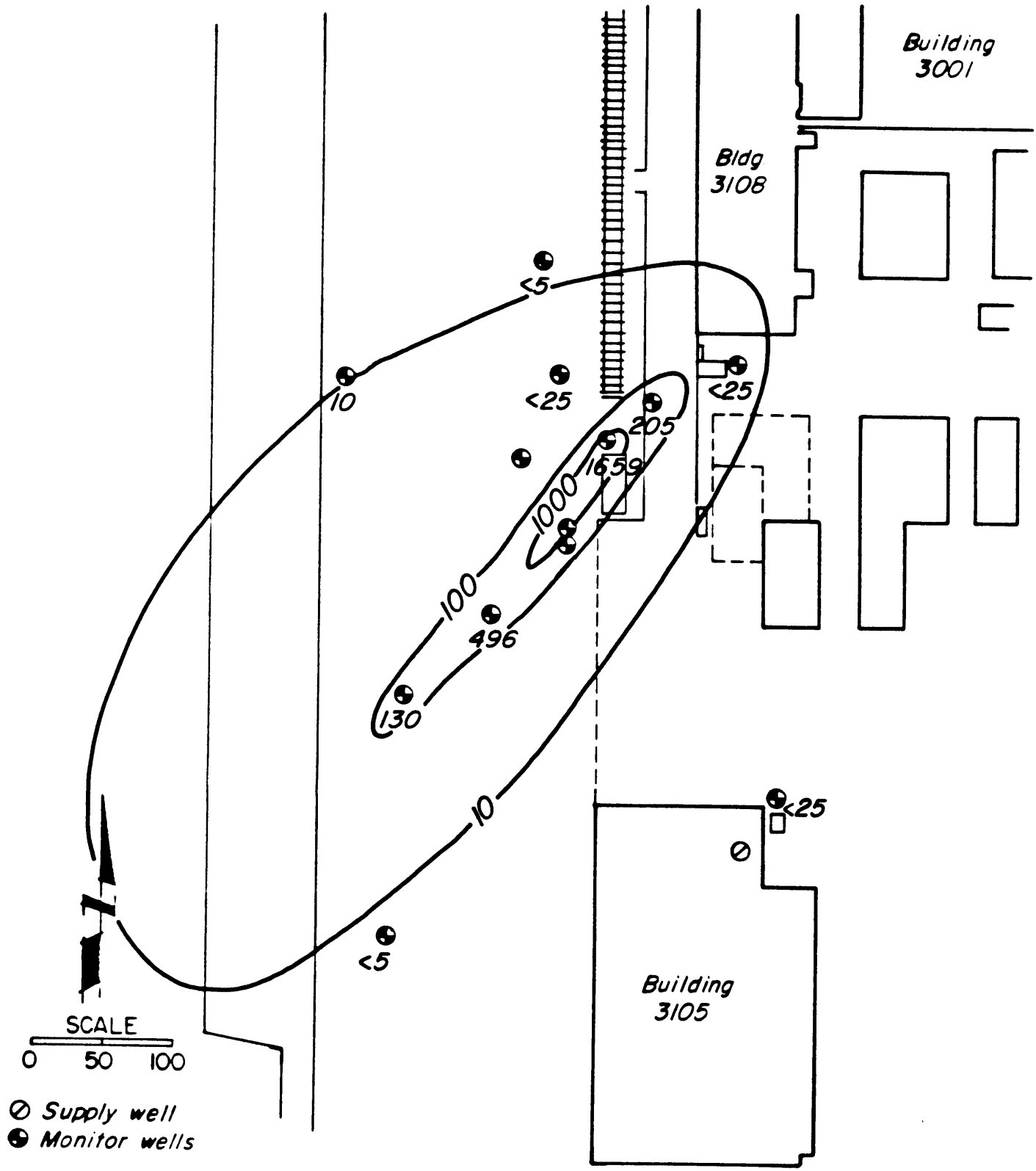
TOLUENE CONCENTRATIONS
(ug/l)
SOUTHWEST TANK AREA

FIGURE 8-2



BENZENE CONCENTRATIONS
(ug/l)
SOUTHWEST TANK AREA

FIGURE 8-3



TOTAL XYLENES CONCENTRATIONS
(ug/l)
SOUTHWEST TANK AREA

FIGURE 8-4

b) North Tank Area. Fuel contamination was first reported in the existing wells installed by A.L. Burke (installed during underground storage tank investigations), well numbers MM-1 through MM-3. Tulsa District COE installed five additional wells (wells 1-26, 1-27, 1-30, 1-31, and 1-32) to further define the extent of fuel contamination. Water and fuel depths have been periodically measured and fuel is present in 7 of the 8 wells. The elevations of the water and fuel (from October 1987 measurements) are listed in Table 8.13. An isopach of the fuel measurements is shown in figure 8-5. It is noted that large amounts of fuel are shown above the water in several wells. The thickness of fuel floating in the formation is probably much less than measured in the wells because fuel product will thicken in the wells. Measured fuel levels in wells can be 4 to 7 times greater than in the formation. A volume of fuel product in the range of 6,000 to 12,000 gallons is estimated to be floating on the groundwater. An analysis of a fuel sample from well 1-30 indicates the product is fuel oil. Some diesel may be present also. Tank 3404 contains fuel oil and is probably leaking. Water samples from the wells indicate the water beneath the fuel product is contaminated with benzene, toluene, and xylene in maximum concentrations of 260, 390, and 780 ug/l, respectively. The plume of contaminated groundwater generally follows the same shape as the fuel plume. The concentrations of benzene, toluene, and xylene are shown in figures 8-6 through 8-8 and also drawings 13, 14, and 15.

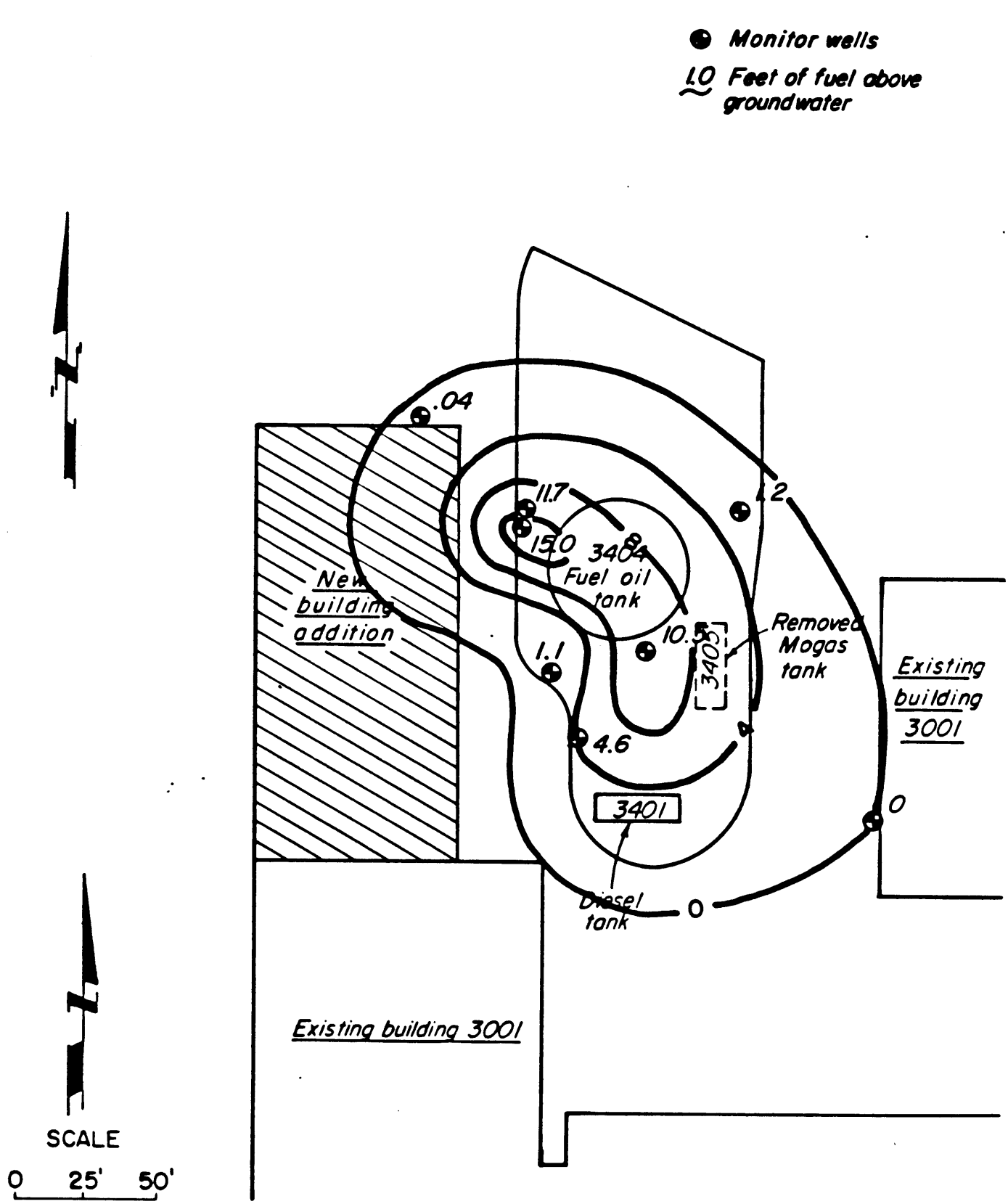
TABLE 8.13
Elevations of Groundwater and Fuel[1]

Well Number	Ground Surface Elevations	Top of Fuel Elevation	Top of Water Elevation	Amount of Fuel (Ft)
1-26	1272	1258.1	1257.0	1.1
1-27	1273	1261.0	1259.8	1.2
1-30	1272	1260.0	1248.3	11.7
1-31[2]	1271	1259.8	1259.8	0.04
1-32	1274	ND[3]	1269.6	ND
MM-1	1272	1258.9	1254.3	4.6
MM-2	1272	1257.5	1247.0	10.5
MM-3	1272	1260.4	1245.4	15.0

[1] Measurements made in November 1987 (except well 1-31).

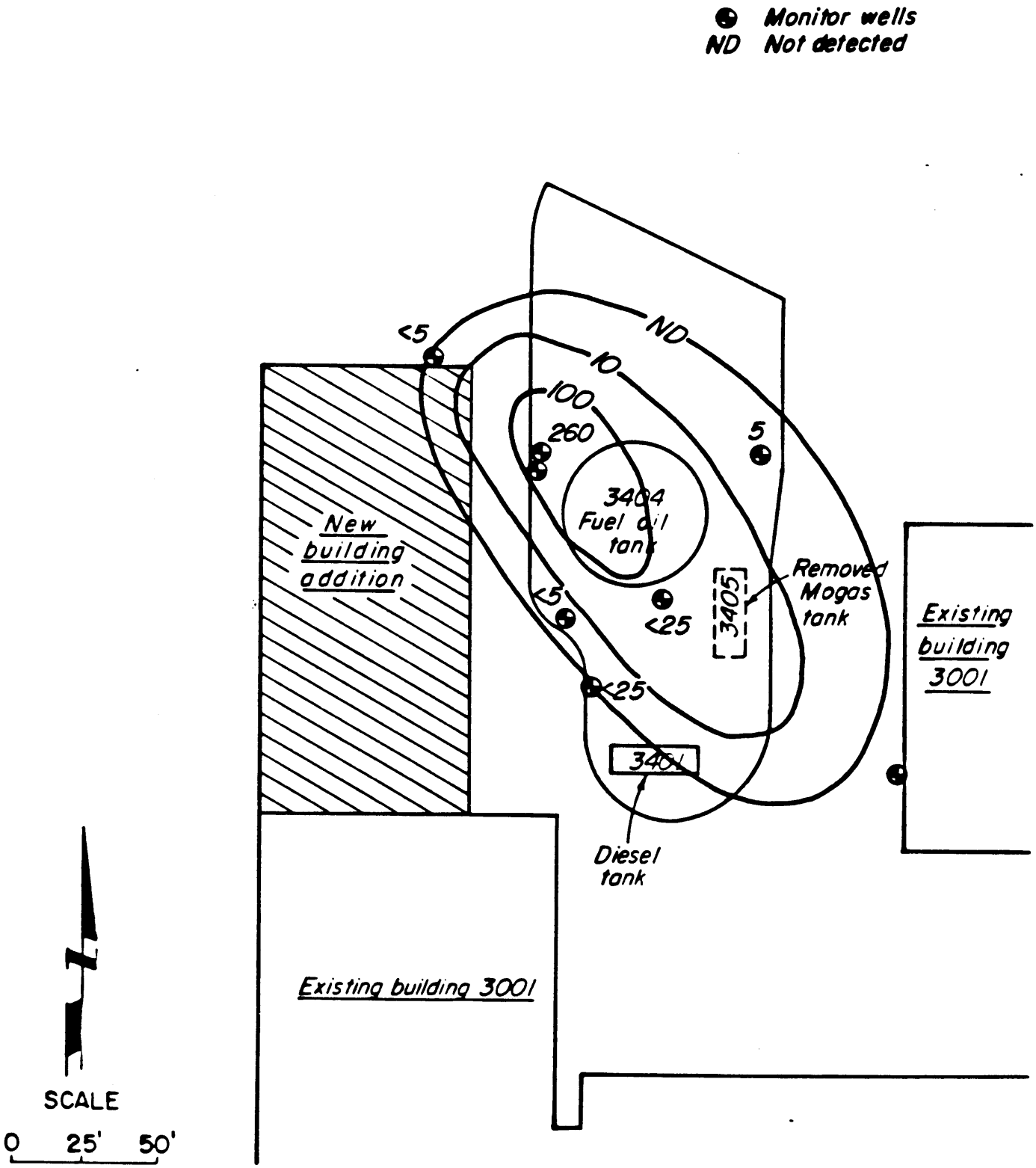
[2] Measurement made in March 1987. Well plugged due to nearby construction.

[3] ND - Not detected



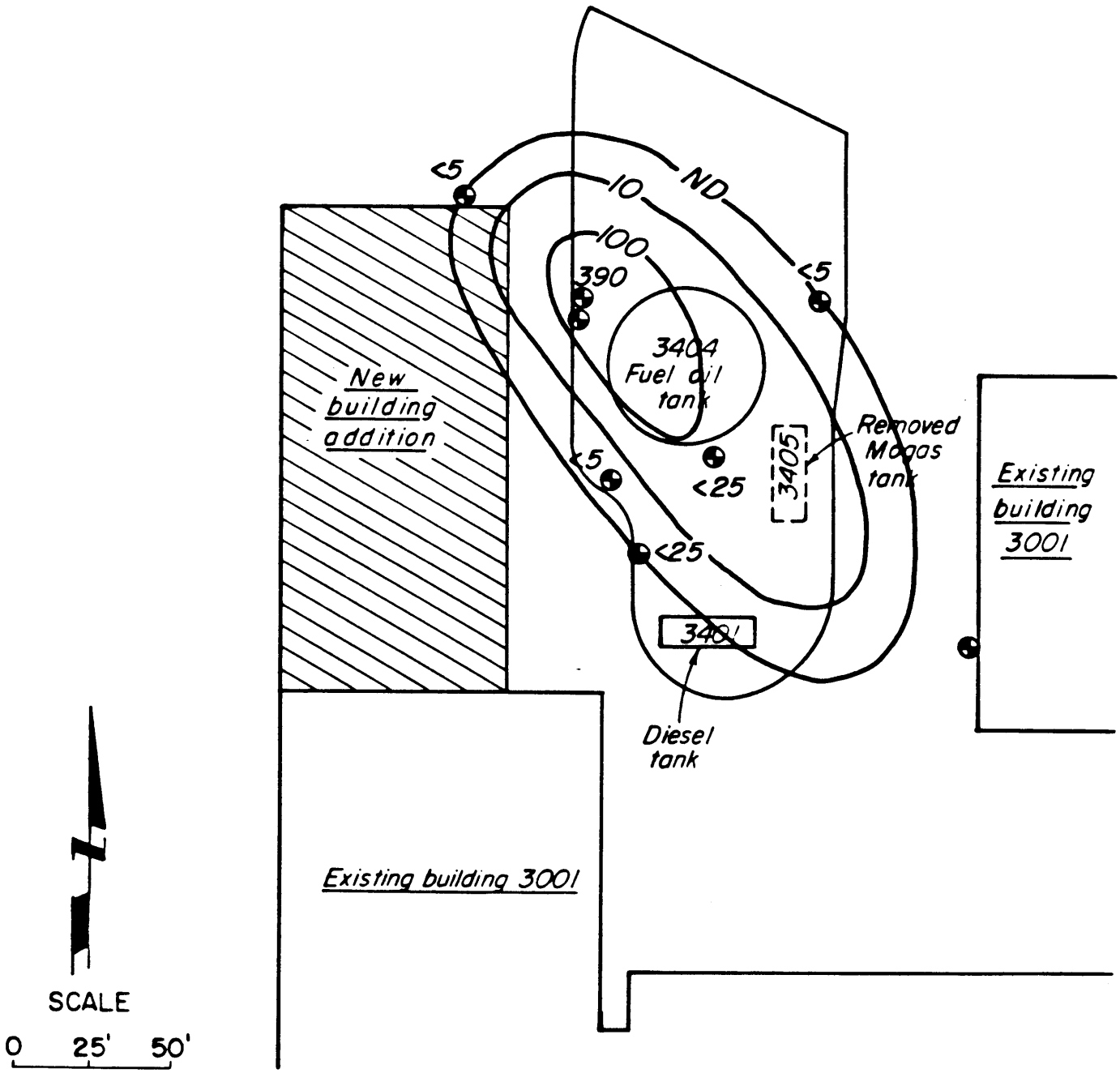
FUEL ISOPACH
NORTH TANK AREA

FIGURE 8-5



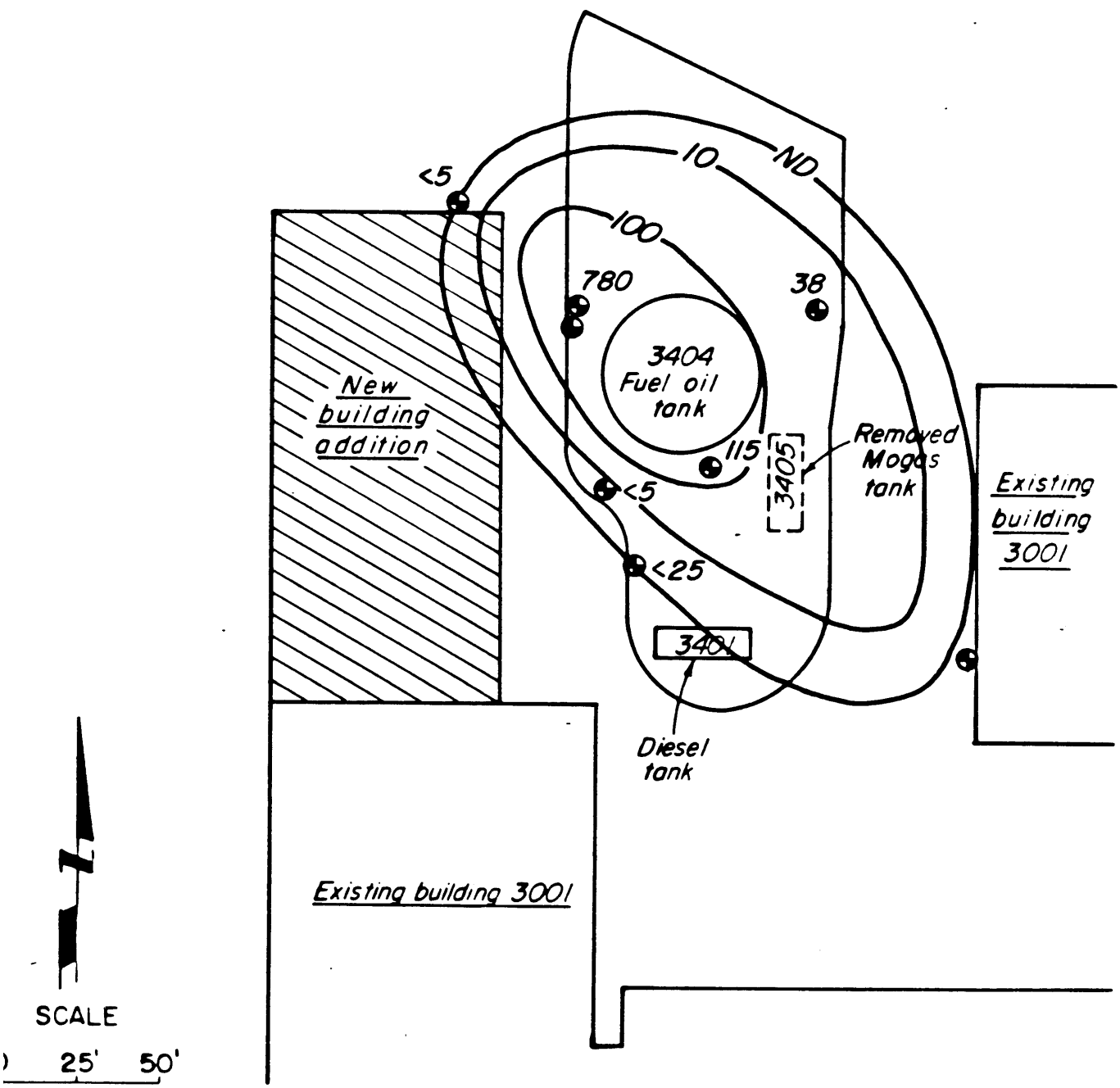
BENZENE CONCENTRATIONS
(ug/l)
NORTH TANK AREA

FIGURE 8-6



TOLUENE CONCENTRATIONS
(ug/l)
NORTH TANK AREA

FIGURE 8-7



TOTAL XYLENES CONCENTRATIONS
(ug/l)
NORTH TANK AREA

FIGURE 8-8

2) Top of Regional Aquifer. The monitoring wells installed in the top of the regional aquifer zone are listed in Table 8.1. Results of the groundwater analysis (Appendix G) show the presence of organic compounds and heavy metals in this zone. Table 8.14 lists the compounds and metals detected, the detection frequency, their range of concentrations, and the well locations of the maximum concentrations. The concentrations of TCE, 1,2-DCE, and Cr in the top of the regional zone are generally lower beneath the building than in the perched zone. PCE concentrations are slightly higher in the top of regional zone. The other compounds with significant contaminant plumes are 1,2-DCE and PCE and other significant metals are Ba and Pb. Table 8.15 lists the contaminants with significant plumes, the approximate plume areas, the quantity of contaminant, and the appropriate drawing number for each.

As shown on the plume drawings, TCE, 1,2-DCE, PCE, Cr, and Pb, contain elevated concentrations in an area northeast of the building (wells 1-11A and 19A). Also, concentrations of chlorobenzene and vinyl chloride were 940 and 530 ug/l in well 1-11A. Chlorobenzene and vinyl chloride are not present in high concentrations at the remainder of the site. The area is hydraulically upgradient from the building and contaminants have apparently migrated from a source other than the building. The source may be an industrial waste line, the industrial waste treatment plant, or an off-Base source.

Table 8.14
Compounds and Metals Detected with Maximum Concentrations and Well Locations in Top of Regional Zone

Compound	Detection Frequency	Concentration Range (ug/l)	Average Conc (ug/l)	Max. Conc. Well Location
TCE	17/25	<5 - 30,000	2330	34B
1,2-DCE	14/25	<5 - 1,400	123	1-11A
PCE	5/25	<5 - 1,200	94	33B
Toluene	5/25	<5 - 84	6	1-13A
1,2 DCA	5/25	<5 - 300	40	33B
Di-n-butyl phthalate	3/10	<10 - 300	41	19A
Phenol	5/10	<10 - 86	23	21A
Bis(2-Ethylhexyl)phthalate	5/10	<10 - 42	19	23A
1,1 DCE	4/25	<5 - 12	8	34B
Chlorobenzene	3/25	<5 - 940	42	1-11A
Vinyl Chloride	2/25	<10 - 530	29	1-11A
Acetone	13/25	<5 - 1400	86	1-6A
Total Metals	**Detection Frequency**	**Conc. Range (mg/l)**	**Average Conc (mg/l)**	**Max. Conc. Well Location**
Cr	27/33	<.01 - 1.7	0.168	34B
Ba	18/23	<.50 - 24	2.6	1-13A
Pb	21/23	<.01 - .41	.09	1-13A
Ni	23/23	.03 - .53	.07	1-13A

Table 8.15
Significant Contaminant Plumes in
Top of Regional Zone

Contaminant	Approximate Area (acres)	Quantity	Drawing
TCE	181	430 gal	21
1.2 DCE	138	50 gal	22
PCE	30	4 gal	23
Acetone	160	55 gal	24
Cr	153	300 lb	25
Ba	132	9500 lb	26
Pb	118	200 lb	27
Ni	73	200 lb	28

The highest concentration of TCE (30,000 ug/l) was detected beneath the building (well 34B) in the same location as in the perched zone. The compound is spread beneath the building and westward, beyond the west monitoring wells as shown by drawing 21. Well 1-28A contained 360 ug/l at the time of sampling. Additional wells to better define the plume in this area are not planned until remedial cleanup limits are established. However, two monitoring wells at the POL facility (which are approximately 400 feet northwest of the site) will be analyzed for TCE concentrations. Contaminant movement is generally toward the west and south in the direction of groundwater flow. TCE is also present with a concentration of 1100 ug/l in well 1-11A and 490 ug/l in well 19A. The highest concentration of 1,2 DCE was 1400 ug/l in well 1-11A. The plume has a similar shape to the TCE. PCE is present primarily beneath the building (drawing 24) with the highest concentration detected in well 33B. A high concentration of PCE was also present northeast of the building in well 1-11A. Cr was present throughout the site in concentrations above background levels (<.010 mg/l). The highest concentration of total Cr (1.7 mg/l) was detected in well 34B and the plume is spread beneath the building and generally toward the west. Pb is significantly present at the site with total concentrations above the background levels of .048 mg/l. The Pb plume (drawing 28) is shaped similar to the Cr plume, indicating movement toward the west and south. Ba is present at the site with concentrations ranging from 24 to less than 0.5 mg/l. The Ba is spread in a similar fashion as the Cr and Pb (drawing 27), with higher concentrations beneath or near the building limits. Therefore, Ba appears to be a result of the operations within the building rather than natural occurrences in the aquifer.

High pH values are present in the top of regional zone with values as high as 12.9. Drawing 29 shows a contour map of the pH values. The pH values in the perched zone ranged from 6.2 to 9.6, which is in the range of background values. Additional studies will be conducted to investigate this anomaly.

3) Regional Aquifer Zone. Groundwater samples from the regional zone were obtained from the monitoring wells listed on Table 8.1. Laboratory test results (Appendix G) from these samples indicate some of the same compounds and metals are present as in the perched and top of regional zones with generally lower concentrations. The compounds and metals detected are listed in Table 8.16

Table 8.16
Compounds and Metals Detected with Maximum
Concentrations and Well Locations in Regional Zone.

Compound	Detection Frequency	Conc. Range (ug/l)	Average Conc (ug/l)	Max. Conc. Well Location
TCE	7/11	<5 - 1000	160	34C
1.2-DCE	4/11	<5 - 46	13.5	32C
PCE	2/11	<5 28	7.3	32C
Methylene Chloride	2/11	<5 - 15	4.4	33C
Benzene	1/11	<5 - 430	41	25C
1.2 DCA	1/11	<5 - 7	2.9	32C
Toluene	3/11	<5 -13,000	1210	25C
Xylene	2/11	<5 - 7	25	1-13C
Acetone	3/11	<10- 100	21	1-13C

Metals	Detection Frequency	Conc. Range (mg/l)	Average Conc (mg/l)	Max. Conc. Well Location
Cr	8/11	1.2	.34	34C
Ba	8/11	27	8.0	1-14C
Pb	11/11	.40	.21	1-14C
Cd	8/11	.013	.011	35C
Ni	11/11	1.9	.35	1-15C

along with the detection frequency, range of concentrations and the well locations of the maximum concentrations. TCE, 1,2-DCE, and PCE have significant plumes which are contained primarily within the north portion of the building. Cr, Pb, Ni, and Ba have significant plumes also. Table 8.17 lists these contaminants, their plume areas, contaminant quantities, and corresponding drawing numbers. The other contaminants present were detected in low levels locally (in one or two wells) and are not spread throughout the site. Toluene is present in well 25C with a concentration of 13,000 ug/l. This well is in the area of the southwest tank area, where toluene is also present in the perched zone. Toluene was not detected in the top of the regional zone below the southwest tank area. An additional monitoring well will be installed in the downgradient location (well 1-45), shown on drawing 1, to further define the extent of toluene in this zone. As shown by the plume drawings, the contaminants are defined in the horizontal direction. TCE and Cr contained concentrations of 1000 and 1200 ug/l respectively at well 34C. An additional well (well 34D) is installed below this aquifer zone and screened from 218 to 253 feet to monitor the next massive, water-bearing sandstone in the aquifer. Results from this well, which are summarized in Table 8.18, indicate that the vertical extent of contamination is adequately defined. Drawings 38 and 39 illustrate the TCE plume in cross sectional view and drawings 40 and 41 illustrate the total Cr plume in cross sectional view.

Table 8.17
Significant Contaminant Plumes in Regional Zone

Contaminant	Approximate Area (acres)	Quantity (gal)	Drawing
TCE	78	13 gal	30
1.2 DCE	54	1 gal	31
PCE	13	<1 gal	32
Cr	145	320 lb	33
Pb	NA	NA	34
Ba	NA	NA	35
Ni	NA	NA	36

Table 8.18
Results of Well 34D

Compound	Concentration Detected (ug/l)
TCE	7
1,2 DCE	1
PCE	2
Methylene Chloride	6
1,1,1-TCA	1

Metals	Concentration Detected (mg/l)
Cr	.44
Pb	.34
Ni	.38
Zn	1.70

4) Producing Zone. The water quality in the producing zones of the aquifer were analyzed in the vicinity of Building 3001 by sampling and testing water supply wells 13, 14, 15, and 16. The well locations are shown on drawing 1 and complete laboratory results are contained in Appendix G. Water supply well 17, which is located in the vicinity, was not sampled because it is out of service. Wells 15 and 16 contain low levels of TCE (0.7 and 1.9 ug/l respectively) and well 16 also contains 1,2-DCE and PCE (1.9 and 0.7 ug/l respectively). Well 17 is probably contaminated also since it is in the vicinity of some contaminant plumes in the top of the regional aquifer. Observations of three supply wells while pumping indicated that, although the water supply wells greatly influenced each other, they had very little effect on the upper contaminated groundwater zones. Therefore, contamination apparently entered these wells by vertical migration from the top of the wells. Wells 18 and 19, which were recently plugged, contained TCE and PCE. These wells were located (drawing 1) within the horizontal limits of the TCE and PCE plumes and the poor condition of these wells allowed for their contamination. As shown on drawings 21, 22 and 23, the TCE, 1,2-DCE, and PCE contamination plumes at the top of the regional aquifer extend over water supply wells 15, 16, and 17.

8.4 Chemical Character of Soil. Soil samples were collected from eight borings drilled inside the north portion of Building 3001 (in the industrial shop areas) during the fire-damaged area investigations (Appendix B). Samples were taken from soil adjacent to some abandoned pits and in areas of required excavations. The samples were analyzed for total metals, EP toxicity, volatile organics, and semi-volatile organics. The results of laboratory analyses are listed in Table 2 of Appendix B. A summary of the organics and metals detected is shown in Table 8.19.

Table 8.19
Summary of Organics and Metals Present in
Soil Samples Beneath Building 3001

Organic Compounds	Maximum Concentration (ug/kg)	Location	Depth (ft)
TCE	120,000	E105	5.0-6.0
1,1,1-TCA	5200	W83	5.0-6.0
Methylene Chloride	2.11	E105	5.0-6.0
1,1-DCA	2.1	W83	14.0-15.0
1,2 DCE	.300	A87	9.0-10.0
PCE	4.21	W83	14.0-15.0
1,1,2-TCA	1.92	W83	14.0-15.0
Trichlorofluoromethane	.102	W83	14.0-15.0
chloroform	5.7	W83	14.0-15.0
Methyl ethyl Ketone	7.3	W88	10.0-20.0
Acetone	41	W88	10.0-20.0
Benzene	73,500	E105	5.0-6.0
Chlorobenzene	730	E105	5.0-6.0
Para-dichlorobenzene	6.5	K107	1.0-5.0
Meta-dichlorobenzene	2.4	K107	1.0-5.0
ortho-dichlorobenzene	2.4	K107	1.0-5.0
pi-n-butylphthalate	4.6	K107	7.0-7.5
bis(2-ethylhexyl)pthalate	5.2	K107	7.0-7.5
carbon tetrachloride	1080	E105	5.0-6.0
chloroethylvinyle ether	960	E105	5.0-6.0
1,1,2,2,-PCA	45,400	E105	5.0-6.0
toluene	45,100	E105	5.0-6.0
ethylbenzene	33,600	E105	5.0-6.0

Metals	Maximum Concentration (ug/kg)	Location	Depth (ft)
Ba	1,138	R85	9.0-10.0
Cr	5.0(EP Tox)	R85	9.0-10.0
Hg			
Cd	1,138	R85	9.0-10.0
Cu	29	R85	9.0-10.0
Pb	14	R85	9.0-10.5
Ni	35	R85	9.0-10.0
Zn	66	R85	9.0-10.0

Results indicate that the upper soils and bedrock (above the perched water table) are contaminated in localized areas beneath the building. Contamination resulted from the migration of solvents and metal-laden wastewaters which leached from sources into the groundwater. Although contamination sources have probably been eliminated, contaminated soils in recharge areas will continue to leach into the perched aquifer as recharge water flushes through the soil. Additional soil sampling will be conducted inside the building to better define the concentrations of contaminants within the zone of aeration. This information will be used to evaluate the feasibility of treating the contaminated soil in-situ and to properly model the contaminant transport in the groundwater under groundwater collection alternatives.

a. North Tank Area. Soil samples were collected at the location of well 1-30 (north tank area) and analyzed for heavy metals, volatile organics, and fuel type. The complete laboratory results, including details of the fuel identification methods, are contained in Appendix I. Low concentrations of As, Ba, Cd, Cr, Ni, Pb, Se, and Zn were detected in the samples. The volatile organics detected are listed in Table 8.20. Fuel and diesel were identified in the soil samples. Diesel was present in one sample and fuel oil was present in 10 samples. Xylene was present in 7 of the 10 samples containing fuel oil. Table 8.21 lists the fuels and total xylenes present with the corresponding depths of the samples. Well 1-30, which is adjacent to fuel tank 3404 (figure 3), also contains fuel floating above the groundwater. The bottom of tank 3404 is approximately 24 feet deep. The highest concentrations of fuel oil and xylene are found from depths of 24 to 33 feet, therefore, the tank probably leaks at or near the tank bottom. Tank 3401, a 20,000 gallon steel diesel tank, is located approximately 75 feet south of Tank 3404. One soil sample (12 to 12.5 feet deep) was identified as containing diesel and fuel oil.

Table 8.20
Volatile Organics Detected in Soil Samples
At Well Location 1-30

Compound	Maximum Concentration (mg/kg)	Depth (ft)
Methylene chloride	.330	20.3
Acetone	9.96	24.7-25.2
Chlorobenzene	.015	12.0-12.5
Ethylbenzene	10.13	27.7-28.2
Toluene	7.73	24.7-25.2
Xylene (total)	31.0	24.7-25.2
Styrene	27.0	27.7-28.2

Table 8.21
Summary of Soil Sample Results
at Well Location 1-30

Depth (ft)	Xylene (mg/kg)	Concentration ug C/g Soil	Fuel Type
2-2.5	ND	<100	-
2.5-3.0	ND	<100	-
5.0-5.3	ND	<100	-
5.5-6.0	ND	<100	-
6.5-7.0	ND	<100	-
7.0-7.5	ND	<100	-
9.0-9.5	ND	<100	-
10.0-10.5	ND	<100	-
12.0-12.5	8	19,000	Diesel & Fuel Oil
12.5-13.0	ND	170	Fuel Oil
17.1-17.6	ND	4500	Fuel Oil
17.8-20.3	.53	120	Fuel Oil
20.3-20.8	ND	<100	-
24.2-24.7	17.	120,000	Fuel Oil
24.7-25.2	31.	130,000	Fuel Oil
27.2-27.4	18.	140,000	Fuel Oil
27.7-28.2	22.00	400,000	Fuel Oil
31.7-32.2	20.00	140,000	Fuel Oil
32.5-33.0	10.475	110,000	Fuel Oil
35.1-35.6	ND	<100	-
37.1-37.6	.082	<100	-

ND - Not Detected
ug C/g Soil = micrograms of carbon per gram of soil.

Soil samples were also collected at well locations 1-26, 1-27, 1-29, and 1-31 and analyzed for noticeable fuel odor. These results are listed in Table 8.22. Fuel odors in the upper zone, above the groundwater, were noticeable in zones of fill material. The fill materials, placed during underground tank and utility construction, may allow fuel vapor movements due to a higher permeability of the fill compared to the natural clays and sands. Vapors from fuel contaminated sites are known to migrate long distances around utility lines. During the underground storage tank investigations (ref. 3), soil samples were collected at well locations MM-1 through MM-3 and also at two boring locations, BM-1 and BM-2. These samples were analyzed for benzene, toluene, and xylene (BTX) and total hydrocarbons. The results are listed in Table 8.23. The perched groundwater table is found at approximately 15 feet deep. Most hydrocarbons were detected in samples below the top of the water table, however, some fuel contamination is present in the soils above the perched water.

Table 8.22
Fuel Detection in Soil Samples

Well Number	Ground Surface Elevation	Sample Depth Feet	Soil Classification	Fuel Detection
1-26	1272	0.0-3.0	CL	ND
		3.0-7.0	CL	P
		7.0-9.5	SP (Fill)	P
		9.5-12.0	SM	ND
		12.0-14.0	SS	ND
		14.0-17.0	SS	ND
1-27	1273	0.0-1.0	CL	ND
		1.0-2.0	SC	ND
		2.0-4.0	SC	ND
		4.0-8.5	ML (Fill)	P
		8.5-9.3	SP (Fill)	P
		9.3-24.0	SS	ND
1-30	1272	11.0-11.4	SC	ND
1-31	1271	0.0-4.0	CL	ND
		4.0-9.0	CL	ND
		9.0-11.0	SC	ND
		13.0-17.0	SS	P
		17.0-20.0	SH	ND

ND - Not Detected
P - Present

Table 8.23
Results of Soil Samples from UST Investigations (mg/kg)[1]

Boring No.	Benzene	Toluene	Xylenes	Total Hydrocarbons
BM-1 8'	<1.0	<1.0	<1.0	5.0
BM-1 15'	<1.0	<1.0	<1.0	3301.0
BM-1 20'	<1.0	<1.0	<1.0	6495.0
BM-1 25'	<1.0	<1.0	<1.0	7770.0
BM-2 8'	<1.0	<1.0	<1.0	<1.0
BM-2 15'	<1.0	<1.0	<1.0	2106.0
BM-2 20'	<1.0	<1.0	<1.0	18033.0
BM-2 25'	<1.0	<1.0	<1.0	40038.0
MM-1 8'	<1.0	<1.0	<1.0	<1.0
MM-1 15'	<1.0	<1.0	<1.0	<1.0
MM-1 20'	<1.0	<1.0	<1.0	<1.0
MM-2 8'	<1.0	<1.0	<1.0	<1.0
MM-2 15'	<1.0	<1.0	<1.0	10,050.0
MM-2 20'	<1.0	<1.0	<1.0	26,173.0
MM-2 25'	<1.0	<1.0	<1.0	60,229.0
MM-3 8'	<1.0	<1.0	<1.0	281.0
MM-3 15'	<1.0	<1.0	<1.0	253.0
MM-3 20'	<1.0	<1.0	<1.0	5.0
MM-3 26.5'	<1.0	<1.0	<1.0	48,936.0

[1] Underground Storage Tank Investigations by A.L. Burke Engineers, Inc. (Ref. 3)

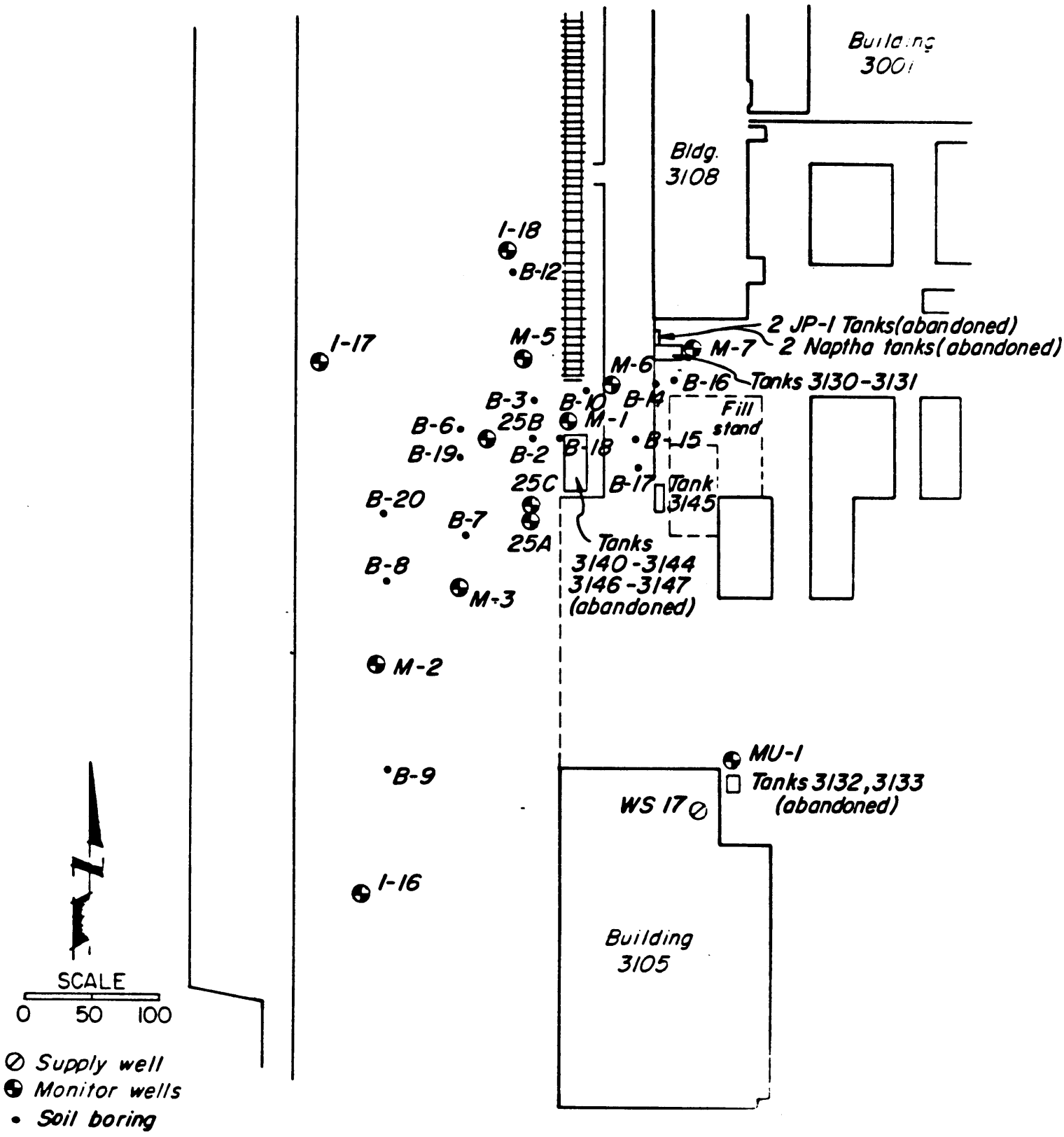
b. Southwest Tank Area. Soil samples collected in this area during the UST Investigations were analyzed for BTX and total hydrocarbons (Ref. 3). Samples were collected from well locations M-1 through M-7 and borings B-1 through B-20 at selected locations (to depths of 35 feet). The locations of these wells and borings are shown on figure 8-9. The results of the laboratory analyses are included in Appendix J. Significant contamination was not observed in the upper soils (above the groundwater), but only at depths within the (greater than 15 feet) perched aquifer. This indicates the contaminant spread is occurring within the groundwater aquifer and any soil contamination is in localized areas (probably adjacent or beneath the abandoned fuel tanks, 3140 through 3144 and 3146 and 3147). The existing contents of the gasoline tanks are unknown.

8.5 Problem Characterization. Contamination of the groundwater has resulted primarily from past industrial practices and storage methods. Contaminants are contained primarily in the upper 175 feet beneath the site. Based on a study of the site hydrogeology, the subsurface aquifer system was simulated by dividing it into four zones; the perched aquifer, the top of the regional aquifer, the regional zone, and the producing zone. A two-dimensional groundwater flow and contaminant transport computer model was developed and calibrated to simulate the aquifer zones and plume movements. The computer model details are contained in a report attached as Appendix K. Aquifer parameters were obtained from field investigations and laboratory tests.

a. Perched Aquifer. The perched aquifer is present throughout the site except near the northeast boundary, east of East Soldier Creek. Groundwater contours (drawing 7) show a high or mounded area beneath and near the building. Perched groundwater flows away from the building in both the east and west directions, but predominately in the southwest direction. Mounded areas generally indicate a recharge zone and the site features tend to support this. One mounded area beneath the southwest portion of the building appears to be affected by storm drains in the area. The mounded area north of the building also appears to be affected by storm drains. Utility lines (based on Base CE drawings) are included on drawing 7A, and the correlations can be seen.

The shapes of the plumes may be partially due to the contaminants discharged into storm drains. For example, elevated TCE concentrations occur north of the building near well 1-30 and northwest of the building at well 1-12B. In the past, West Soldier Creek has received discharges from storm drains that contained TCE and grab samples from the creek have shown concentrations of TCE (ref. 15). The TCE plume shape in this area may be partially due to leaking of the storm drain near well 1-30 and 1-31 and migration from West Soldier Creek. The perched zone is a water table aquifer and contaminant movement is primarily a function of the water table gradient. Figures 8-10 and 8-11 show three-dimensional maps of the perched aquifer bottom and water table with the TCE and Cr plumes superimposed. These figures illustrate the relationships of the groundwater gradient and bottom confining layers with the contaminant dispersion. Slug tests in the aquifer zone show horizontal permeabilities in the range of 10^{-4} to 10^{-3} cm/sec, depending on the amount of shale present.

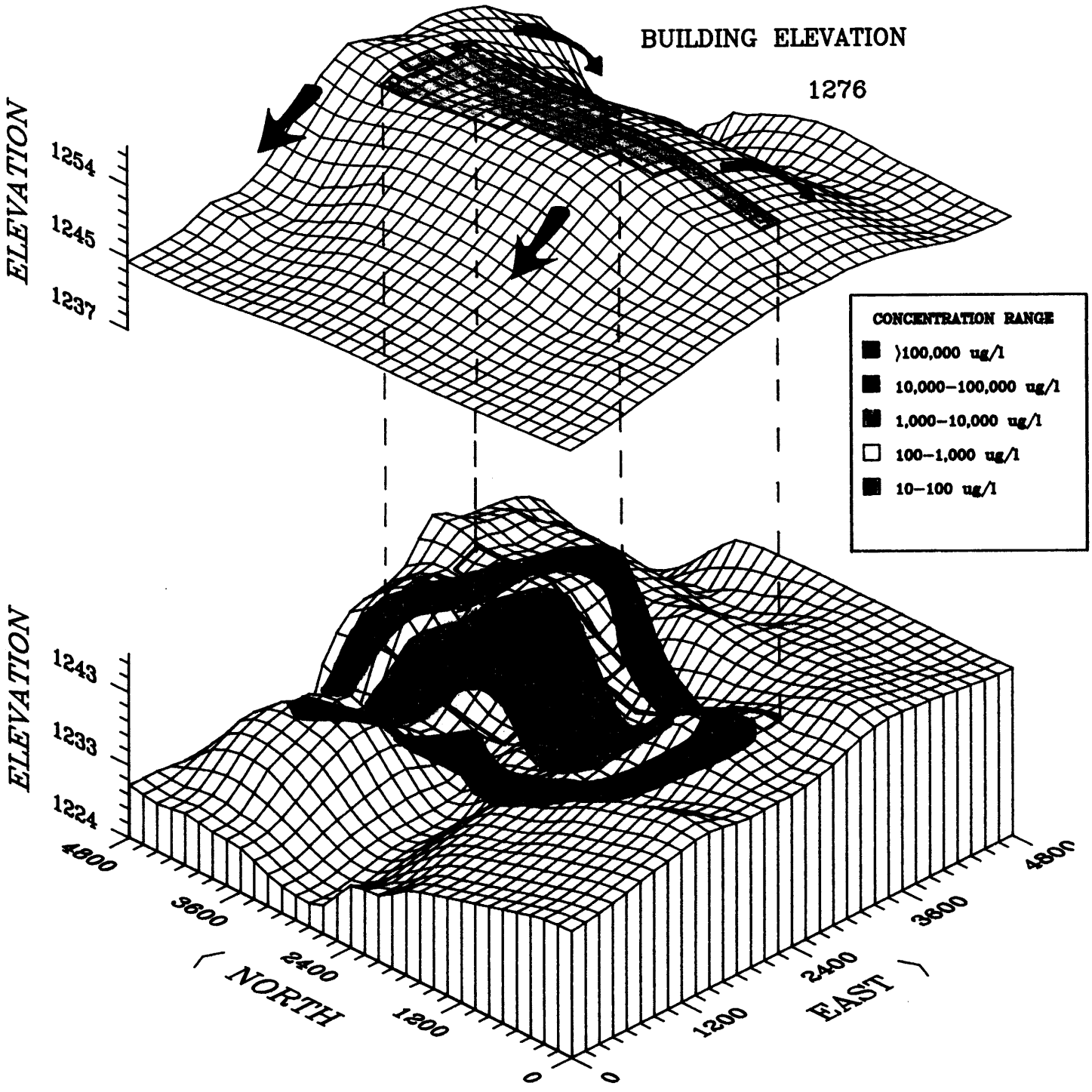
The porosities calculated from undisturbed samples in this zone ranged from .17 to .32 and a value of .20 was assigned as an effective porosity. The shale bottom confining layer had laboratory permeability values of 10^{-8} cm/sec. The



SOUTHWEST TANK AREA

FIGURE 8-9

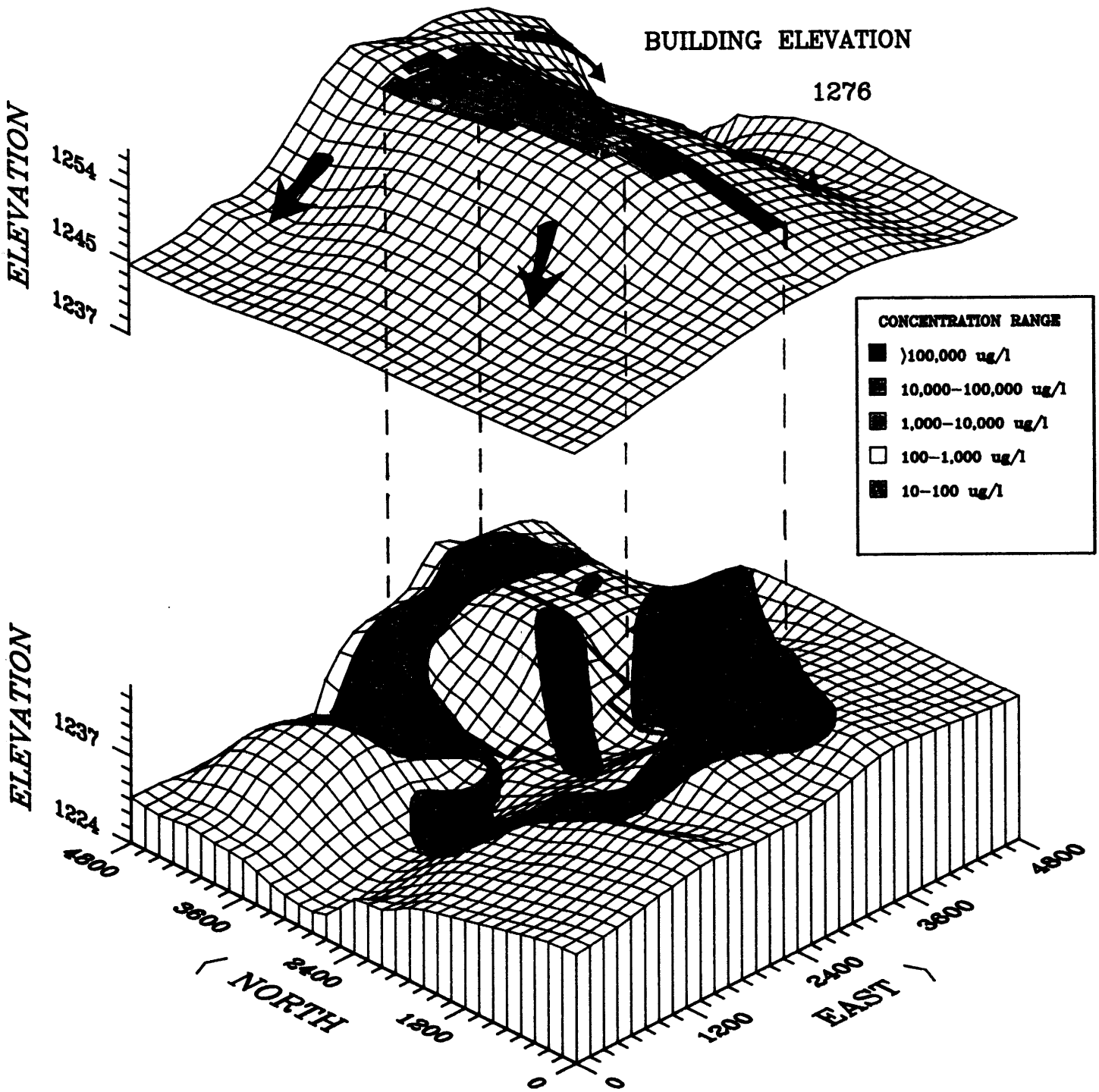
PERCHED GROUNDWATER SURFACE AND FLOW



BOTTOM OF THE PERCHED AQUIFER WITH TCE PLUME

FIGURE 8–10

PERCHED GROUNDWATER SURFACE AND FLOW



PERCHED AQUIFER BOTTOM CONFINING LAYER

WITH CHROMIUM CONCENTRATION PLUME

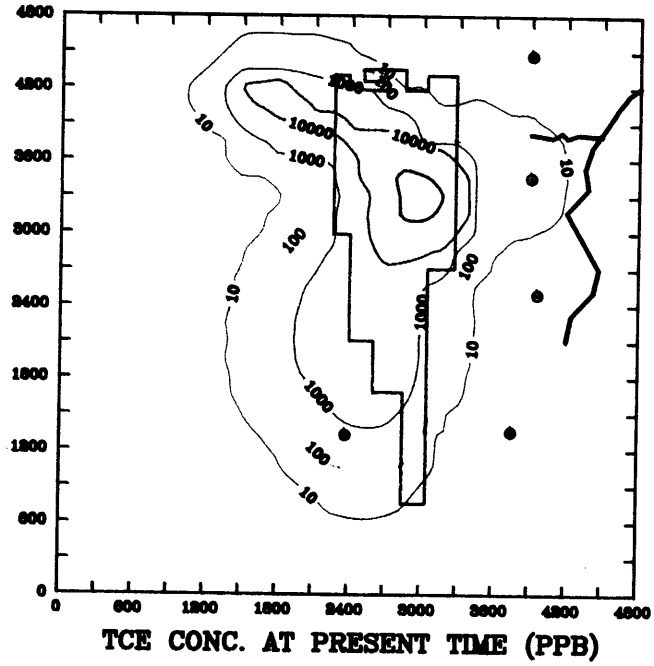
FIGURE 8–11

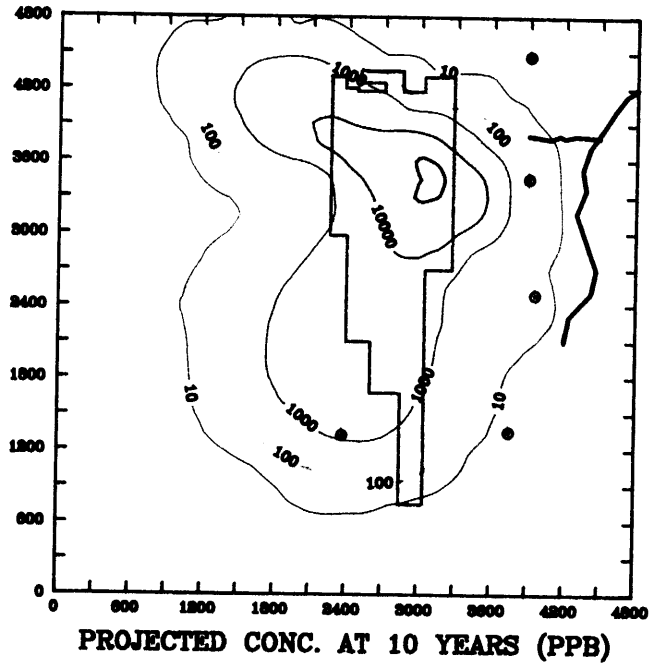
percent saturation was calculated for the confining layer and values ranged from 68 to 100 percent. The computer model was used to simulate contaminated water migration within this perched zone. The horizontal migration of TCE and Cr was modeled over time periods of 10, 25, and 50 years. The model simulated plume movements as continued vertical migration of contaminants into and out of the perched zone occurred. The TCE and Cr projected plumes are shown in figures 8-12 and 8-13. Results of the modeling indicate that peak TCE concentrations beneath the building decrease approximately an order of magnitude over 25 years from dispersion and vertical migration. Peak Cr concentrations decrease approximately an order of magnitude over 50 years of simulated plume movement. The plumes increases in size with time, moving in both the east and west directions with downgradient flow.

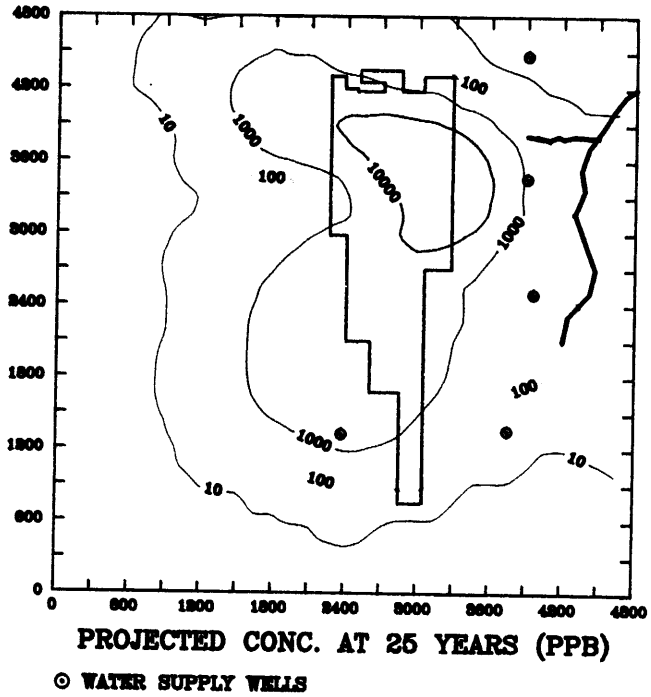
The rates of migration vary due to differences in hydraulic gradient. Other factors which may also affect the migration rates include variances in porosity, permeability, and retardation of the aquifer media, distances from the contaminant source to the aquifer, and densities of the water and contaminants. Both plumes move about 20 feet per year toward the west and southwest and 15 feet per year toward the east. As the eastward moving plume nears East Soldier Creek the rate of migration increases to about 50 feet per year. Over the entire 50 year simulation period, the plumes remain within the Base property boundaries. However, eastward plume movements allow discharge into East Soldier Creek, and with no remedial actions to control the plumes, TCE and Cr concentrations greater than 100 ug/l reach the creek within 10 years.

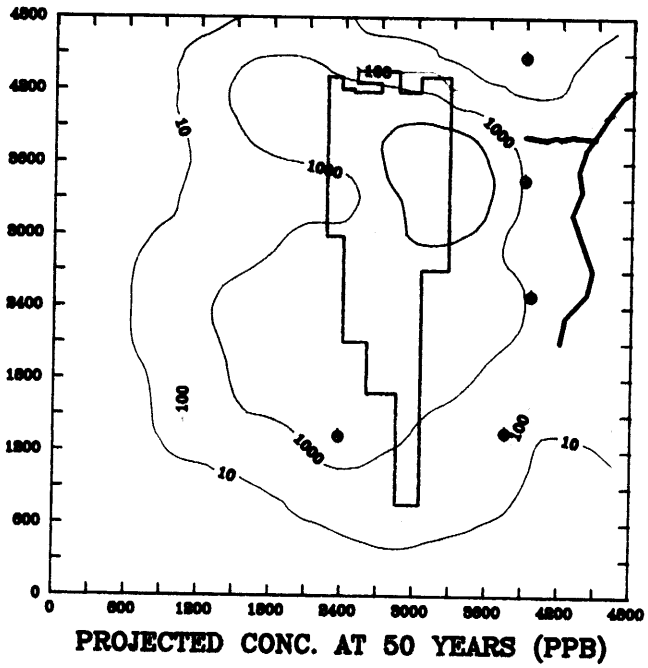
b. Top of Regional Zone. This zone was simulated as a confined aquifer. Aquifer thicknesses ranged from 11 to 32 feet and field tests indicated horizontal permeabilities ranging from 10^{-4} to 10^{-3} cm/sec. Figures 8-14 and 8-15 show the TCE and Cr plumes superimposed on the aquifer thickness. Plume shapes are reflective of the aquifer thickness, hydraulic gradient, source locations, formation dip, and chemical dispersion within the media. The primary source of contaminants is the perched zone, beneath the building, where vertical migration has taken place. Vertical migration rates of approximately 6 feet per year are estimated to occur between the perched and top of regional zone. The vertical migration occurs along paths of preferential flow. The source of the high concentrations northeast of the building is unknown without further investigations upgradient of the site and resampling of the existing upgradient wells.

Future plume movements for TCE and Cr were simulated as shown in figures 8-16 and 8-17. The plume migrations were modeled assuming additional contamination was vertically migrating into and out of the aquifer zone with no contaminated water collected (no action plan). Both plumes are slowly migrating westward approximately 20 feet per year, and remain within the Base boundaries over the entire 50 years.



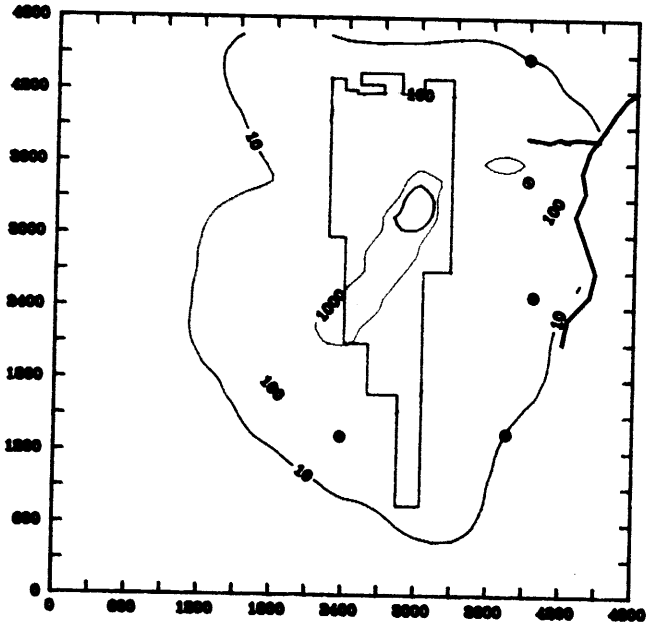


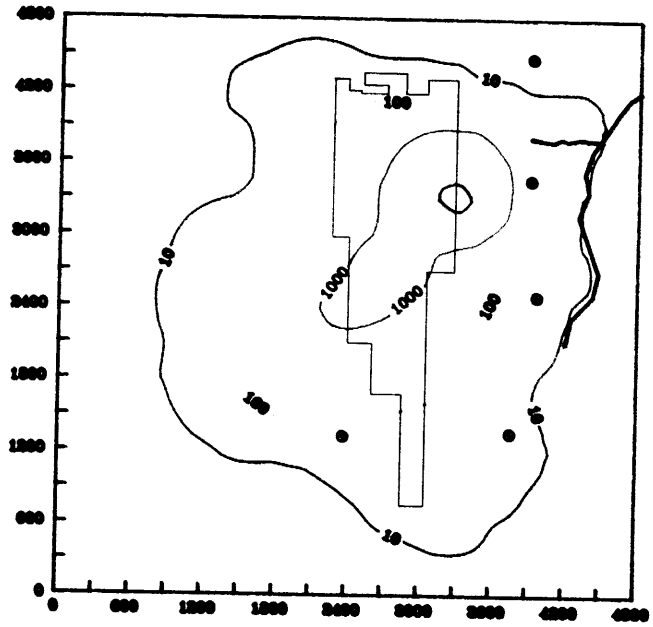


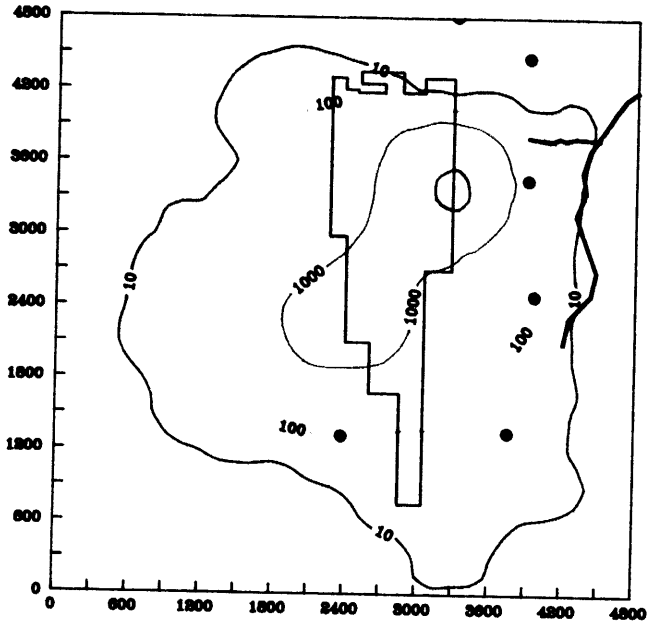


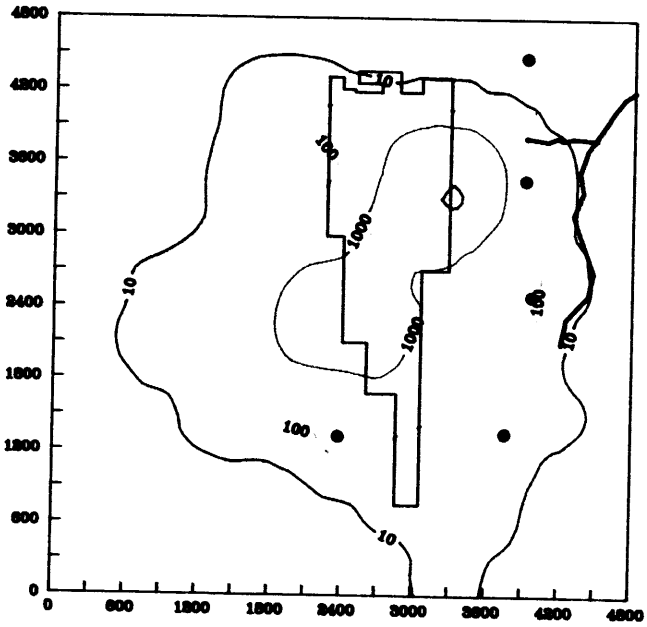
TCE PLUMES IN THE PERCHED AQUIFER AT 3001

FIGURE 8-12



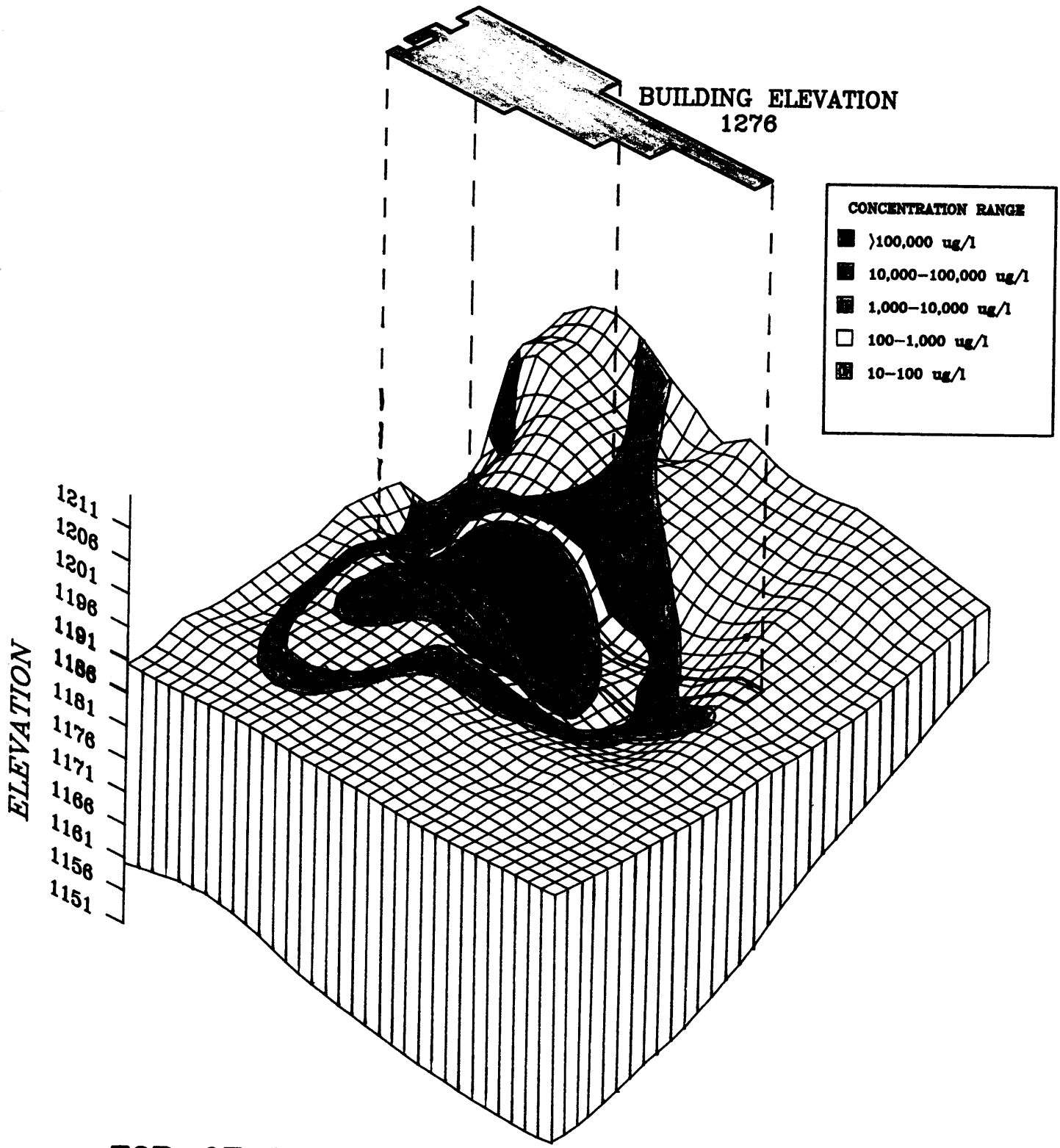






CHROMIUM PLUMES IN PERCHED AQUIFER AT 3001

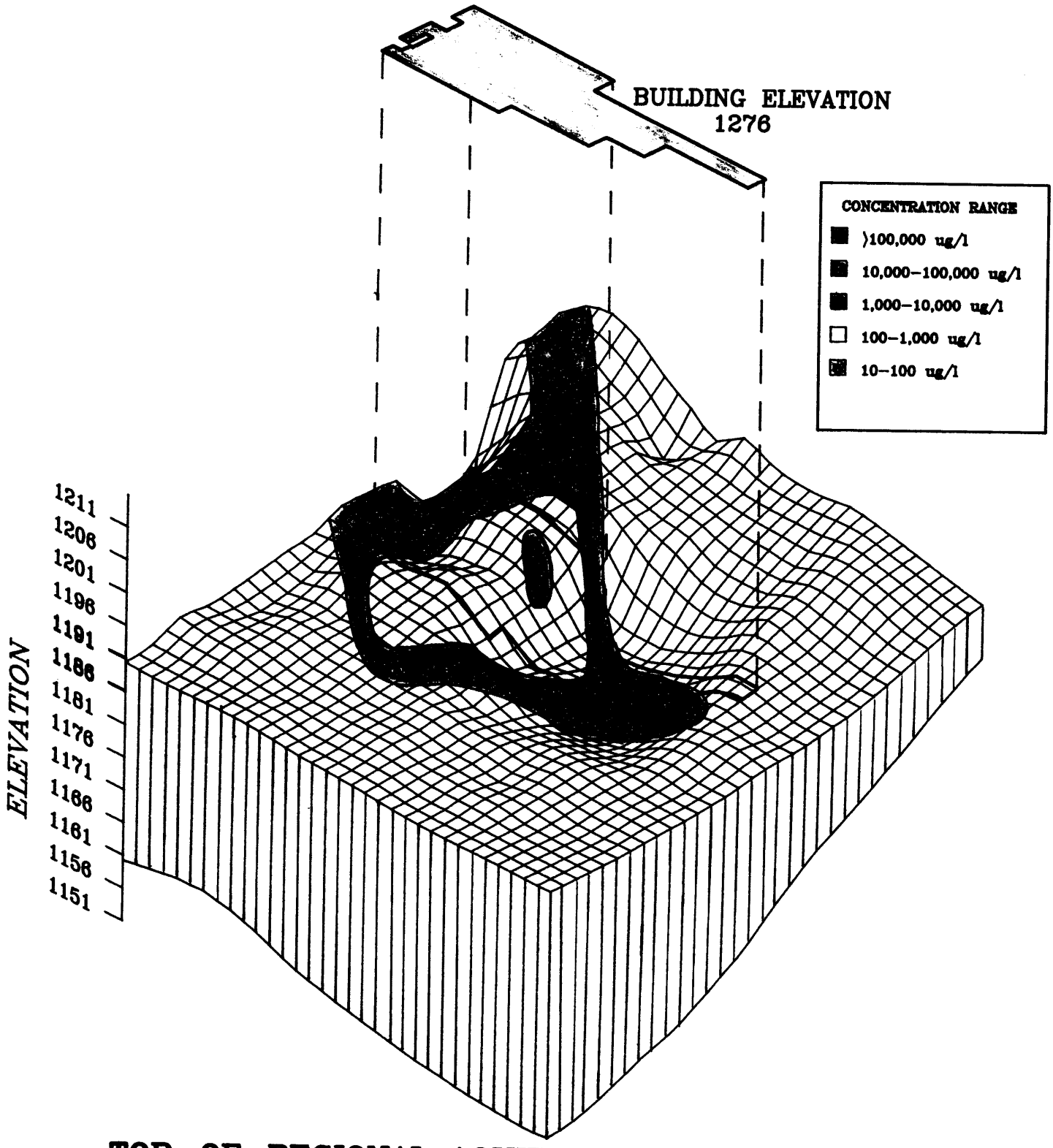
FIGURE 8-13



TOP–OF–REGIONAL AQUIFER CONFINED THICKNESS

WITH TCE CONCENTRATION PLUME

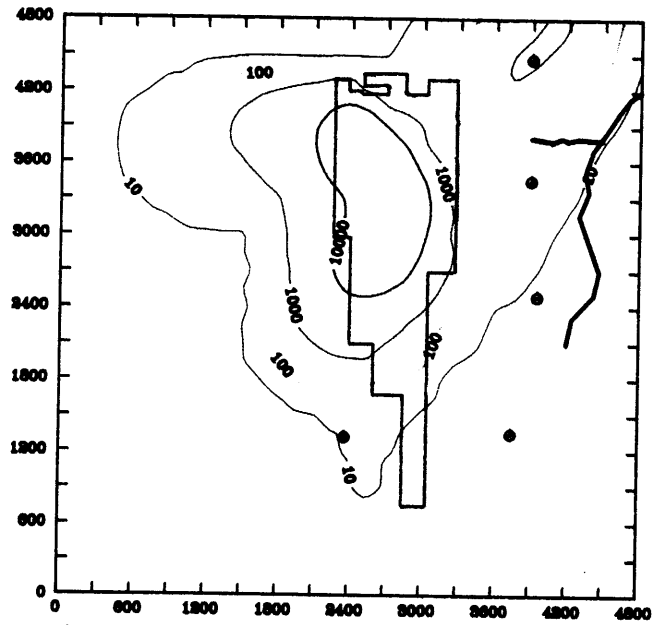
FIGURE 8–14

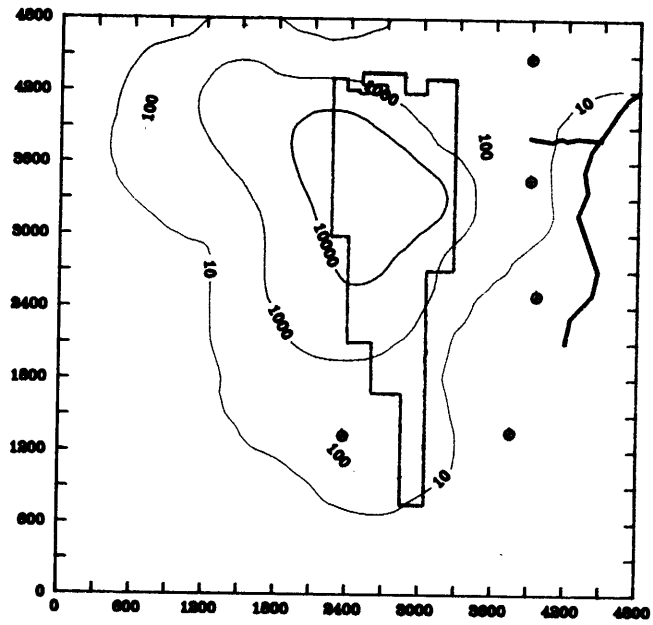


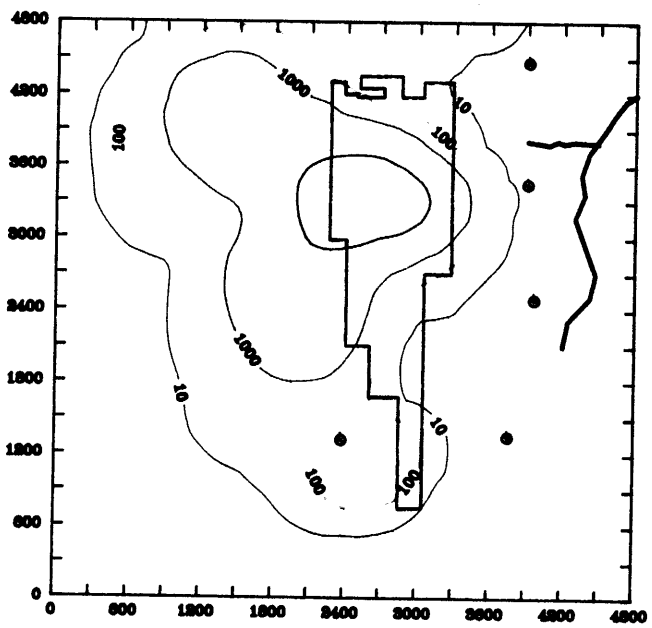
TOP–OF–REGIONAL AQUIFER CONFINED THICKNESS

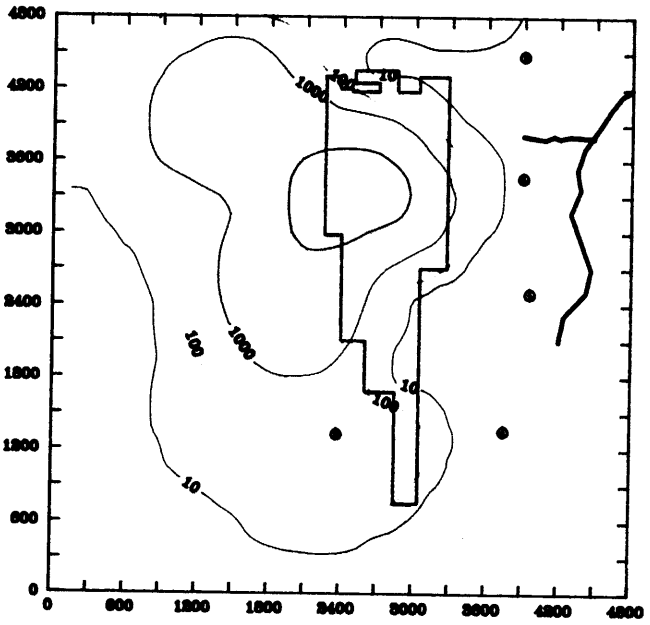
WITH CHROMIUM CONCENTRATION PLUME

FIGURE 8–15



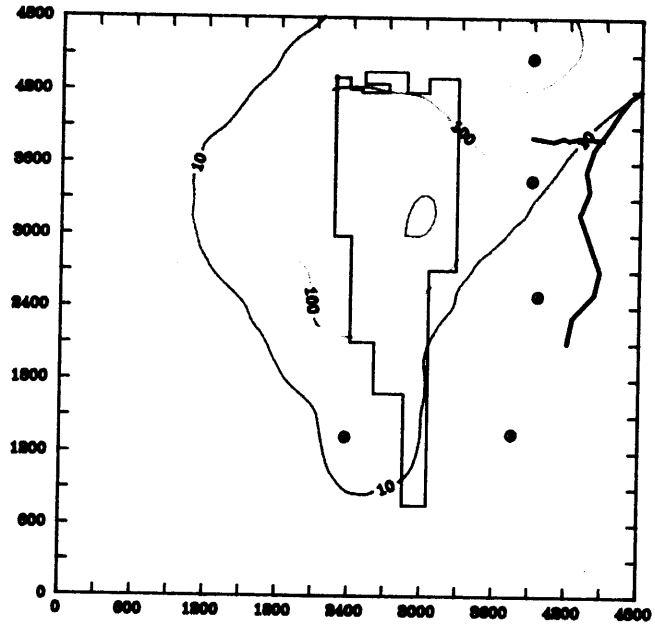




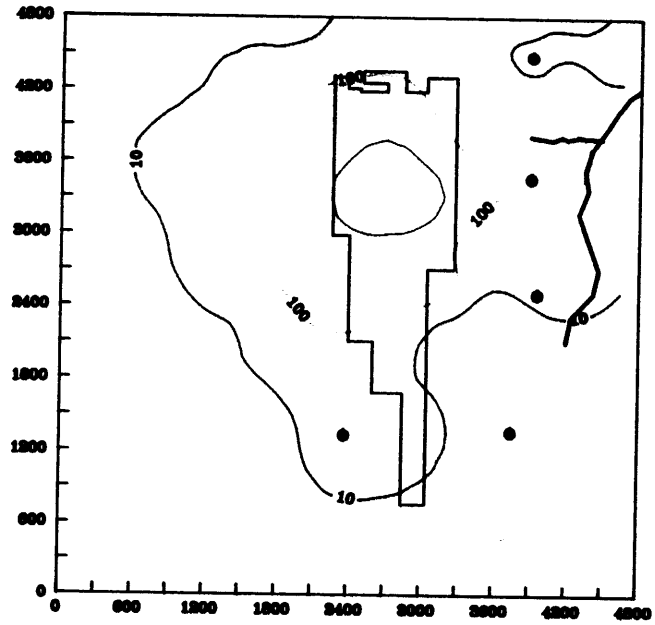


TCE PLUMES IN THE TOP OF REGIONAL ZONE

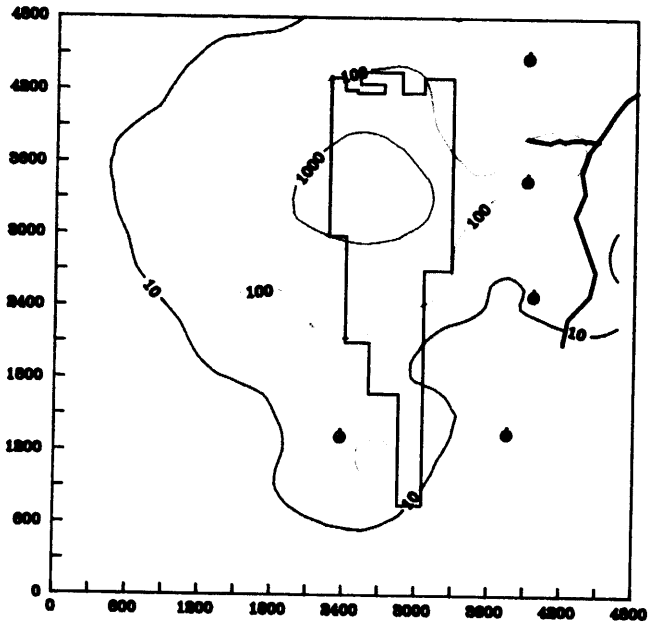
FIGURE 8-16



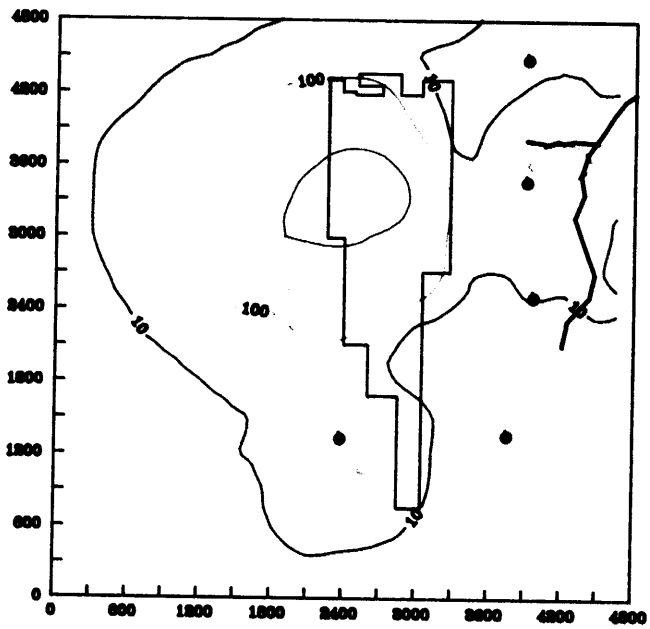
CHROMIUM CONC. AT PRESENT (PPB)



PROJECTED CONC. AT 10 YEARS (PPB)



PROJECTED CONC. AT 25 YEARS (PPB)



PROJECTED CONC. AT 50 YEARS (PPB)

⊙ WATER SUPPLY WELLS

CR PLUMES IN THE TOP OF REGIONAL ZONE

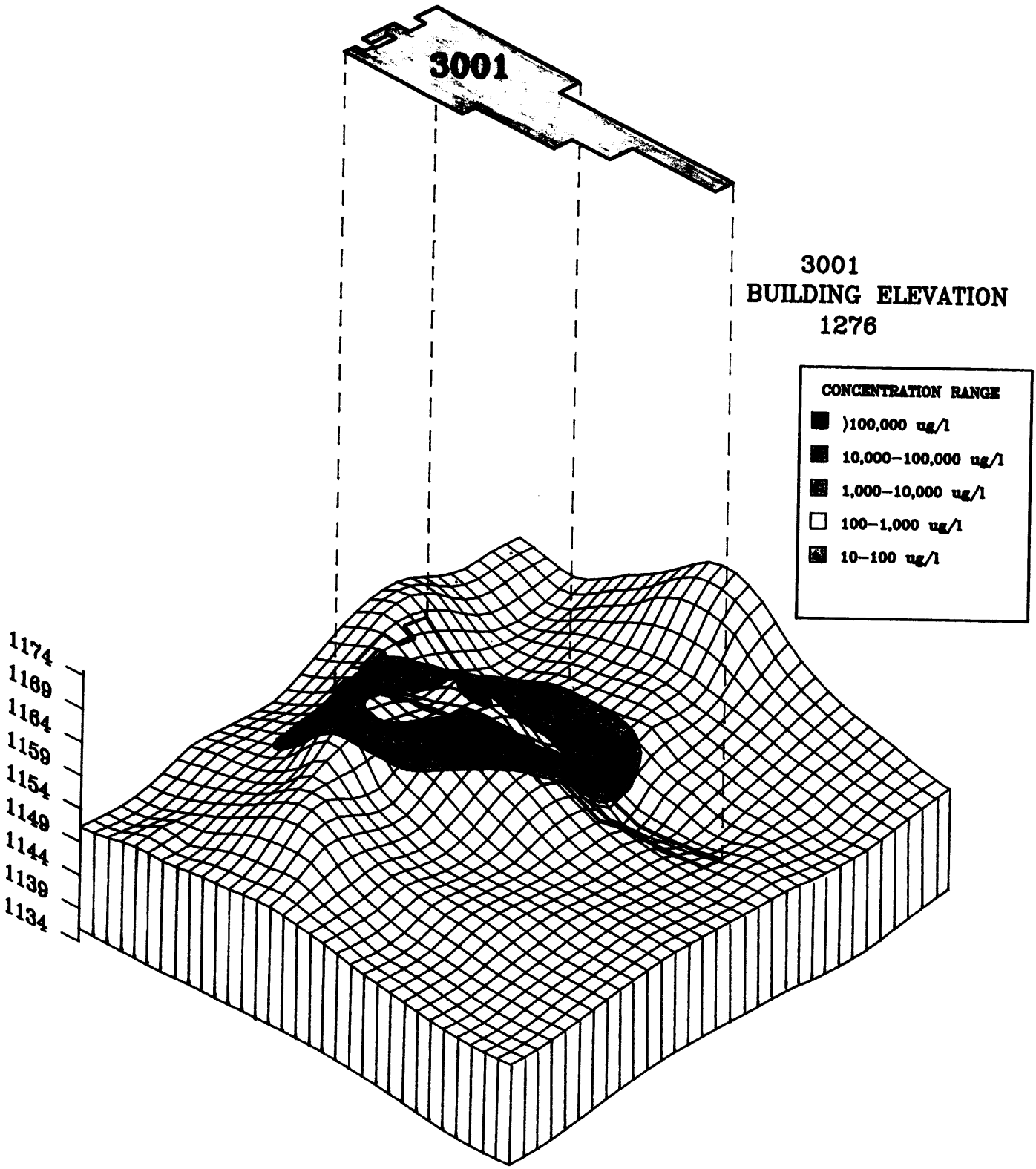
FIGURE 8-17

c. Regional Zone. This zone was simulated as a confined aquifer with thicknesses ranging from 10 to 24 feet. Field permeability tests indicated values of 10^{-4} cm/sec. TCE and Cr plumes are shown in relation to the aquifer zone thickness in figures 8-18 and 8-19.

The source of contamination is the top of the regional zone, where vertical migration has taken place. Vertical migration rates of approximately 4 to 6 feet per year are estimated. The horizontal plume migrations were simulated over time periods of 10, 25, and 50 years as shown in figures 8-20 and 8-21. The modeling in this zone was also done assuming additional contamination was vertically migrating into and out of the zone and no contaminated water was being collected. Both plumes are moving to the west in the direction of groundwater flow. The migration rates are approximately 10 feet per year. Over the entire 50 year period the contaminants remain within the Base boundaries with the highest concentrations beneath the buildings. Contamination continues to slowly spread vertically towards the deeper zones at approximately 4 to 6 feet per year.

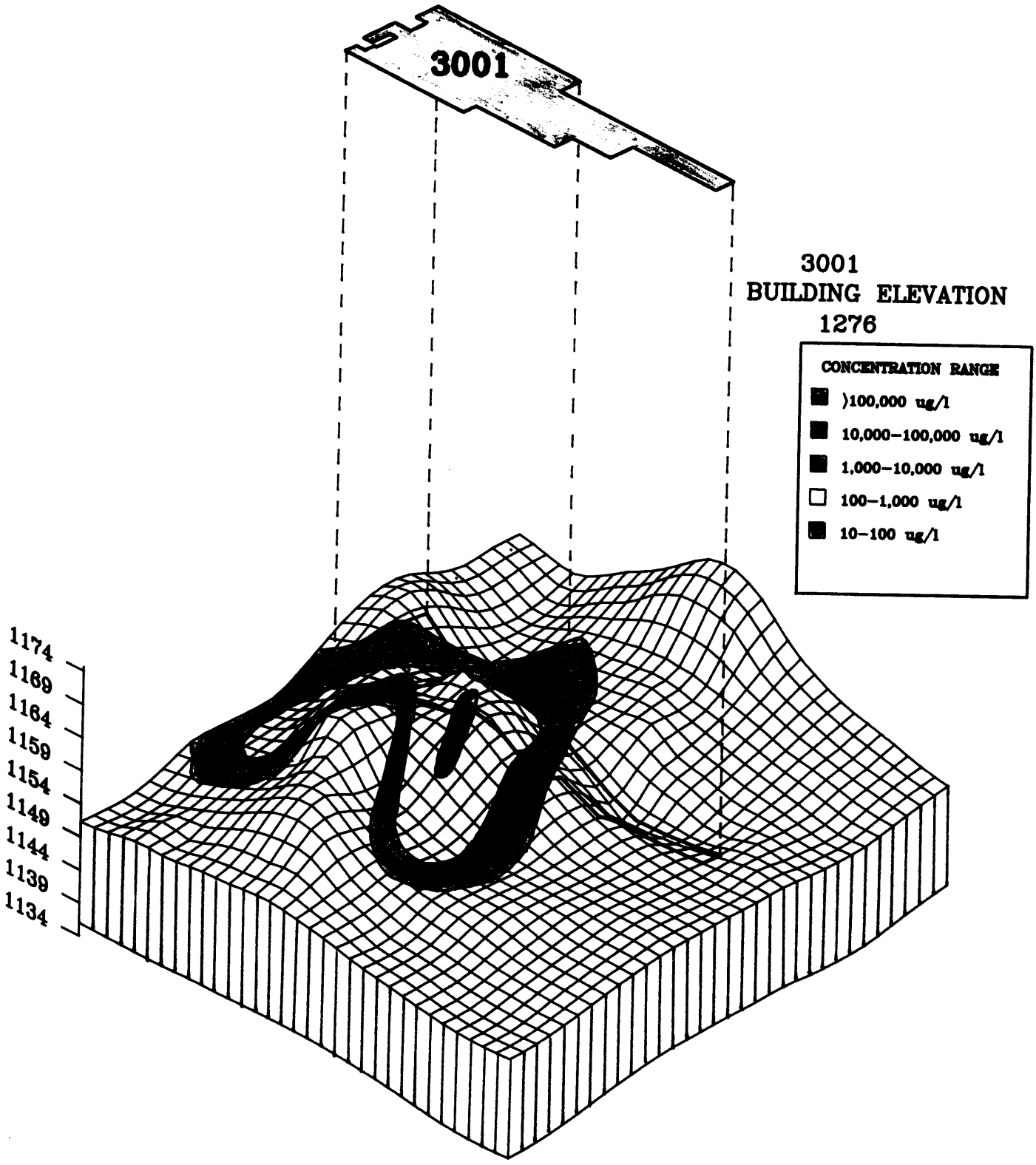
d. Producing Zone. The observations made during the two week recording of the pumping water supply wells and nearby monitoring wells indicated that the producing wells influence each other when pumping, but did not seem to have any effect on the upper groundwater zones. Contamination of wells 15 and 16 probably occurred from vertical migration of contaminants down the well shafts from the top of the regional zone. The contaminant transport modeling of the top of regional and regional zones indicate that contaminants are migrating west, away from the water supply wells on the east side of the building (wells 13, 14, 15, and 16). However, contaminants migrating vertically into the top of regional zone from the perched aquifer will continue to provide the potential for further contamination of these water supply wells. The TCE plume in the top of regional zone (figure 8-16) is spread beyond well 17 with concentrations greater than 10 ug/l. The plume movement indicates that concentrations will continue to increase as the plume migrates westward. Contaminants in the regional aquifer will continue to vertically migrate towards the producing zone. At estimated migration rates of 4 to 6 feet per year, contaminants could reach the producing zone in 16 to 25 years.

8.6 Consultant Technical Review Summary. In March 1987 a technical review of the Tulsa District COE remedial investigations was conducted by P.E. LaMoureaux and Associates, a consulting firm in hydrogeology and environmental science. The purpose of the review was to recommend any additional data necessary to complete a feasibility study and evaluate the validity of the COE's interpretation of the complex hydrogeologic conditions at the site. The report is included in Appendix L. The appendix also contains a memorandum (dated June 11, 1987) which summarizes the COE's responses to the recommendations made in the technical review.



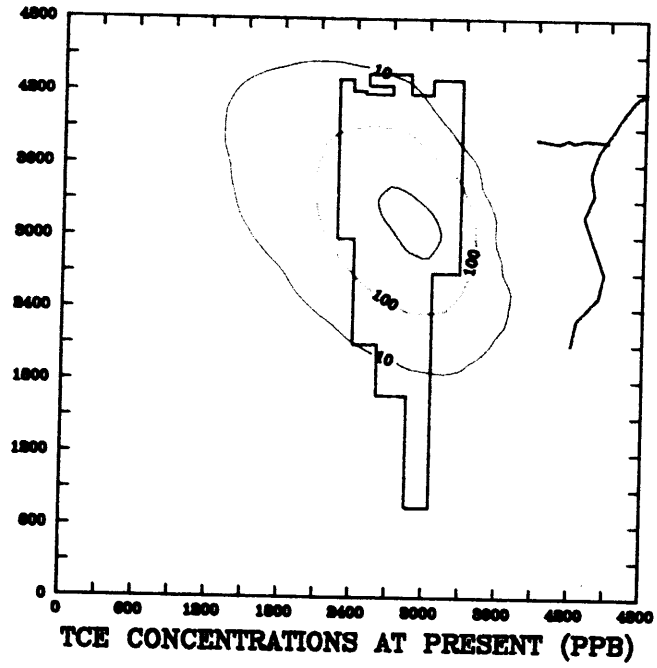
REGIONAL AQUIFER CONFINED THICKNESS WITH TCE CONCENTRATION PLUME

FIGURE 8–18

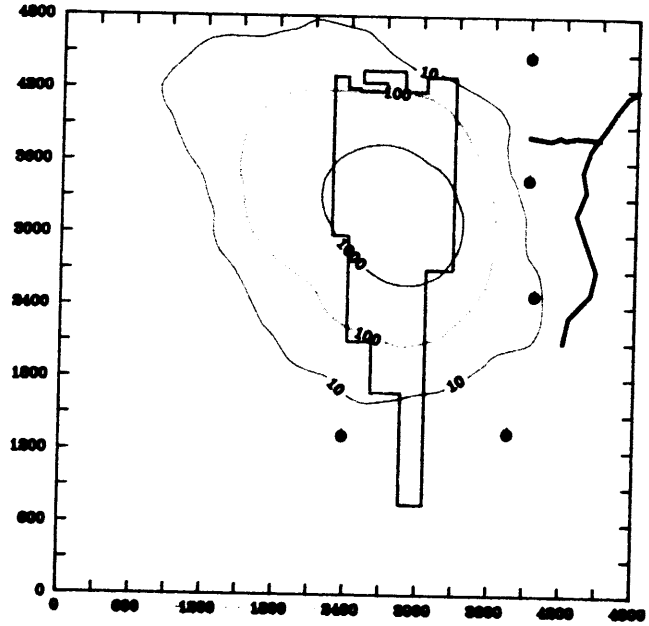


REGIONAL AQUIFER CONFINED THICKNESS WITH CHROMIUM CONCENTRATION PLUME

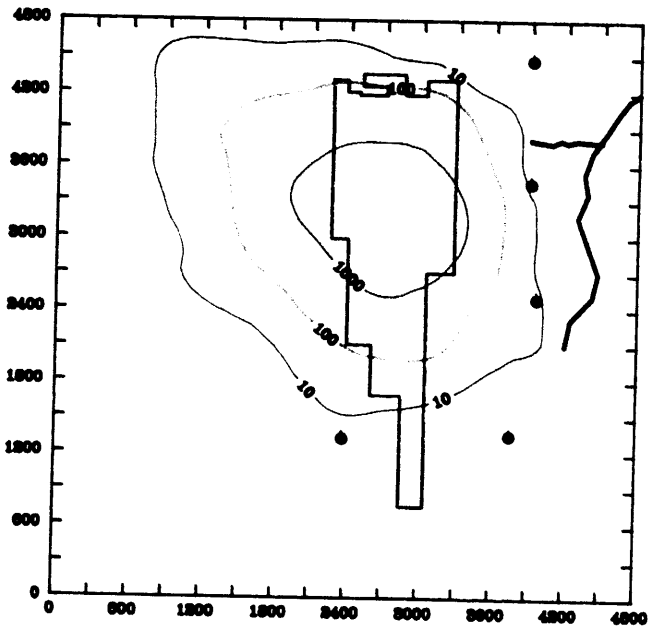
FIGURE 8–19



TCE CONCENTRATIONS AT PRESENT (PPB)

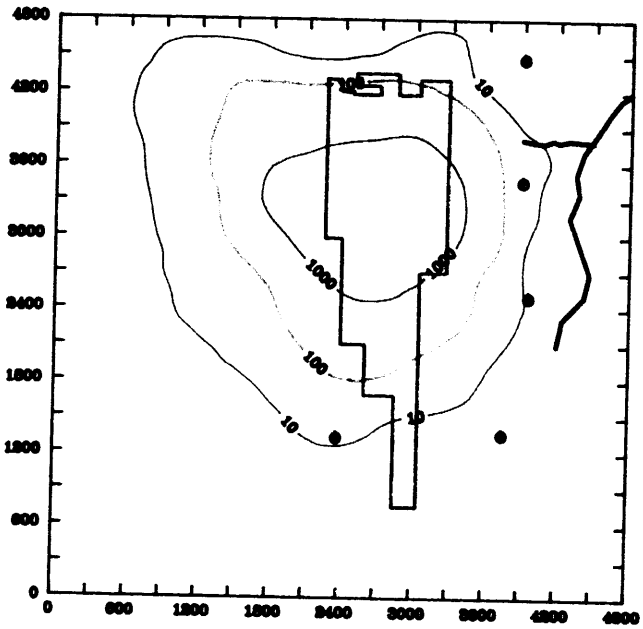


PROJECTED CONC. AT 10 YEARS (PPB)



PROJECTED CONC. AT 25 YEARS (PPB)

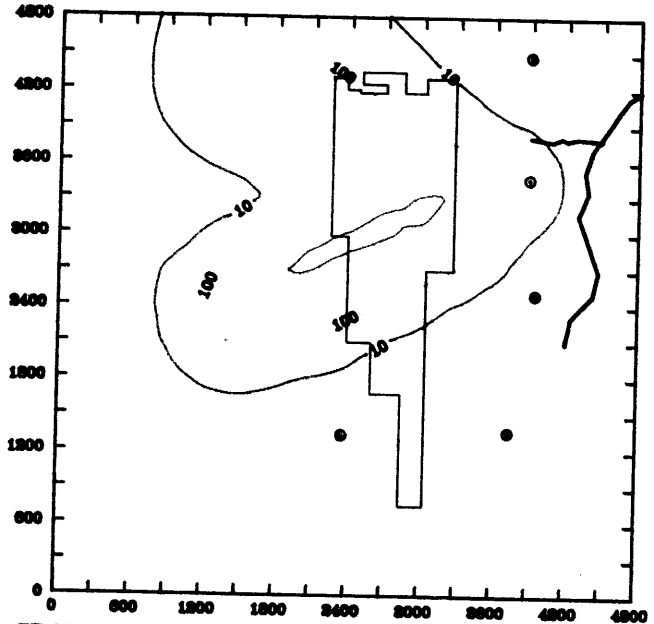
⊙ WATER SUPPLY WELLS



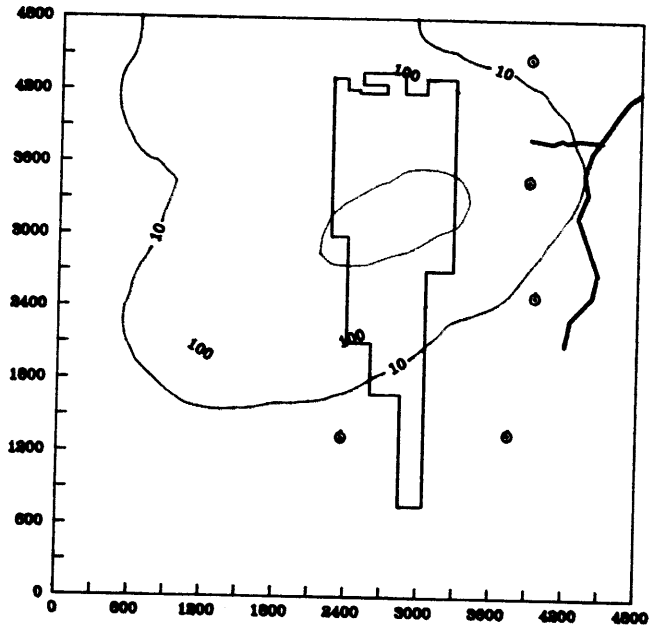
PROJECTED CONC. AT 50 YEARS (PPB)

TCE PLUMES IN THE REGIONAL ZONE

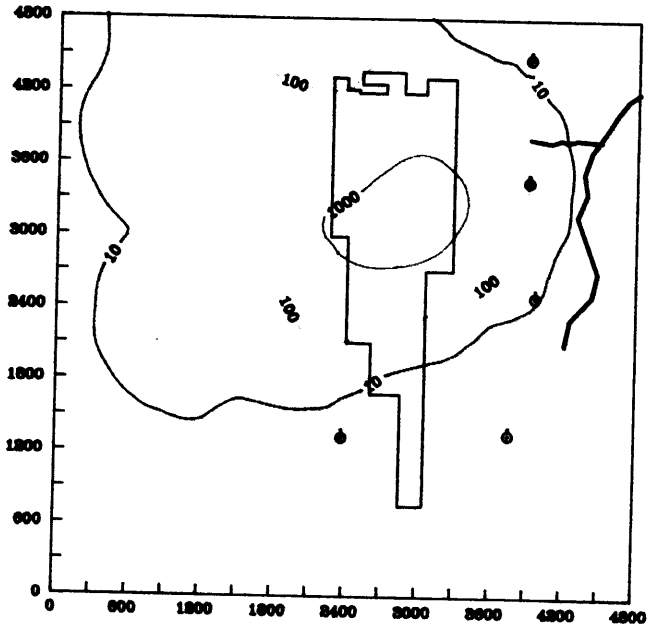
FIGURE 8-20



CROMIUM CONCENTRATIONS AT PRESENT (PPB)

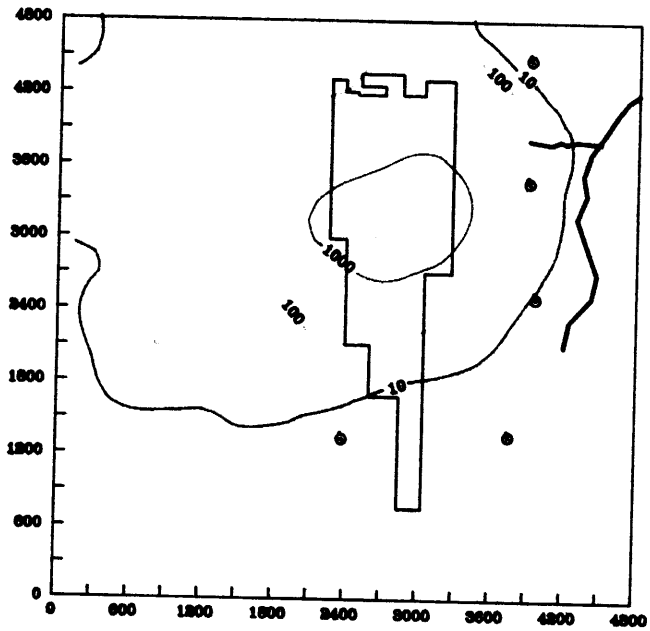


PROJECTED CONC. AT 10 YEARS (PPB)



PROJECTED CONC. AT 25 YEARS (PPB)

⊙ WATER SUPPLY WELLS



PROJECTED CONC. AT 50 YEARS (PPB)

CHROMIUM PLUMES IN THE REGIONAL ZONE

FIGURE 8-21

CHAPTER 9

PUBLIC HEALTH AND ENVIRONMENTAL CONCERNS

Contaminated groundwater and the presence of a fuel contaminated site are primary public health and environmental concerns. The contaminated groundwater exists in a perched aquifer and the upper zones of the regional Garber-Wellington aquifer. The Garber-Wellington is a primary source of water for a seven county area. Contaminants are degrading to this natural resource and contaminant migration can affect the users.

9.1 Contaminated Groundwater Migration. The immediate concern of contaminant migration is the protection of the water supply wells in the immediate vicinity of the site (water supply wells 13, 14, 15, 16, and 17). Wells 15 and 16 contain low levels of TCE and well 16 also contains low levels of DCE and PCE. As previously discussed, well 17 also lies within the horizontal extent of TCE and DCE contaminant plumes in the top of the regional zone.

Eastward contaminant migration of Cr and TCE in the perched aquifer discharges toward East Soldier Creek, and therefore, may contribute to contamination of the creek. Levels of Cr above the primary drinking water standard are present in the perched waters near the creek (drawing 17) and low levels of TCE (<10 ug/l) are near the northern most storm drain outlet at the creek. Additional concerns of contaminant migration include the potential for migration to other Base supply wells further downgradient, vertical migration into the producing zones, and migration of plumes beyond the Base boundaries.

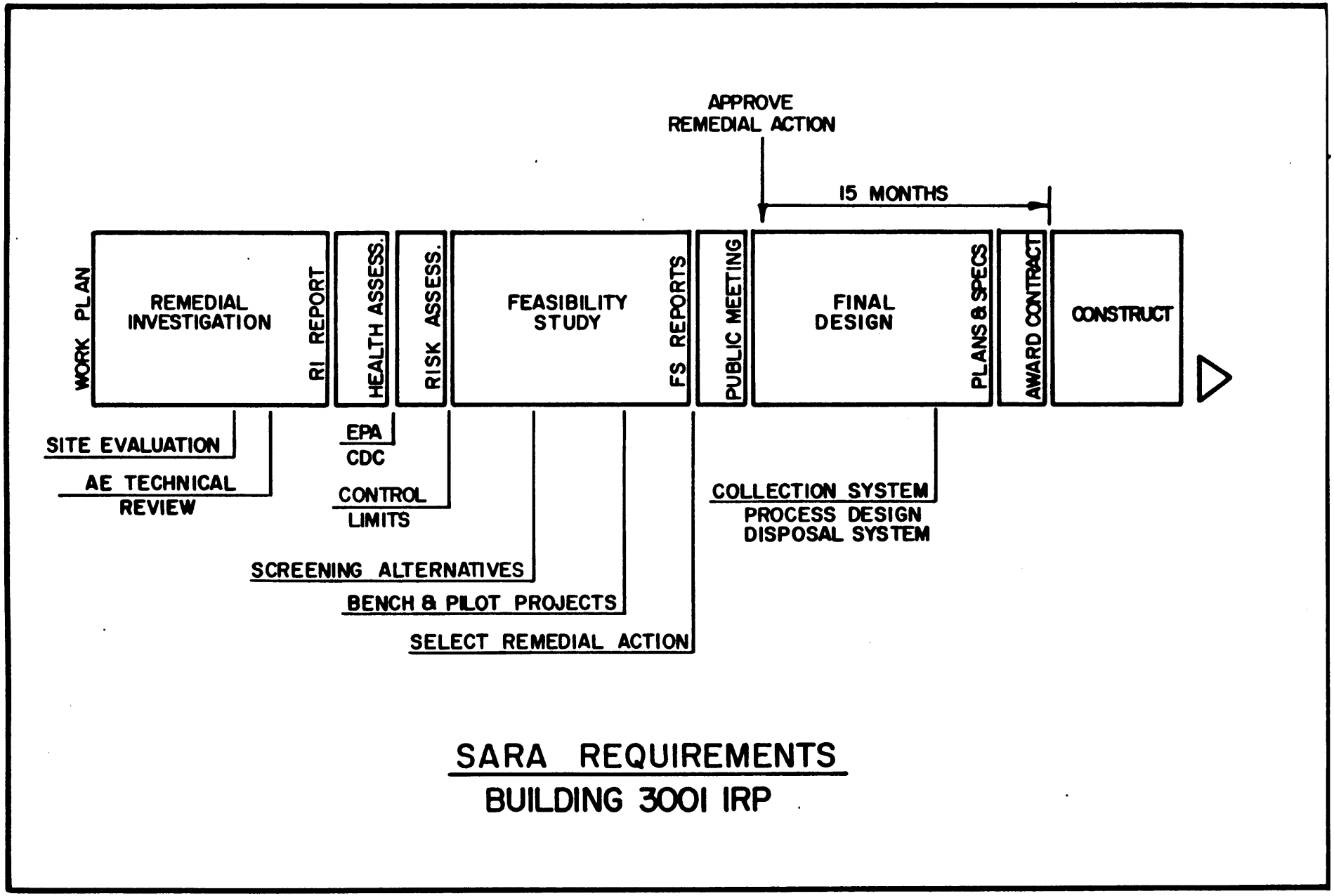
9.2 Fuel Contaminated Site. The presence of the fuel contaminated site at the north tank area is an environmental and public health concern. The potential for exposure to vapors, and contact with fuel contaminated soils are health and safety hazards.

CHAPTER 10

CONCLUSIONS AND RECOMMENDATIONS

10.1 Summary. The Building 3001 site has contaminated groundwater in perched and regional aquifer zones above the producing zones of the Garber-Wellington Aquifer. The contamination, which consists of organic solvents, metals, and fuel products, exists within the Base property boundaries, beneath and near the building, in the upper 175 feet. The contamination is a result of past industrial operations and storage practices, which are now being corrected. Contamination has entered the perched aquifer system by vertical migration from solvent pits in the building, storm drains, West Soldier Creek, and underground tanks. The hydrologic and hydrogeologic systems at the site are complex and interdependent. Runoff is carried to East and West Soldier Creeks by surface drainage and storm drains. Both West Soldier Creek and the storm drain system apparently recharge the perched aquifer beneath the site. In the past, contaminants may have been discharged into the storm drains and later detected in both East Soldier Creek and West Soldier Creek. The contaminants are also present in the perched aquifer. Hydrogeologic investigations indicate that the perched aquifer (beneath the east portion of the building) discharges toward East Soldier Creek and therefore some contaminants are probably discharged into East Soldier Creek. Contaminant plumes are estimated to move horizontally at a rate of approximately 15 feet per year, primarily toward East Soldier Creek. The perched aquifer and East Soldier Creek may allow the vertical migration of contamination. The geologic formations at the site are characterized by very low vertical permeabilities and therefore limited vertical migration has occurred compared to horizontal migration. The horizontal spread has extended beyond water supply well locations within Tinker AFB and has allowed migration of contaminants down the sides of poorly sealed wells. Two wells have been plugged because of this (wells 18 and 19) and two wells (wells 15 and 16) currently contain trace levels of organic compounds.

10.2 Project Status and Requirements. The Superfund Ammendments and Reauthorization Act to the Comprehensive Environmental Response, Compensation, and Liability Act, passed in November of 1986, require that federal facilities be treated similarly to privately owned sites. The groundwater contamination problem beneath Building 3001 has placed Tinker AFB on the National Priority List (NPL). Because of the NPL ranking, the SARA Amendments require, in addition to the Remedial Investigations (RI) Report, a health assessment, risk assessment, feasibility study (FS), public comment opportunity, and development of final remedial plans. A concept diagram of the process is shown in figure 10-1. Upon receipt of the RI report, a health assessment will be performed by the Environmental Protection Agency in conjunction with the Federal Center for Disease Control. A risk assessment will be performed by the COE and will be incorporated into the FS. Groundwater control limits will be established based on the baseline risk assessment of existing conditions. The first phase of the FS is complete which consists of screening applicable technologies and selecting remedial alternatives for development. Upon selection of a remedial action and completion of the FS report, the public will have the opportunity to review and comment on the FS. After approval of the FS, the final design will be completed. The additional field work to be conducted in the near future will include the



SARA REQUIREMENTS

BUILDING 3001 IRP

FIGURE 10-1

installation of well cluster 1-45, which is southwest of the southwest tank area, and the soil survey inside the building. The results of this additional field work will be included in a supplemental remedial investigations report.

10.3 Interim Recommendations. Based on the results of the remedial investigations, several recommendations are discussed below.

a. Groundwater Monitoring. All monitoring wells at the site (table 8.1) and water supply wells 13, 14, 15, 16, and 17 should be resampled and tested for the parameters listed in Table 10.1.

Table 10.1
Recommended Parameters to be Tested

All Wells

Metals, Total	Organics	Others
arsenic	total organic carbon	pH
barium	volatiles	conductivity
cadmium		temperature
chromium		
lead		
mercury		
nickel		
selenium		
silver		
zinc		

Additional Parameters for Water Supply Wells

potassium	semivolatiles	total dissolved solids
sodium		aklalinity
calcium		chloride
magnesium		sulfate

Additional Parameters for Selected Monitor Wells

potassium	alkalinity
sodium	calcium hardness
calcium	sulfates
magnesium	chlorides
iron	nitrates
manganese	total dissolved solids

Parameters for Quarterly Sampled Monitor Wells

arsenic	total organic carbon	pH
barium	volatiles	conductivity
cadmium		temperature
chromium		
lead		
mercury		
nickel		
selenium		

Water supply wells 13, 14, 15, 16, and 17 (when it becomes operational) should be sampled on a quarterly basis (as recommended in the Base groundwater assessment, ref. 20) since they are part of the water supply network and either have low levels of volatile organics or have the potential to become contaminated. Well 17 should be sampled as soon as it is repaired. After sampling, it should be taken off-line until the results are reviewed. All monitoring wells should be sampled annually and a select number should continue to be sampled on a quarterly basis. The supplemental remedial investigations report will include the results of the first year of continued groundwater monitoring.

b. North Tank Area. Tanks 3404 and 3401 should be inspected or tested for leaks. Tank 3404 (concrete tank) should be emptied and visually inspected for tank integrity and tank 3401 (steel tank) should be either tested or replaced. Also free fuel product floating on the groundwater should be recovered.

c. Pit Removal. The contents of four abandoned pits inside Building 3001 (pit numbers MN36, P75, Q51, and U51) should be removed due to high concentrations of organics and metals which may contribute to groundwater contamination beneath the building. Pits MN36 and P75 contain approximately 8 and 4 cubic yards of sand, respectively, and pits Q51 and U51 contain approximately 45 and 60 gallons of liquid, respectively. These contents should be containerized and disposed of as hazardous waste.

d. Southwest Tank Area. The abandoned gasoline storage tanks (tank numbers 3140, 3141, 3142, 3143, 3146, and 3147) should be inspected to insure that tanks are empty or filled with inert materials. Records indicate that fuels were contained in them until the late 1960's, then solvents were stored there. The tanks were abandoned in 1972. Due to the high concentrations of toluene and benzene, verification that the contamination source has been removed is necessary.

e. Investigations Northeast of Site. High organics concentrations are present in well 1-11A and 19A located in the top of the regional aquifer. Trace levels of some of these contaminants (TCE, DCE and PCE) are also present in nearby water supply wells 15 and 16. Wells 1-11A and 19A are upgradient from the site and contain contaminant levels not characteristic to the Building 3001 site. The industrial waste treatment plant (IWTP) is located approximately 400 feet east of well 1-11A and the property boundary is 200 feet north and 1,000 feet east of the well. Wells should be installed upgradient and downgradient of the IWTP to investigate the possibility of a different source of contamination to the aquifer, and water supply wells. These wells will be installed during the early part of 1988. The results of these investigations will be included in the supplemental remedial investigations report.

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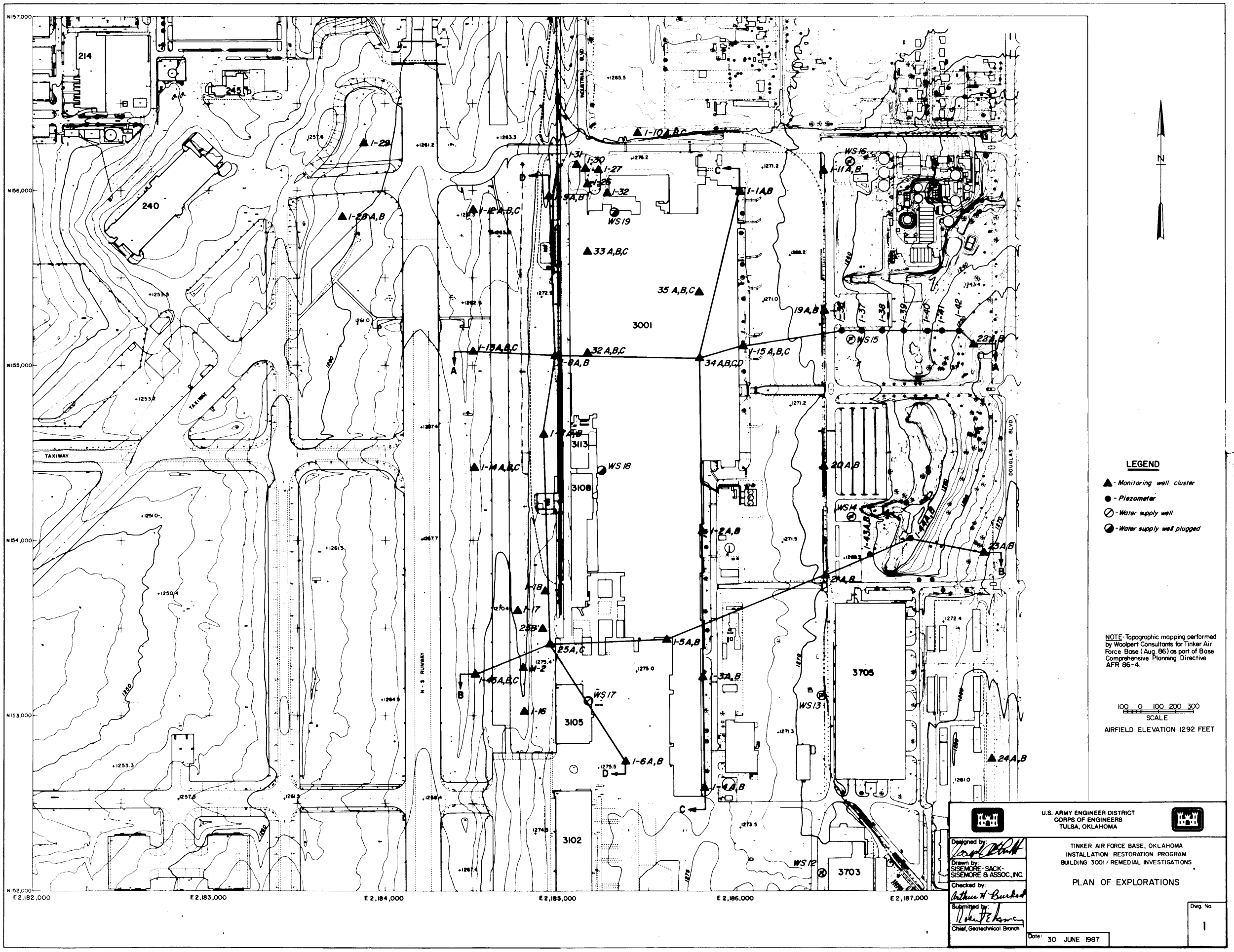

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Arthur H. Burkett

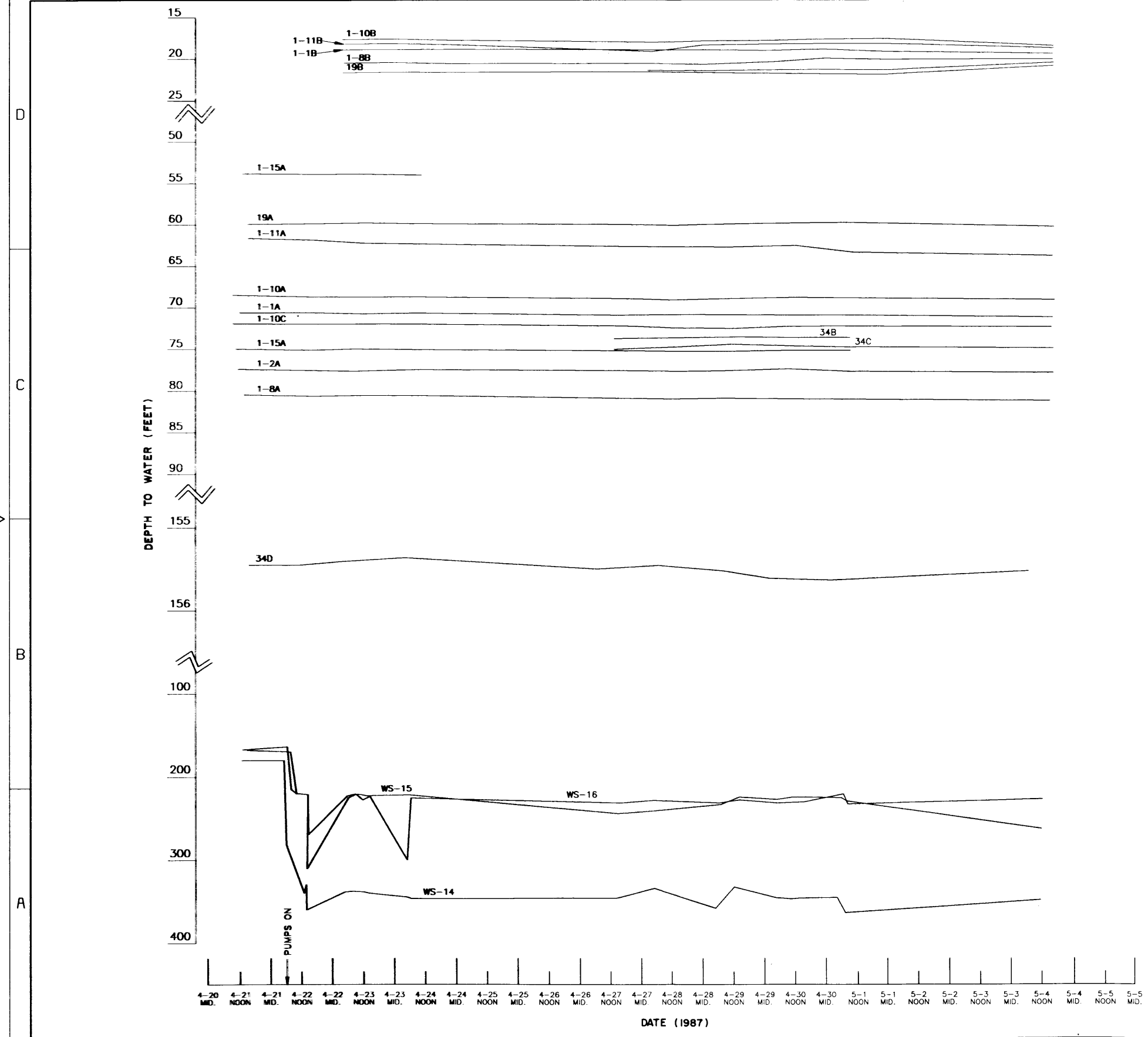
Submitted by:
Chief, Geotechnical Branch

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

PLAN OF EXPLORATIONS

Dwg. No. 1

Date: 30 JUNE 1987



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TULSA, OKLAHOMA

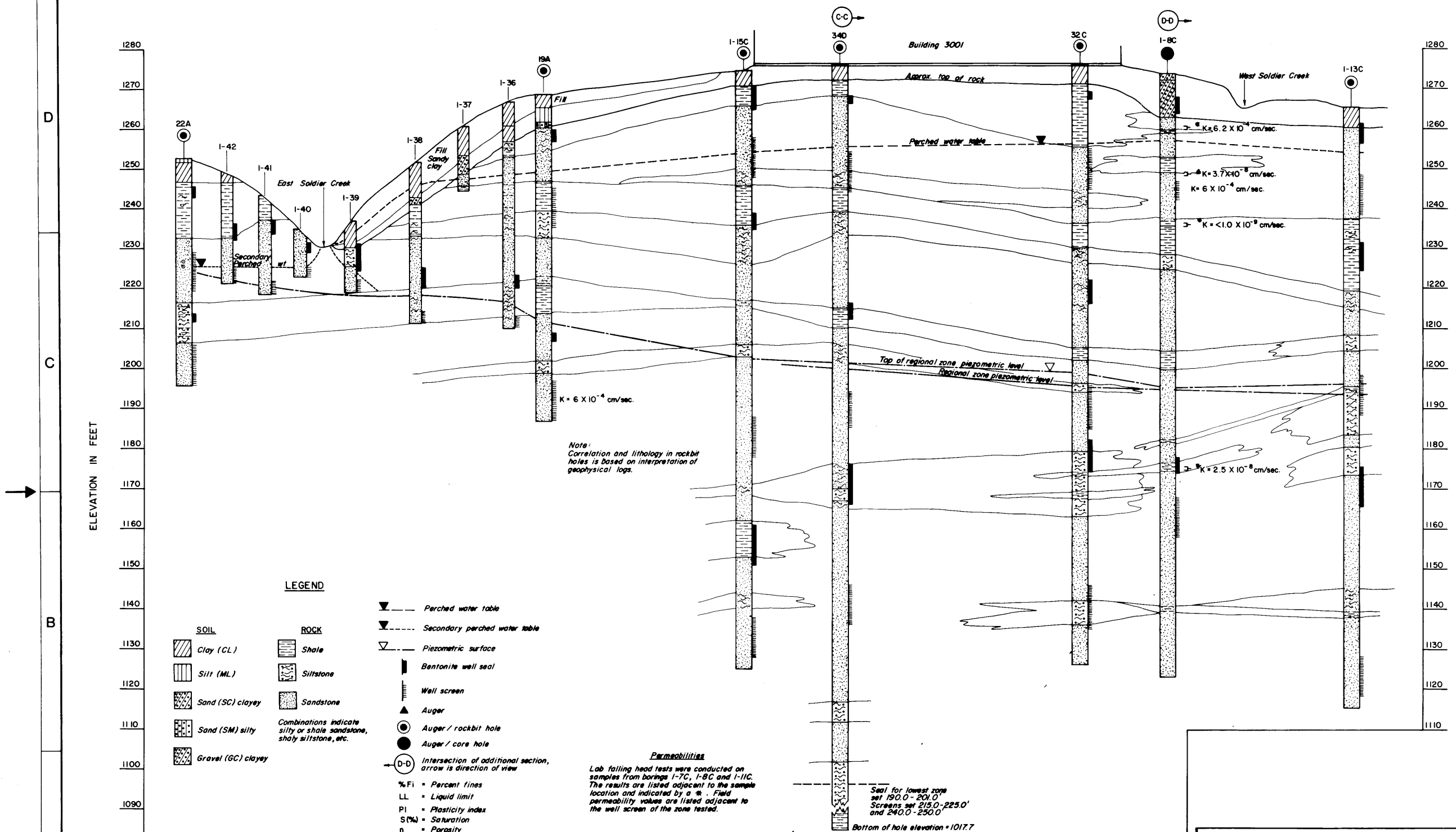
Designed by: C.L.H. Warren
Drawn by: DGJ
Checked by: Ramona E. Wagner
Submitted by: [signature]
Chief, GEOTECH. BR.

TINKER AIR FORCE BASE
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

PUMP TEST WATER LEVEL MEASUREMENTS

Date: 30 JUNE 1987

DWG. NO. 2



SECTION A-A

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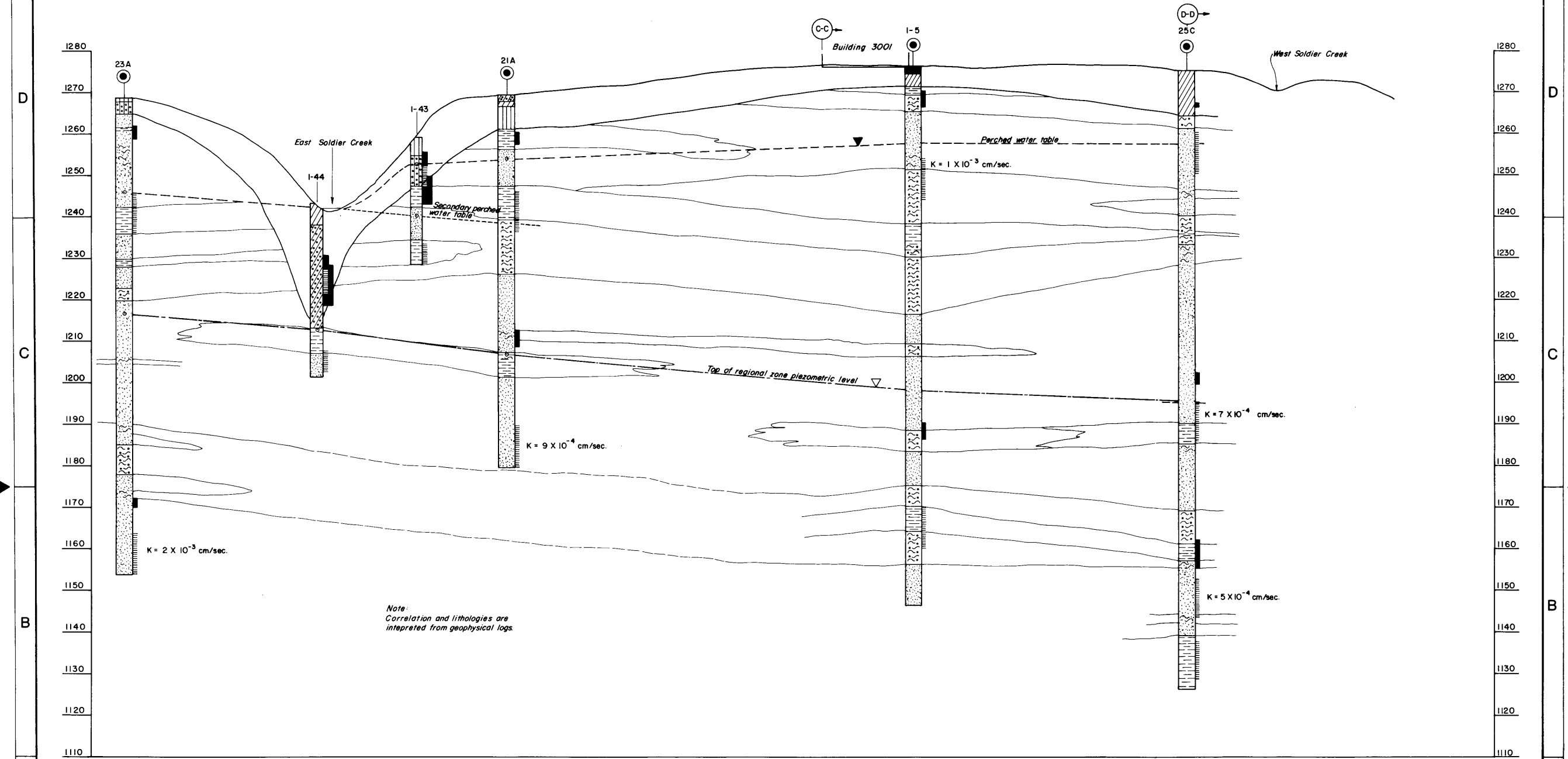
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

GEOLOGIC SECTION A A'

Date: 30 JUNE 1987

Dwg. No. 3



SECTION B-B

0 100 200 300 400 500

SCALE OF FEET

SEE SECTION A-A (DRAWING 3)
FOR LEGEND

U.S. ARMY ENGINEER DISTRICT
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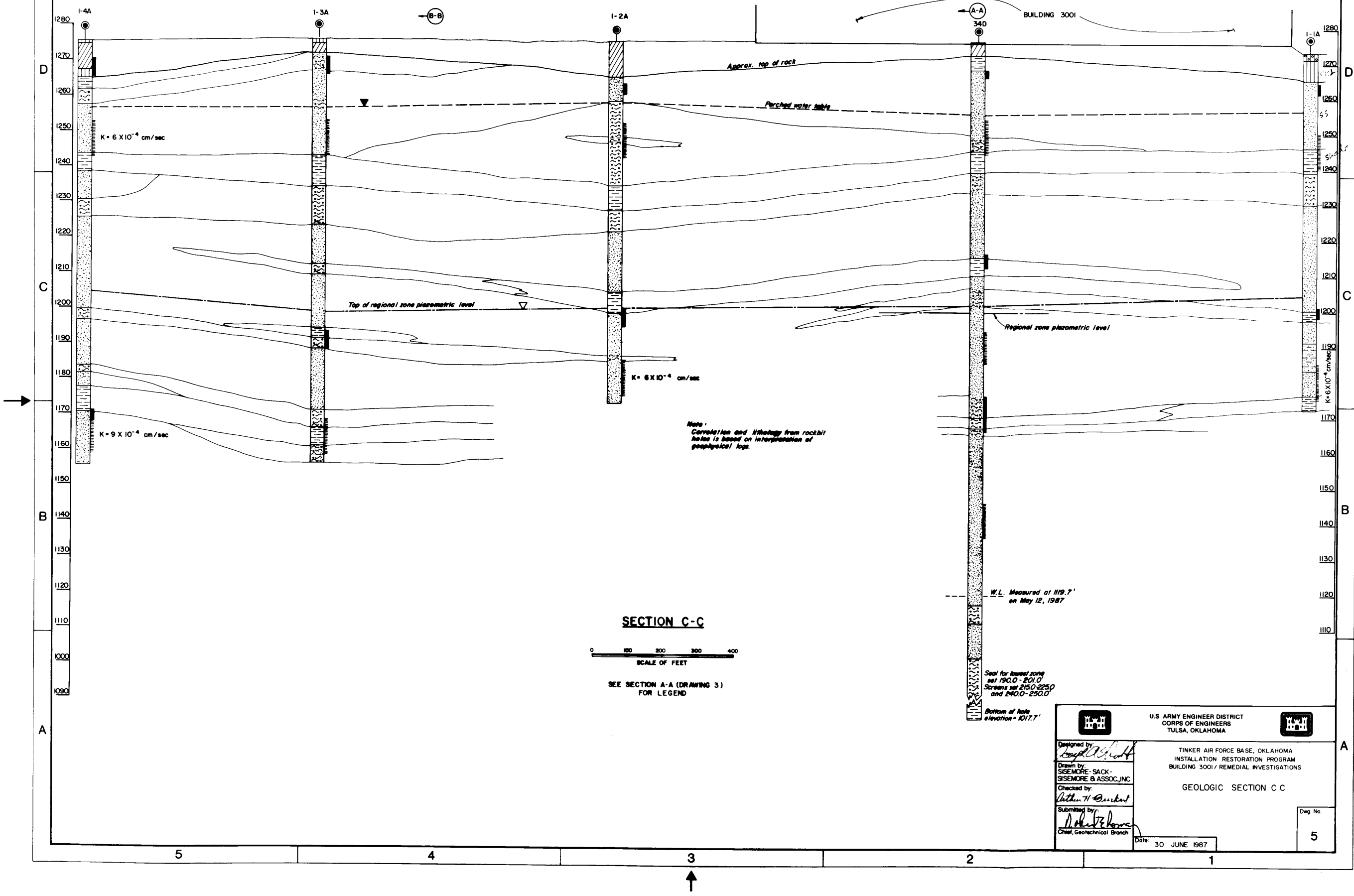
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

GEOLOGIC SECTION B B

Dwg. No. 4

Date: 30 JUNE 1987



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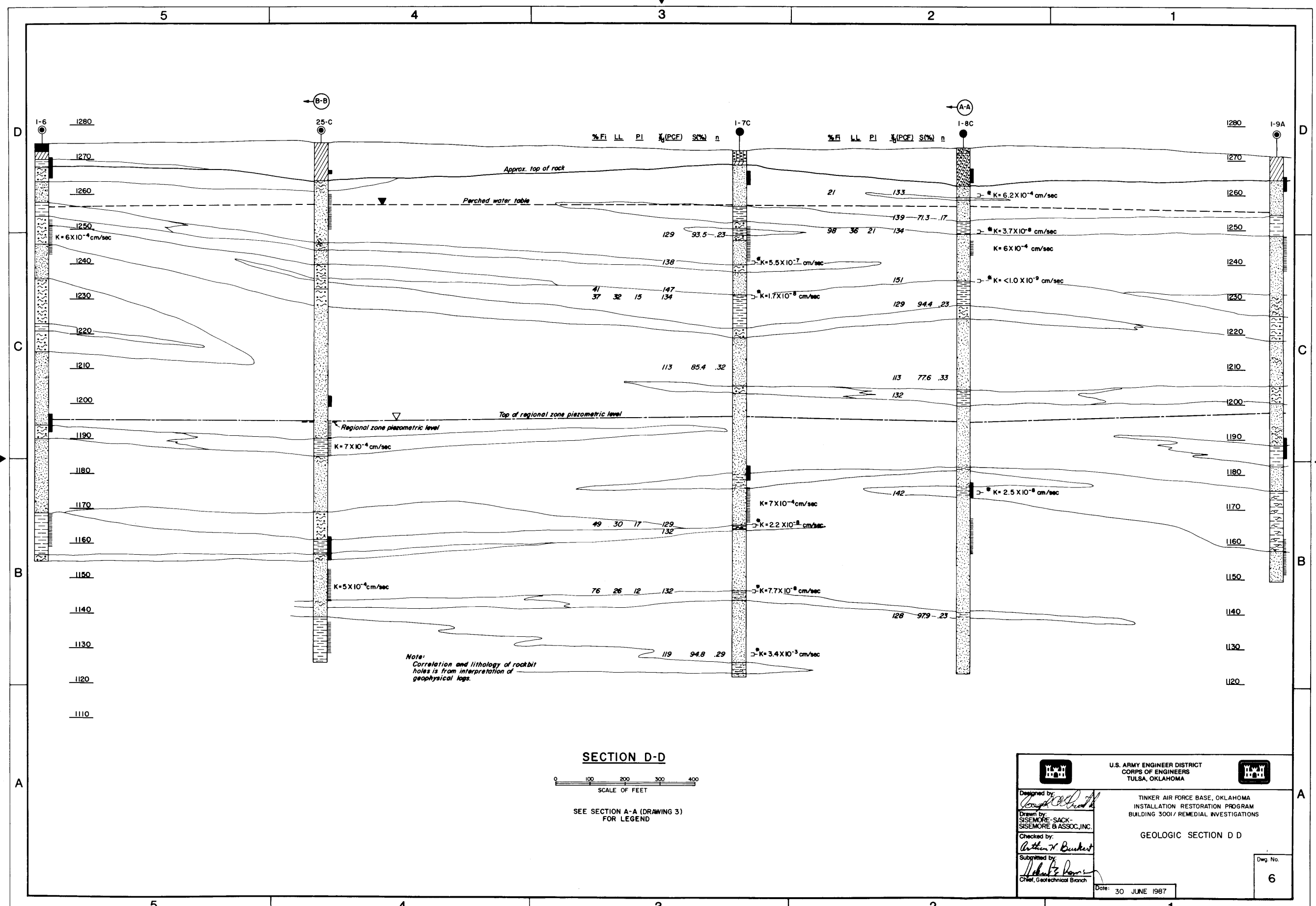
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

GEOLOGIC SECTION C C

Dwg. No. 5



SECTION D-D

0 100 200 300 400
SCALE OF FEET

SEE SECTION A-A (DRAWING 3) FOR LEGEND

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by:

Drawn by:
SISEMORE-SACK-SISEMORE & ASSOC., INC.

Checked by:
Arthur H. Burkert

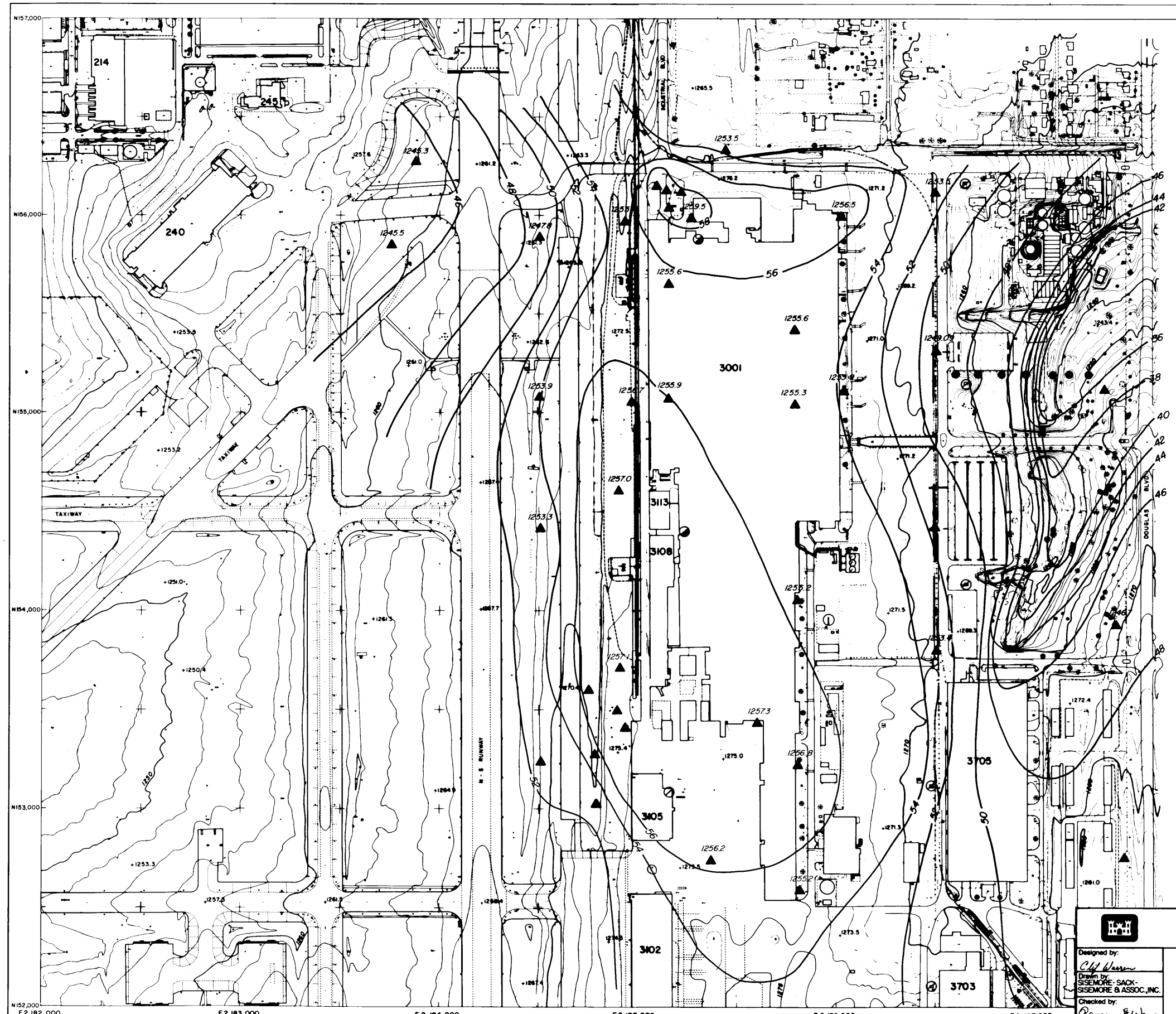
Submitted by:
Chief, Geotechnical Branch

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

GEOLOGIC SECTION D D

Dwg. No. 6

Date: 30 JUNE 1987



U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

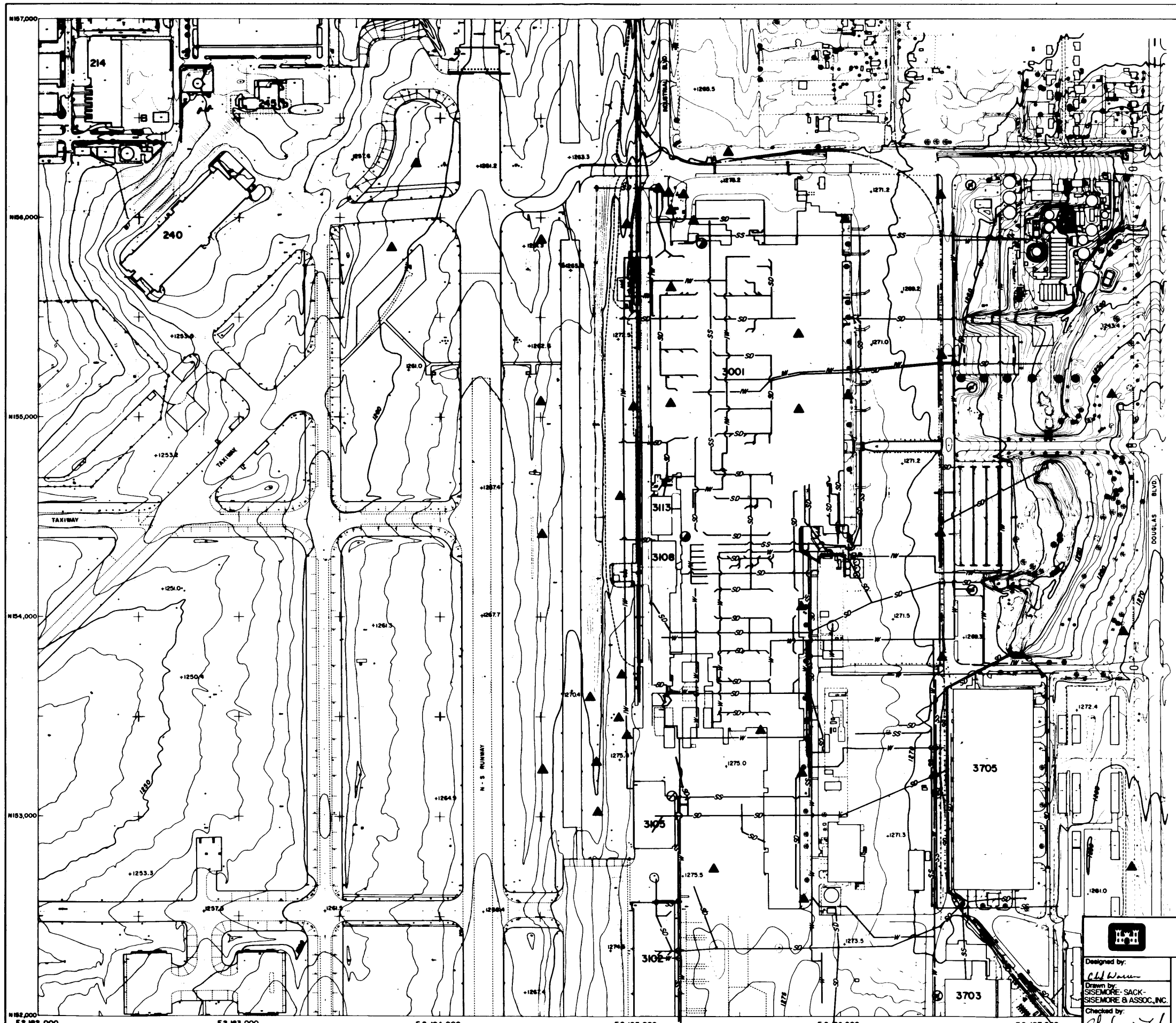
Designed by: Cliff Warren
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.
Checked by: Ramona E. Wagner
Submitted by: Chief, Geotechnical Branch

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

PERCHED AQUIFER

Date: 30 JUNE 1987

Dwg. No. 7



N

UTILITIES

—SD— Storm drain
—W— Water line
—IW— Industrial waste
—SS— Sanitary sewer

LEGEND

▲ - Monitoring well cluster
● - Piezometer
⊘ - Water supply well
◒ - Water supply well plugged

NOTE: Topographic mapping perform
by Woolpert Consultants for Tinker Ai
Force Base (Aug. 86) as part of Base
Comprehensive Planning Directive
AFR 86-4.

100 0 100 200 300
SCALE

AIRFIELD ELEVATION 1292 FEE

Utilities shown are based on combine
utility maps (dwg. numbers MU-157, 15
169, 170, 179, 180, 190, 191, 201 and
obtained from base civil engineering.
Not all utilities are shown.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

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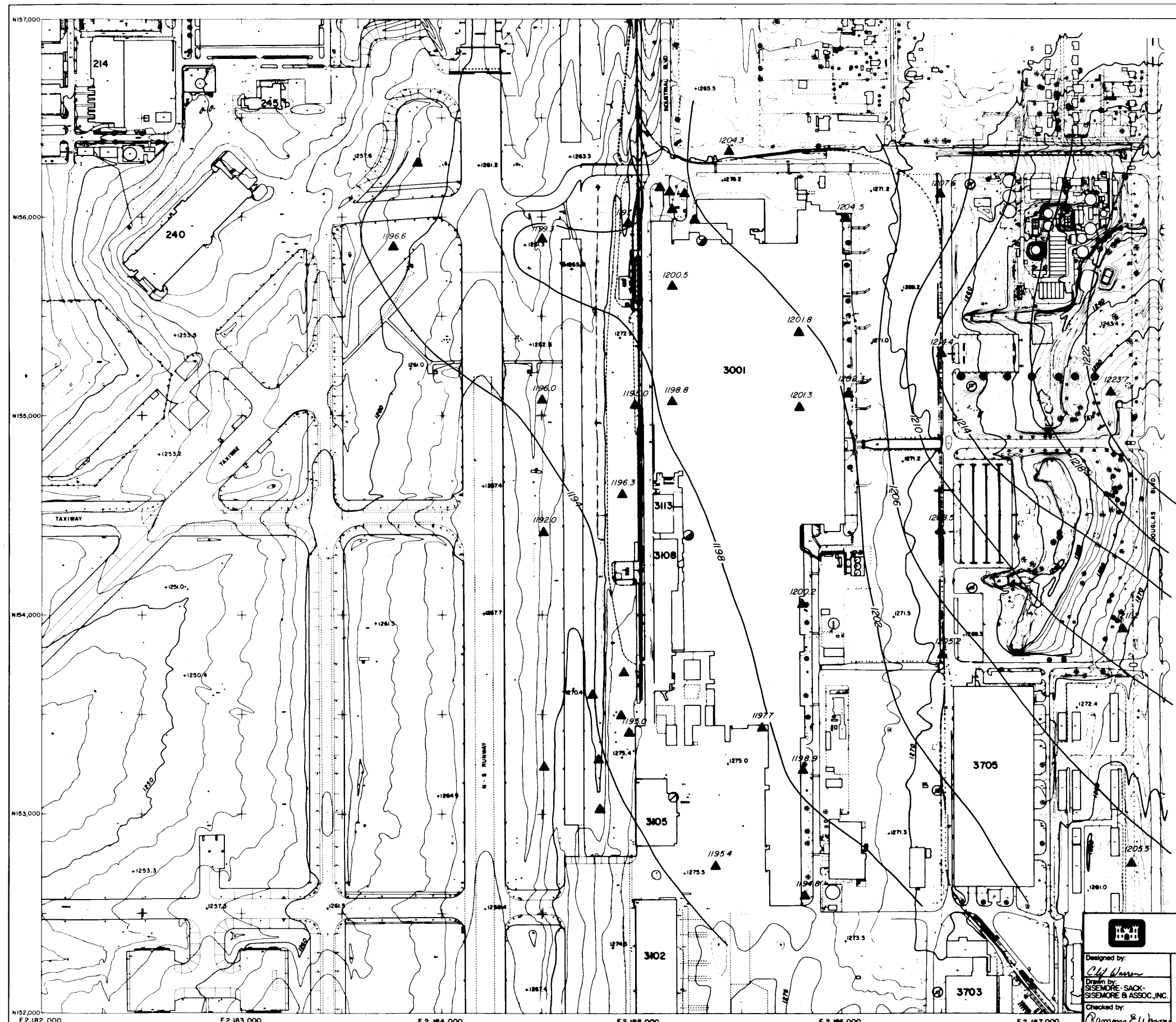
Checked by:
Submitted by:
Chief, Geotechnical Branch

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

PERCHED GROUNDWATER AND UNDERGROUND UTILITIES

Date: 30 JUNE 1987

Dwg. No. 7 A



N

LEGEND

- ▲ Monitoring well cluster
- ● Piezometer
- ⊘ - Water supply well
- ◒ Water supply well plugged
- 1196.0 Potentiometric surface in top of regional aquifer
- —1202— Potentiometric contour

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE
AIRFIELD ELEVATION 1292 FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

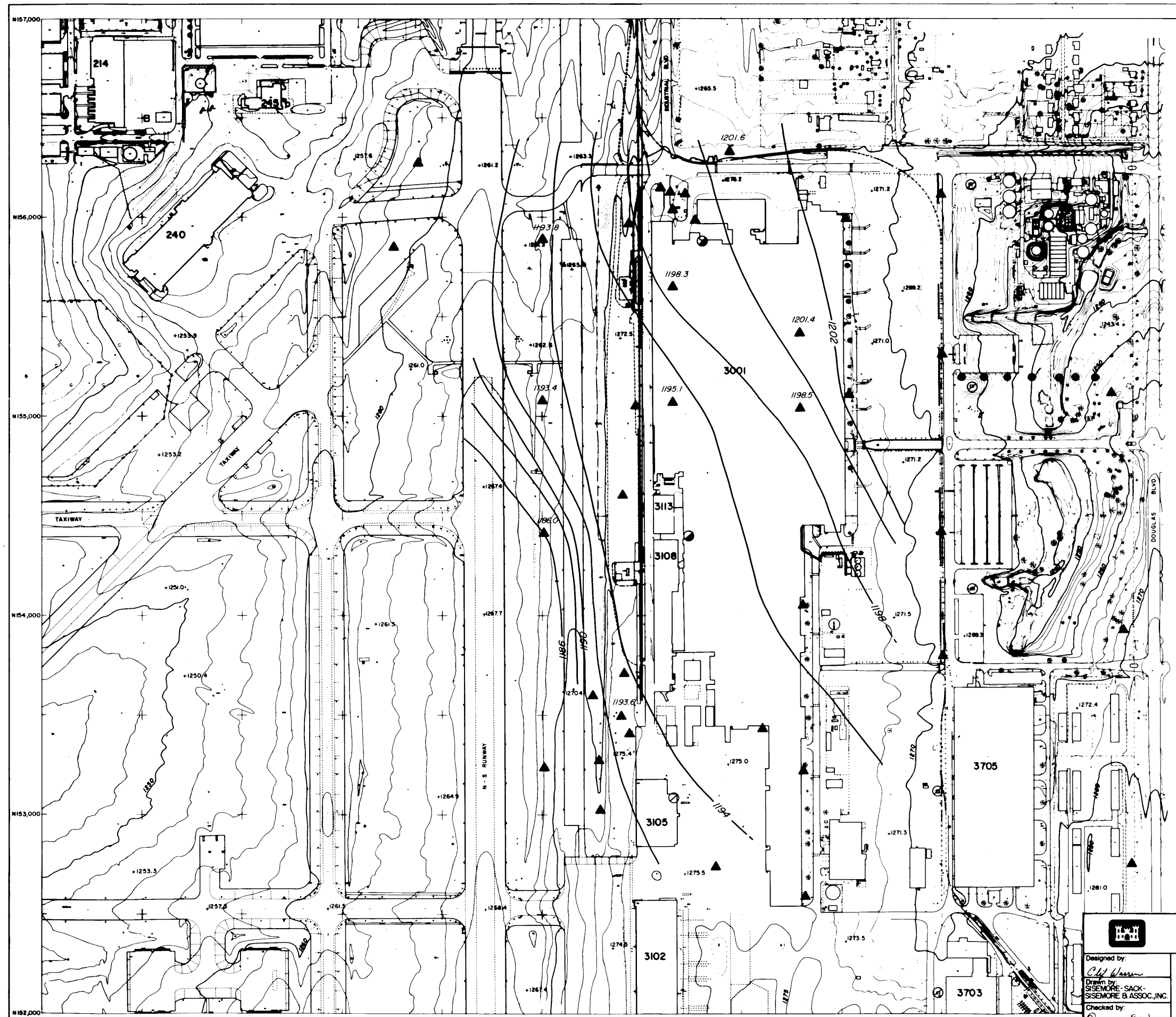
Designed by: Cliff Warren
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.
Checked by: Ramona E. Wagner
Submitted by: Chief, Geotechnical Branch

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

TOP OF REGIONAL ZONE

Date: 30 JUNE 1987

Dwg. No. 8



N

LEGEND

- ▲ Monitoring well cluster
- ● Piezometer
- ⊘ Water supply well
- ◒ Water supply well plugged
- 1198.5 Elev. of potentiometric su
- —1200— Potentiometric contour

NOTE: Topographic mapping perfor by Woolpert Consultants for Tinker Force Base (Aug. 86) as part of Ba Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE

AIRFIELD ELEVATION 1292 FI

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: Cliff Warren
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.
Checked by: Ramona E. Wagner
Submitted by: Chief, Geotechnical Branch
Date: 30 JUNE 1987

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

REGIONAL ZONE

Dwg.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

PERCHED AQUIFER

TCE CONTOURS

Designed by: CLA
Drawn by: SISEMORE - SACK -
Checked by: SISEMORE & ASSOC., INC.
Approved by: Chief, Geotechnical Branch
Date: 30 JUNE 1987

Dwg. No. 10

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

AIRFIELD ELEVATION 1292 FEET

SCALE
100 0 100 200 300

LEGEND

- Monitoring well cluster
- Piezometer
- Water supply well
- Water supply well plugged
- 1253.9 Water table elevation in perched aquifer (feet)
- 50 — Water table contour (1250 = elevation)
- 440 Trichloroethylene (TCE) concentration in monitoring well (ug/l)
- 100 — Trichloroethylene contour(ug/l)

N

E2,182,000 E2,183,000 E2,184,000 E2,185,000 E2,186,000 E2,187,000

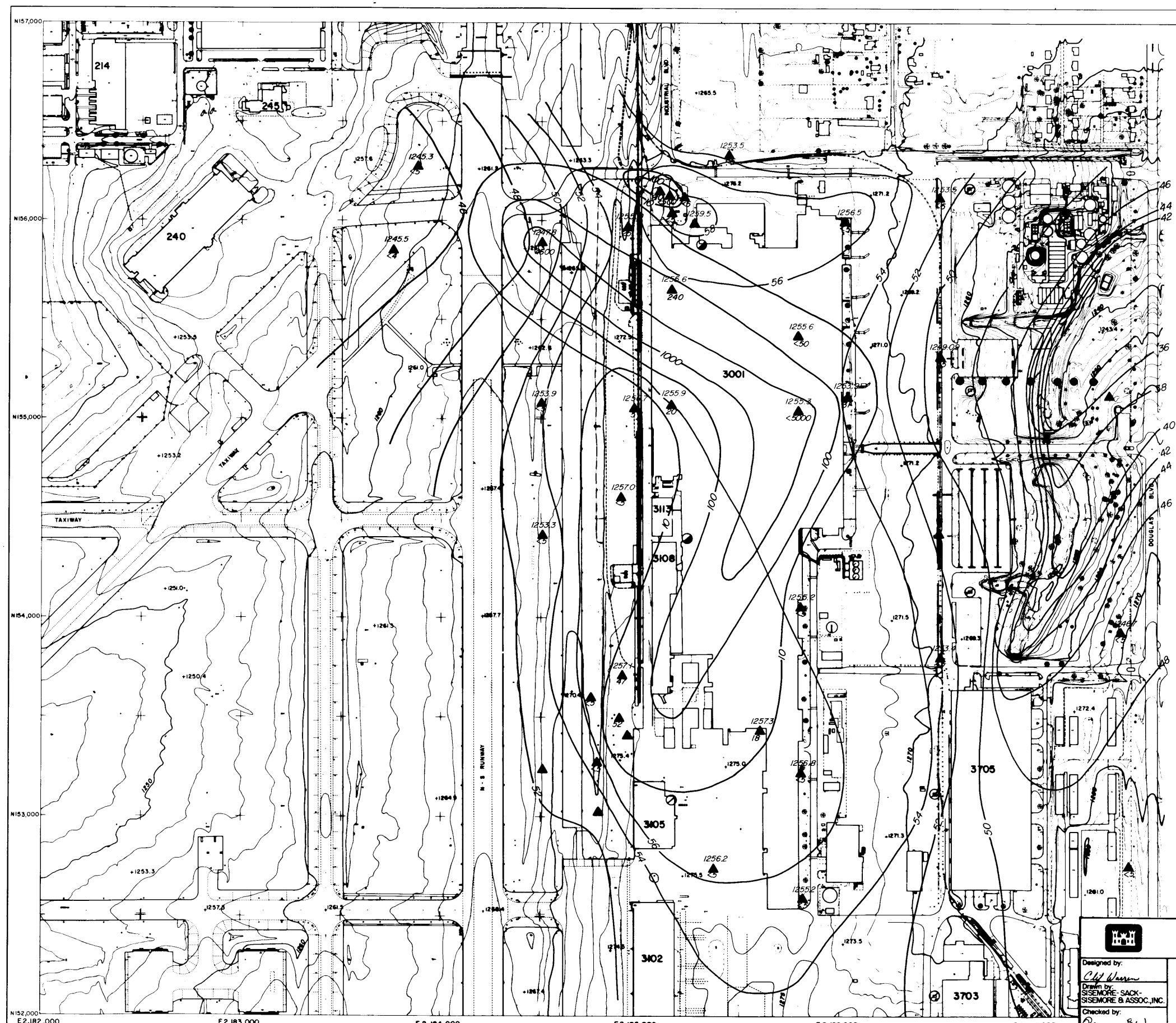
N152,000 N153,000 N154,000 N155,000 N156,000 N157,000

3703 3702 3105 3113 240 214 245

TAXIWAY

N - S RUNWAY

DOUGLAS BLVD



N

LEGEND

- ▲ *Monitoring well cluster*
- ● *Piezometer*
- ⊘ *Water supply well*
- ◕ *Water supply well plugged*
- *1253.9 Water table elevation in perched aquifer (feet)*
- *—50— Water table contour (50 = elevation 1250)*
- *31 Trans 1,2- Dichloroethylene (DCE) concentrations in monitoring well (ug/l)*
- *—100— 1,2-DCE contour (ug/l)*

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE

AIRFIELD ELEVATION 1292 FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: Cliff Warren
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.
Checked by: Ramona E. Wagner
Submitted by: Chief, Geotechnical Branch

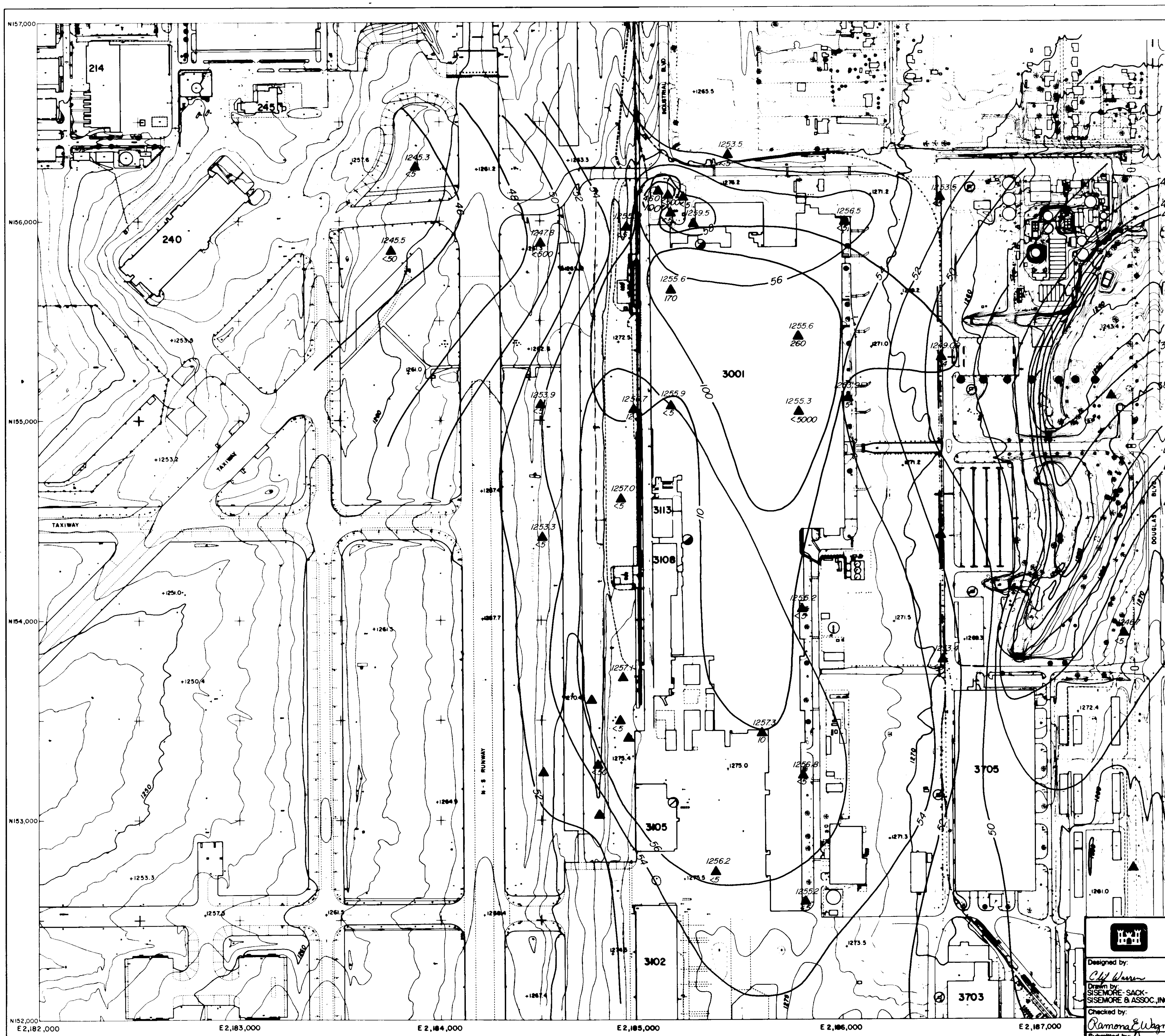
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

PERCHED AQUIFER

1,2 DCE CONTOURS

Dwg. No. 11

Date: 30 JUNE 1987



LEGEND

- ▲ Monitoring well cluster
- ● Piezometer
- ⊘ - Water supply well
- ◐ Water supply well plugged
- 1253.9 Water table elevation in perched aquifer (feet)
- —50— Water table contour (50 = elevation 1250)
- 260 Tetrachloroethylene (PCE) concentration in monitoring well (ug/l)
- —100— PCE contour (ug/l)

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE

AIRFIELD ELEVATION 1292 FEET

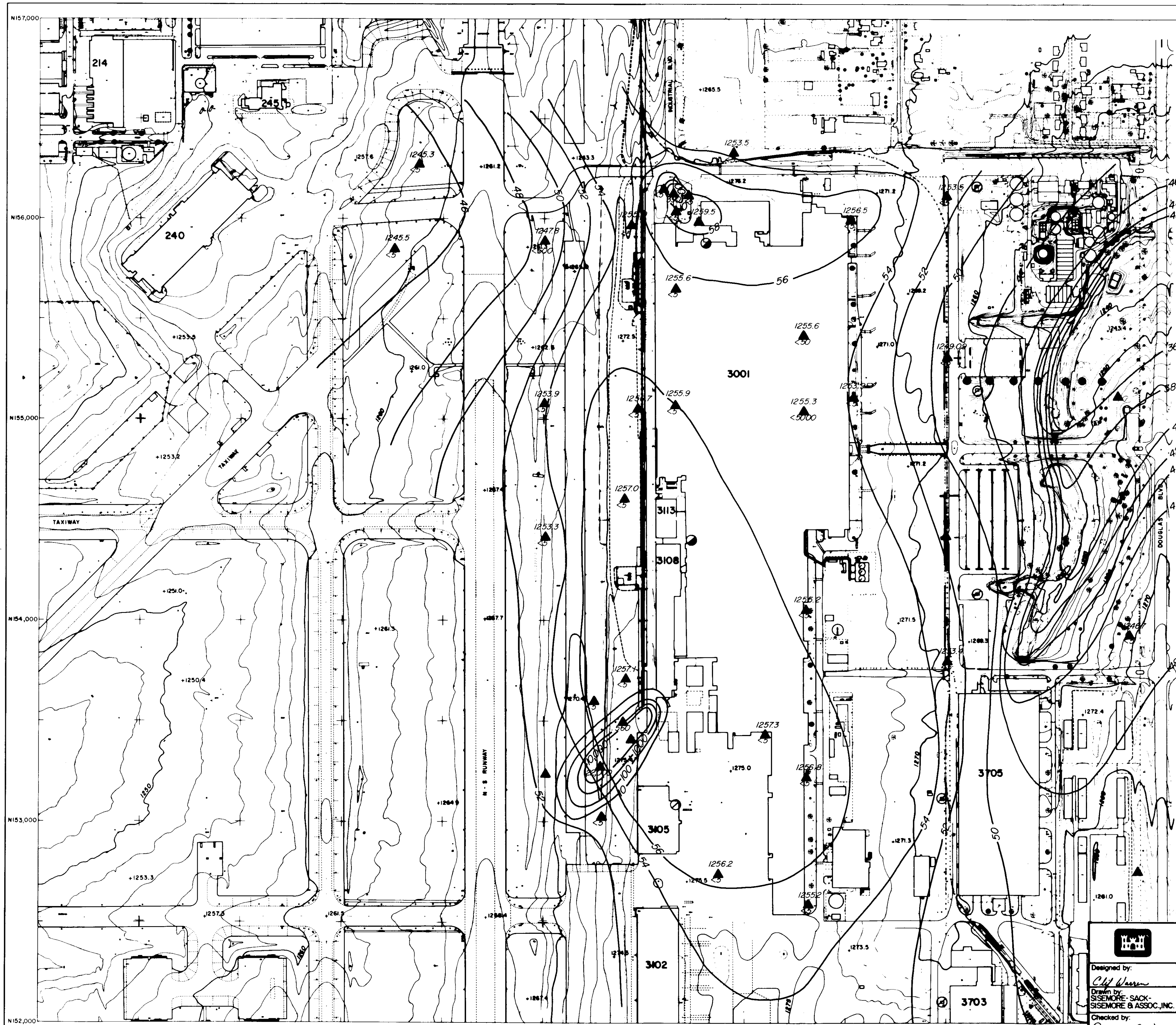
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001/REMEDIAL INVESTIGATIONS

PERCHED AQUIFER

PCE CONTOURS

Designed by:	Clif Warren
Drawn by:	SISEMORE-SACK-SISEMORE & ASSOC.,INC.
Checked by:	Ramona E. Wagner
Submitted by:	[signature] Chief, Geotechnical Branch
Date:	30 JUNE 1987
Dwg. No.	12



LEGEND

- ▲ Monitoring well cluster
- ● Piezometer
- ⊘ - Water supply well
- Water supply well plugged

1253.9 Water table elevation in perched aquifer (feet)

—50— Water table contour (50 = elevation 1250)

560 Toluene concentration in monitoring well (ug/l)

—100— Toluene contour (ug/l)

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE

AIRFIELD ELEVATION 1292 FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

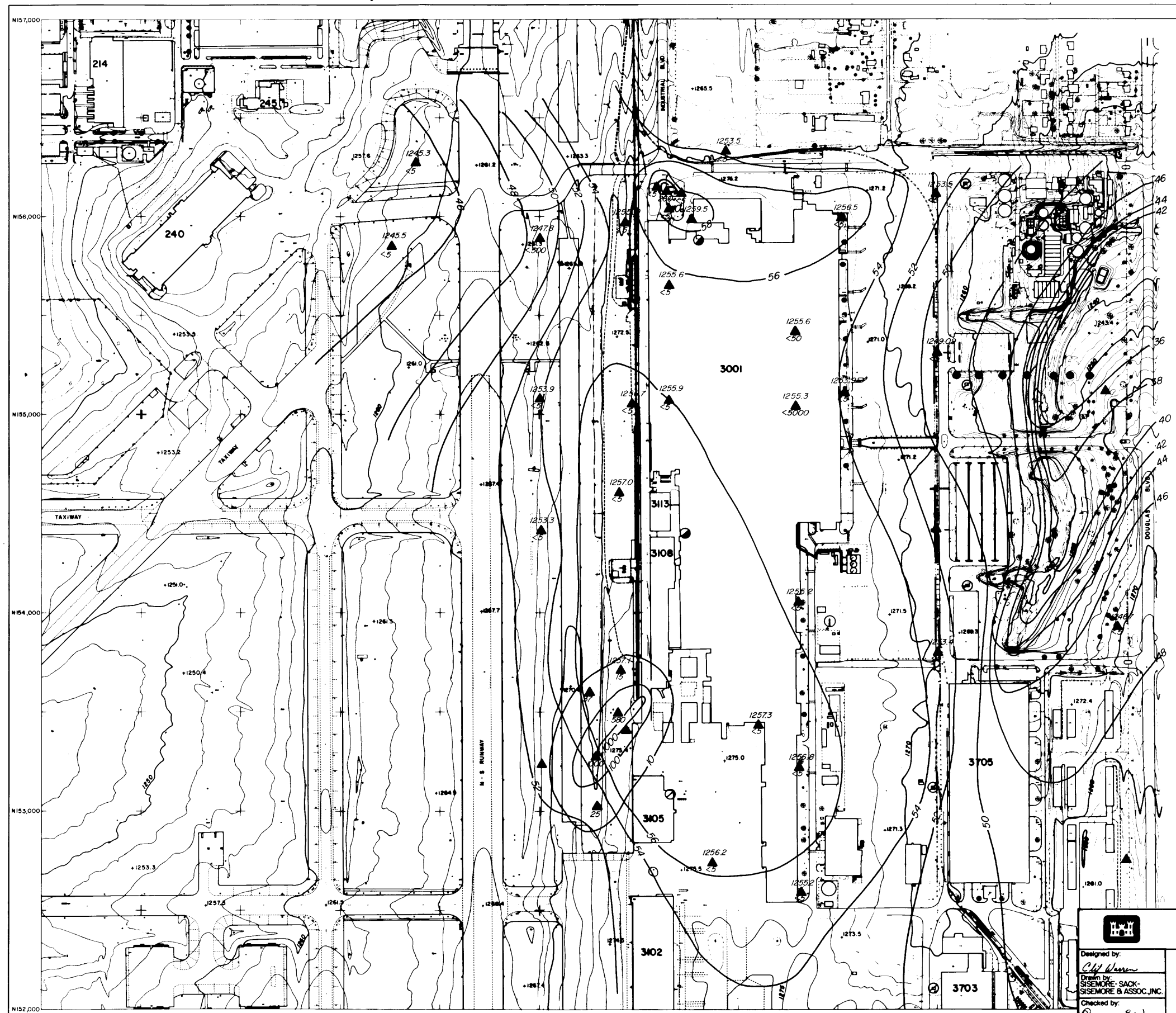
PERCHED AQUIFER

TOLUENE CONTOURS

Designed by: Cliff Warren
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC.,INC.
Checked by: Ramona E. Wagner
Submitted by: [signature]
Chief, Geotechnical Branch

Date: 30 JUNE 1987

Dwg. No. 13



LEGEND

- ▲ *Monitoring well cluster*
- ● *Piezometer*
- ⊘ *Water supply well*
- ◒ *Water supply well plugged*
- *1253.9 Water table elevation in perched aquifer (feet)*
- *— 50 — Water table contour (50 = elevation 1250)*
- *260 Benzene concentration in monitoring well (ug/l)*
- *— 100 — Benzene contour (ug/l)*

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE
AIRFIELD ELEVATION 1292 FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: Cliff Warren
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.
Checked by: Ramona E. Wagner
Submitted by: Chief, Geotechnical Branch

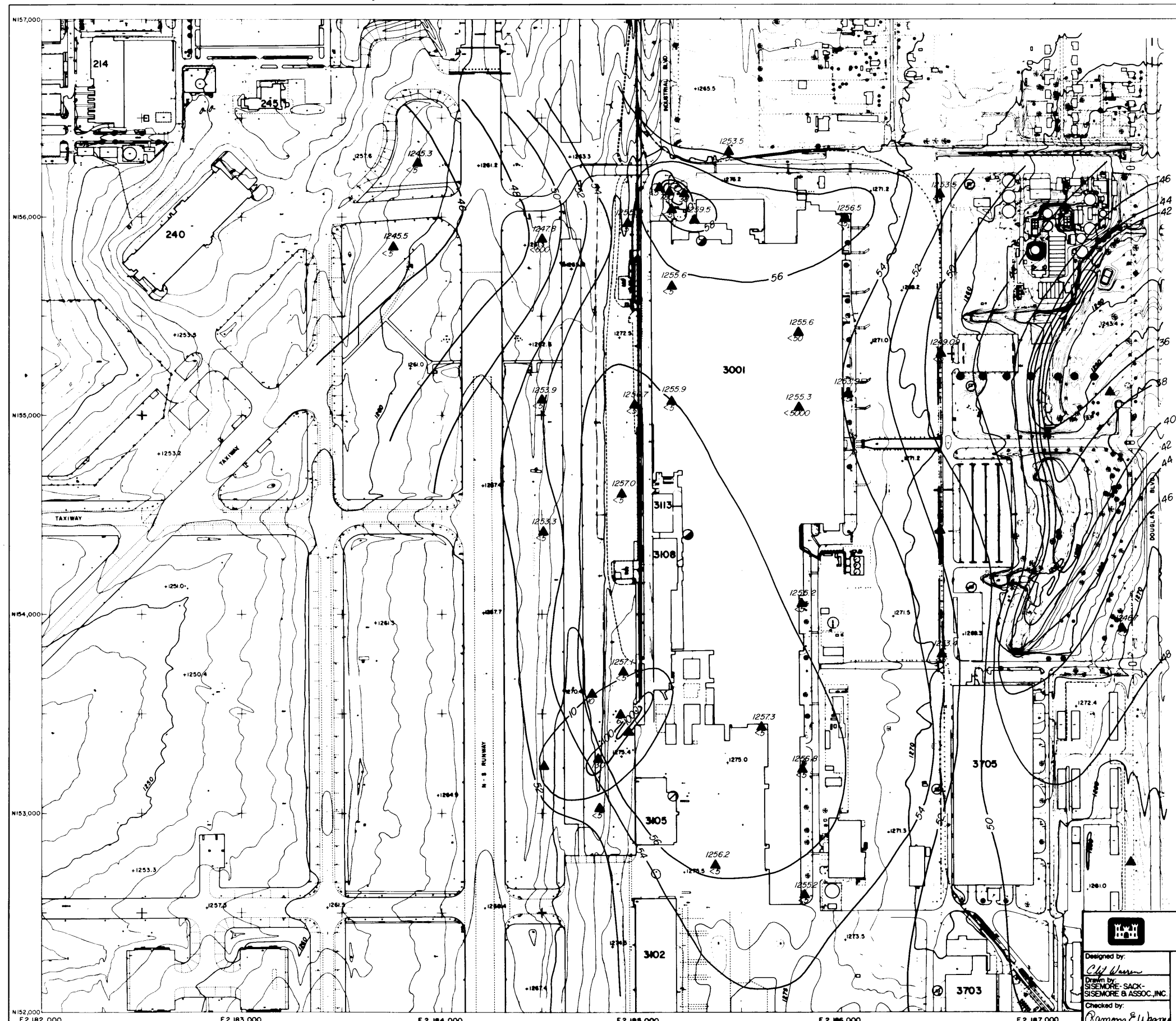
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

PERCHED AQUIFER

BENZENE CONTOURS

Dwg. No. 14

Date: 30 JUNE 1987



LEGEND

- ▲ *Monitoring well cluster*
- ● *Piezometer*
- ⊘ *Water supply well*
- ◒ *Water supply well plugged*
- *1253.9 Water table elevation in perched aquifer (feet)*
- *— 50 — Water table contour (50 = elevation 1250)*
- *10 Xylenes concentration in monitoring well (ug/l)*
- *— 10 — Xylenes contour (ug/l)*

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE
AIRFIELD ELEVATION 1292 FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: Clif Warren
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.
Checked by: Ramona E. Wagner
Submitted by: Chief, Geotechnical Branch

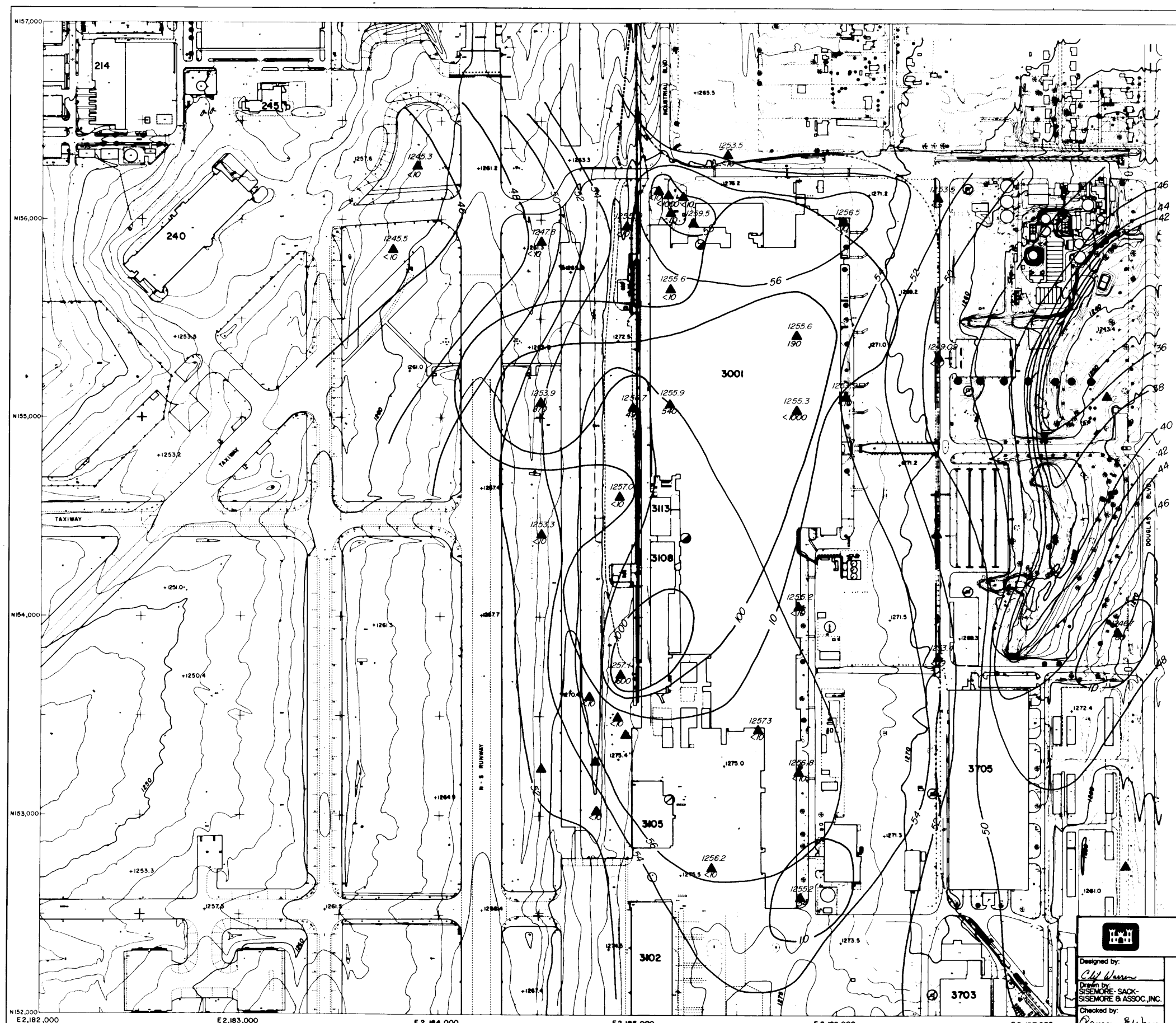
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

PERCHED AQUIFER

TOTAL XYLENES CONTOURS

Date: 30 JUNE 1987

Dwg. No. 15



U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: Cly Warren
Drawn by: SISEMORE, SACK-SISEMORE & ASSOC., INC.
Checked by: Ramona E. Wagner
Submitted by: Chief, Geotechnical Branch

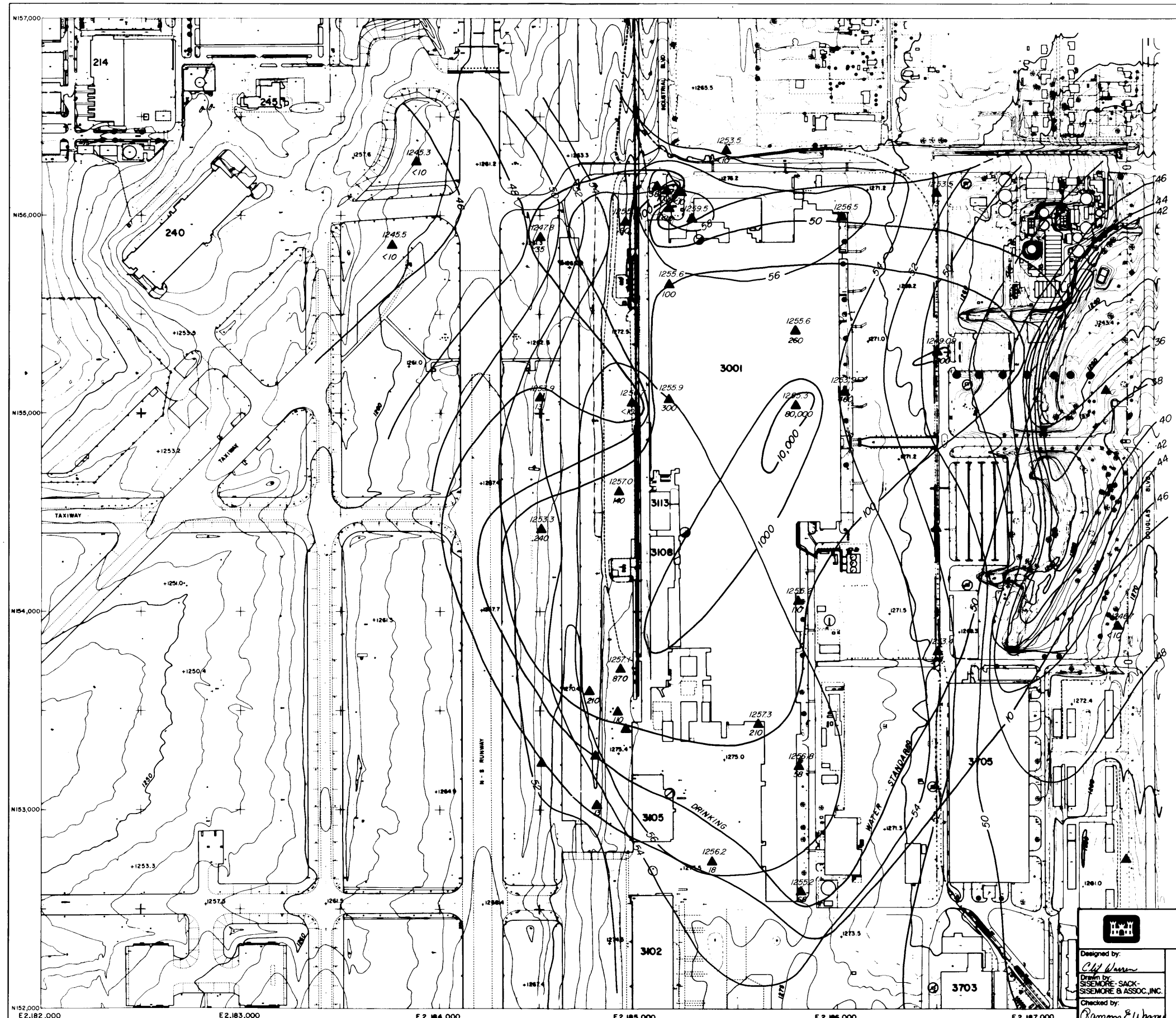
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

PERCHED AQUIFER

ACETONE CONTOURS

Dwg. No. 16

Date: 30 JUNE 1987



U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: Cliff Warren
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.
Checked by: Ramona E. Wagner
Submitted by: Chief, Geotechnical Branch

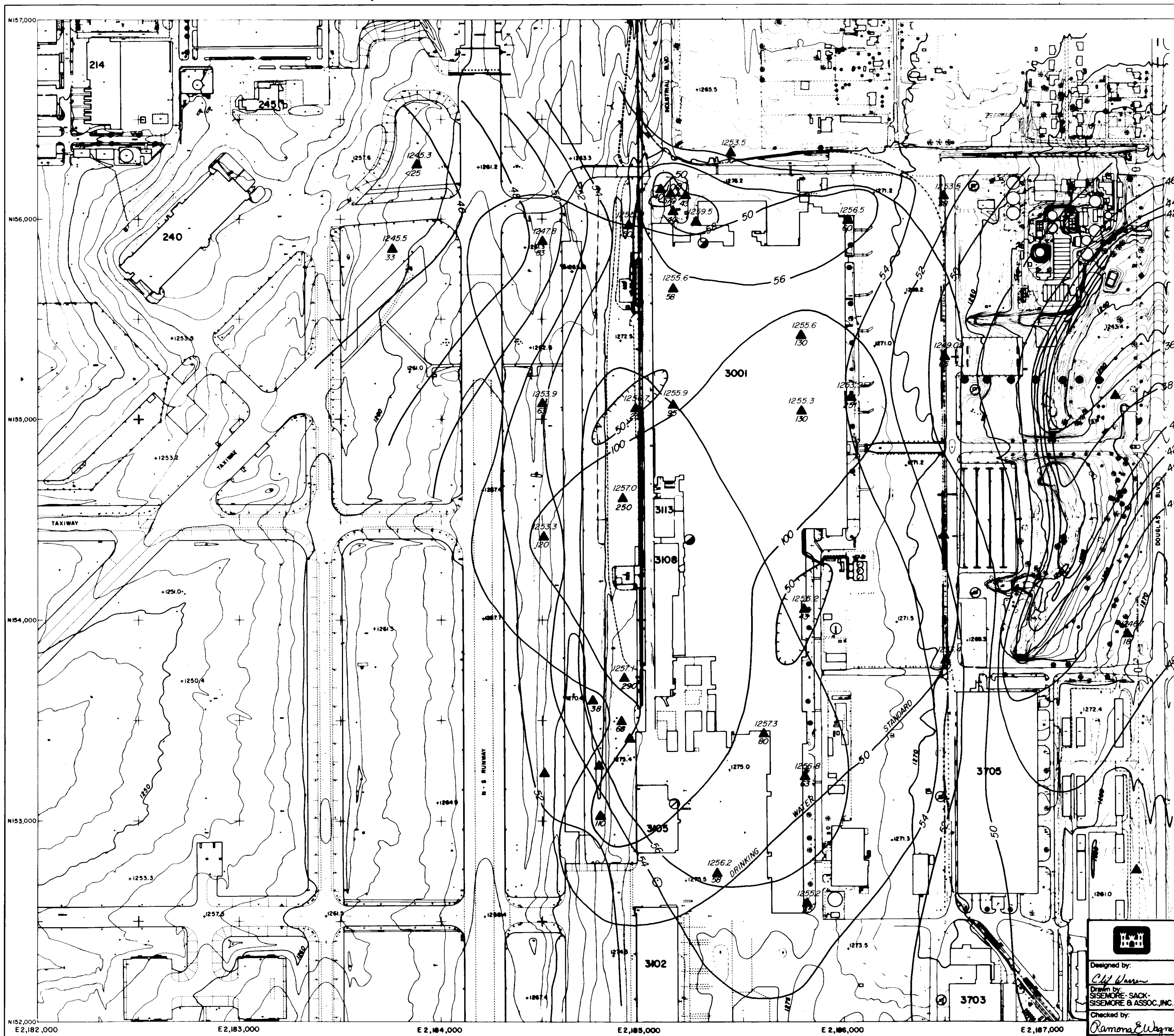
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

PERCHED AQUIFER

TOTAL CR CONTOURS

Dwg. No. 17

Date: 30 JUNE 1987



LEGEND

- ▲ *Monitoring well cluster*
- ● *Piezometer*
- ⊘ - *Water supply well*
- ◐ *Water supply well plugged*

1253.9 Water table elevation in perched aquifer (feet)

—50— Water table contour (50 = elevation 1250)

130 Total lead concentration in monitoring well (ug/l)

—100— Total lead contour (ug/l)

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE

AIRFIELD ELEVATION 1292 FEET

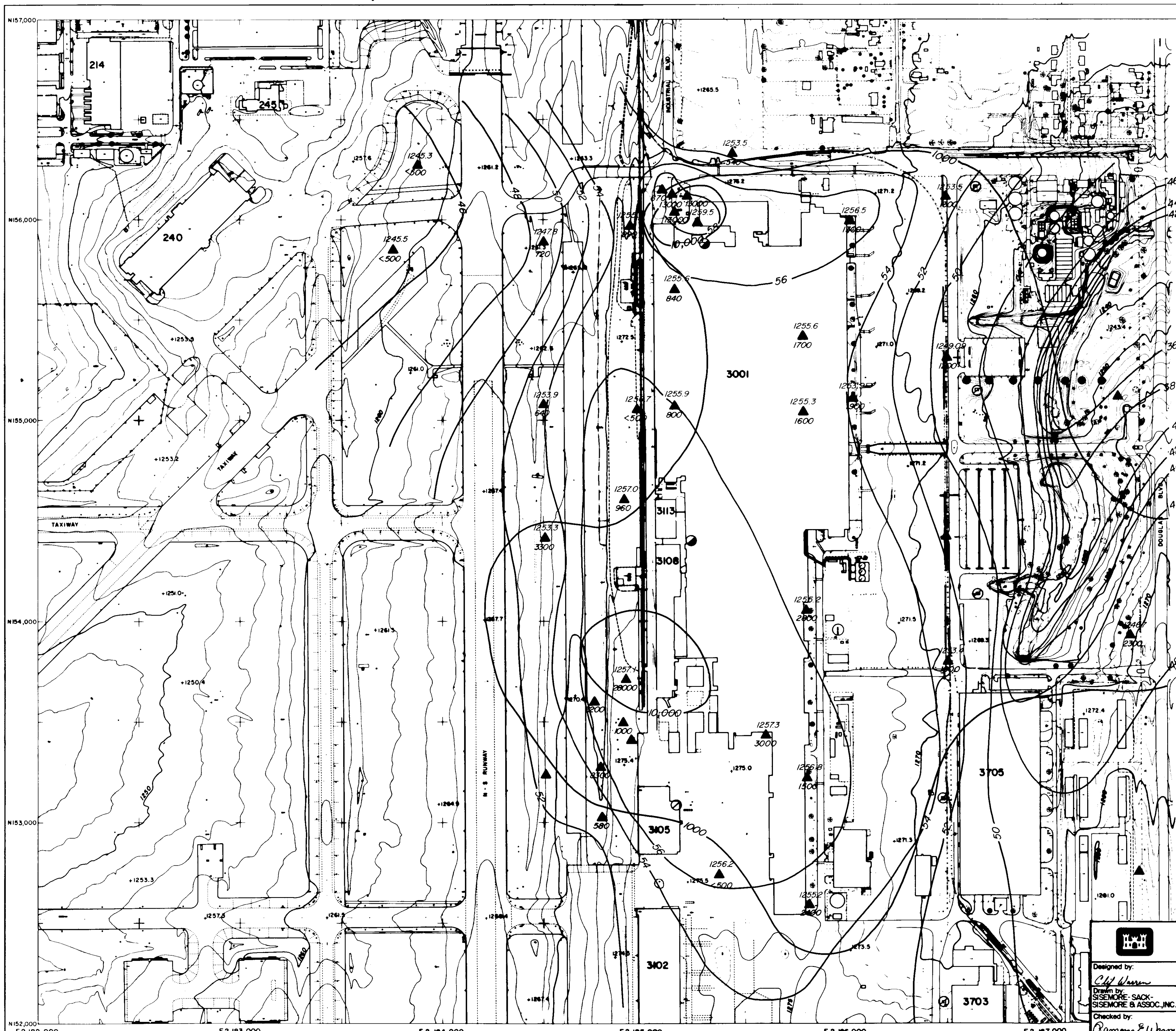
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

PERCHED AQUIFER

TOTAL LEAD CONTOURS

Designed by:	Cliff Warren
Drawn by:	SISEMORE-SACK-SISEMORE & ASSOC.,INC.
Checked by:	Ramona E Wagner
Submitted by:	[signature]
Chief, Geotechnical Branch	
Date:	30 JUNE 1987
Dwg. No.	18



LEGEND

- ▲ Monitoring well cluster
- ● Piezometer
- ⊘ - Water supply well
- Water supply well plugged

1253.9 Water table elevation in perched aquifer (feet)

—50— Water table contour (50 = elevation 1250)

2800 Total barium (Ba) concentration in monitoring well (ug/l)

—1000— Total Ba contour (ug/l)

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300

SCALE

AIRFIELD ELEVATION 1292 FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: Cliff Warren

Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.

Checked by: Ramona E. Wagner

Submitted by: [signature]

Chief, Geotechnical Branch

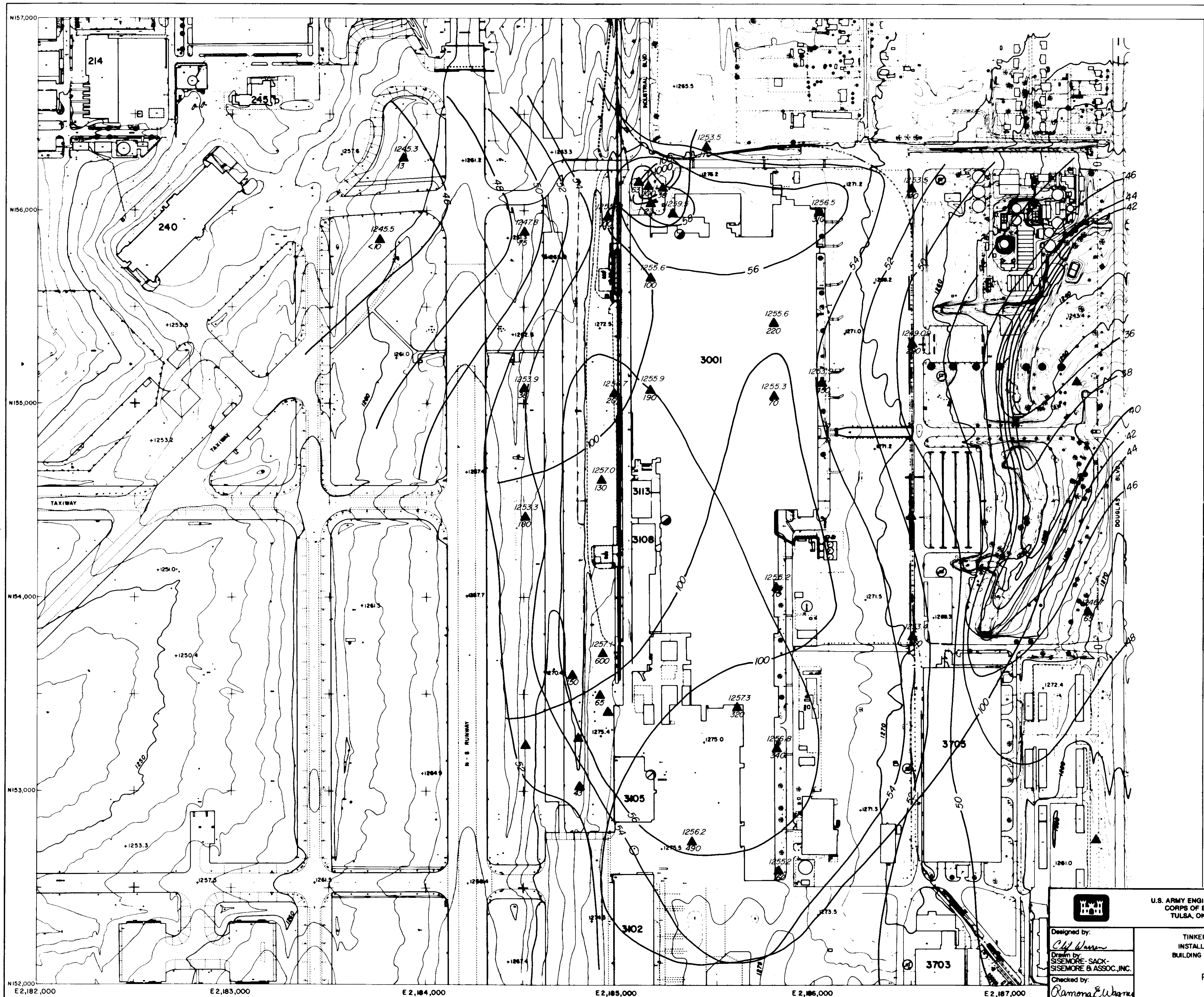
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

PERCHED AQUIFER

TOTAL BA CONTOURS

Dwg. No. 19

Date: 30 JUNE 1987



LEGEND

- ▲ Monitoring well cluster
- ● Piezometer
- ⊘ - Water supply well
- ◐ Water supply well plugged

1253.9 Water table elevation in perched aquifer (feet)

— 50 — Water table contour (50 = elevation 1250)

450 Total nickel (Ni) concentrations in monitoring well (ug/l)

— 100 — Total Ni contour (ug/l)

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE

AIRFIELD ELEVATION 1292 FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001/REMEDIAL INVESTIGATIONS

PERCHED AQUIFER

TOTAL NI CONTOURS

Designed by: Cliff Warren

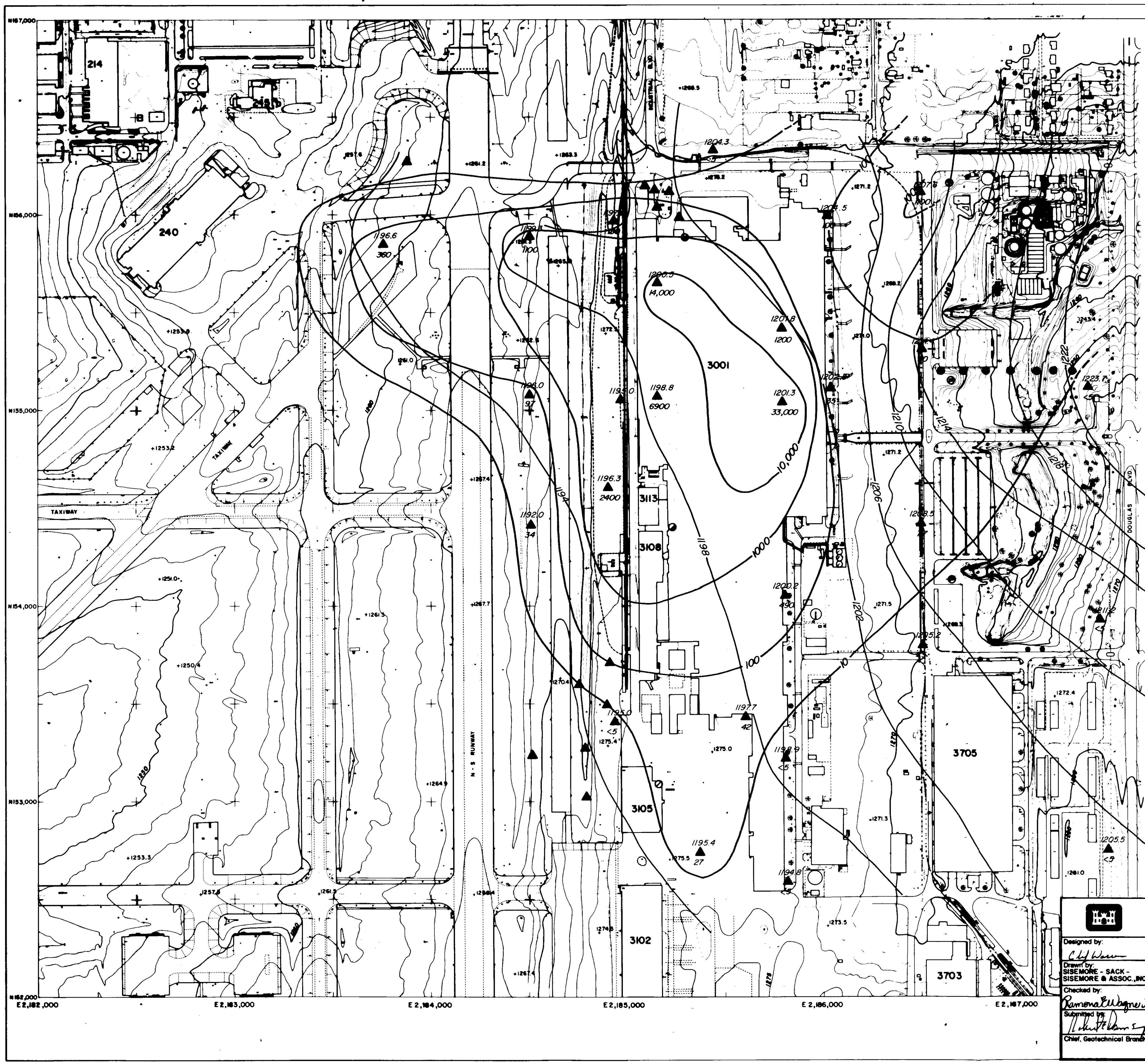
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC.,INC.

Checked by: Ramona E. Wagner

Submitted by: Chief, Geotechnical Branch

Date: 30 JUNE 1987

Dwg. No. 20



LEGEND

- ▲ - Monitoring well cluster
- ● - Piezometer
- ⊘ - Water Supply Well
- ◑ - Water Supply Well plugged

35 Trichloroethylene (TCE) concentrations in monitoring well (ug/l)

—100— TCE contour (ug/l)

1196.0 Potentiometric sur... in top of regional ...

—1202— Potentiometric con...

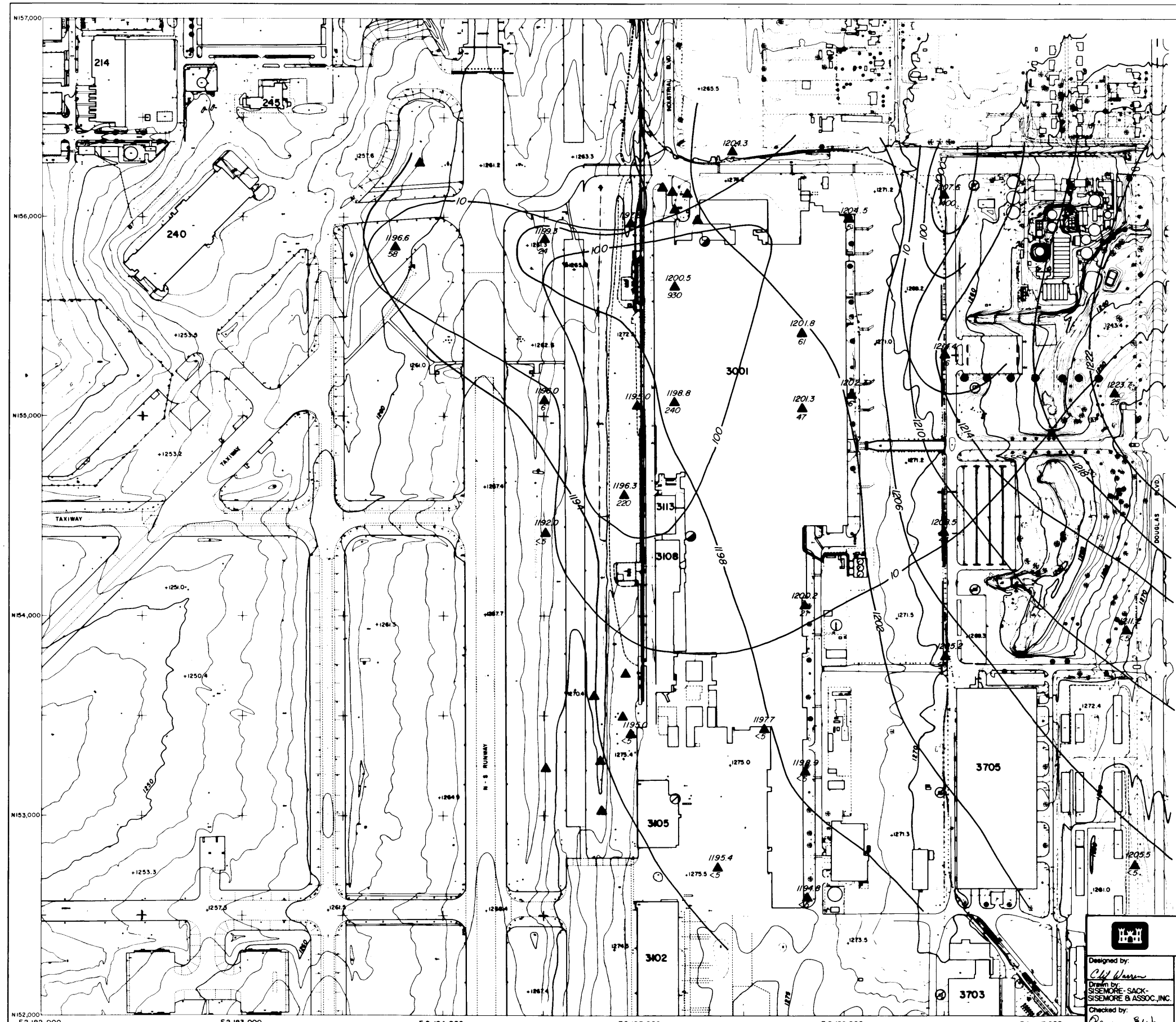
NOTE: Topographic mapping perform... by Woolpert Consultants for Tinker A... Force Base (Aug. 86) as part of Bas... Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE

AIRFIELD ELEVATION 1292 FEE...

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: [signature]	TINKER AIR FORCE BASE, OKLAHOMA INSTALLATION RESTORATION PROGRAM BUILDING 3001/REMEDIAL INVESTIGATIONS
Drawn by: SISEMORE - SACK - SISEMORE & ASSOC., INC.	TOP OF REGIONAL ZONE
Checked by: Ramona E. Wagner [signature]	
Submitted by: [signature] Chief, Geotechnical Branch	TCE CONTOURS
Date: 30 JUNE 1987	Dwg. No. 21



U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: Clif Warren
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.
Checked by: Ramona E. Wagner
Submitted by: Chief, Geotechnical Branch

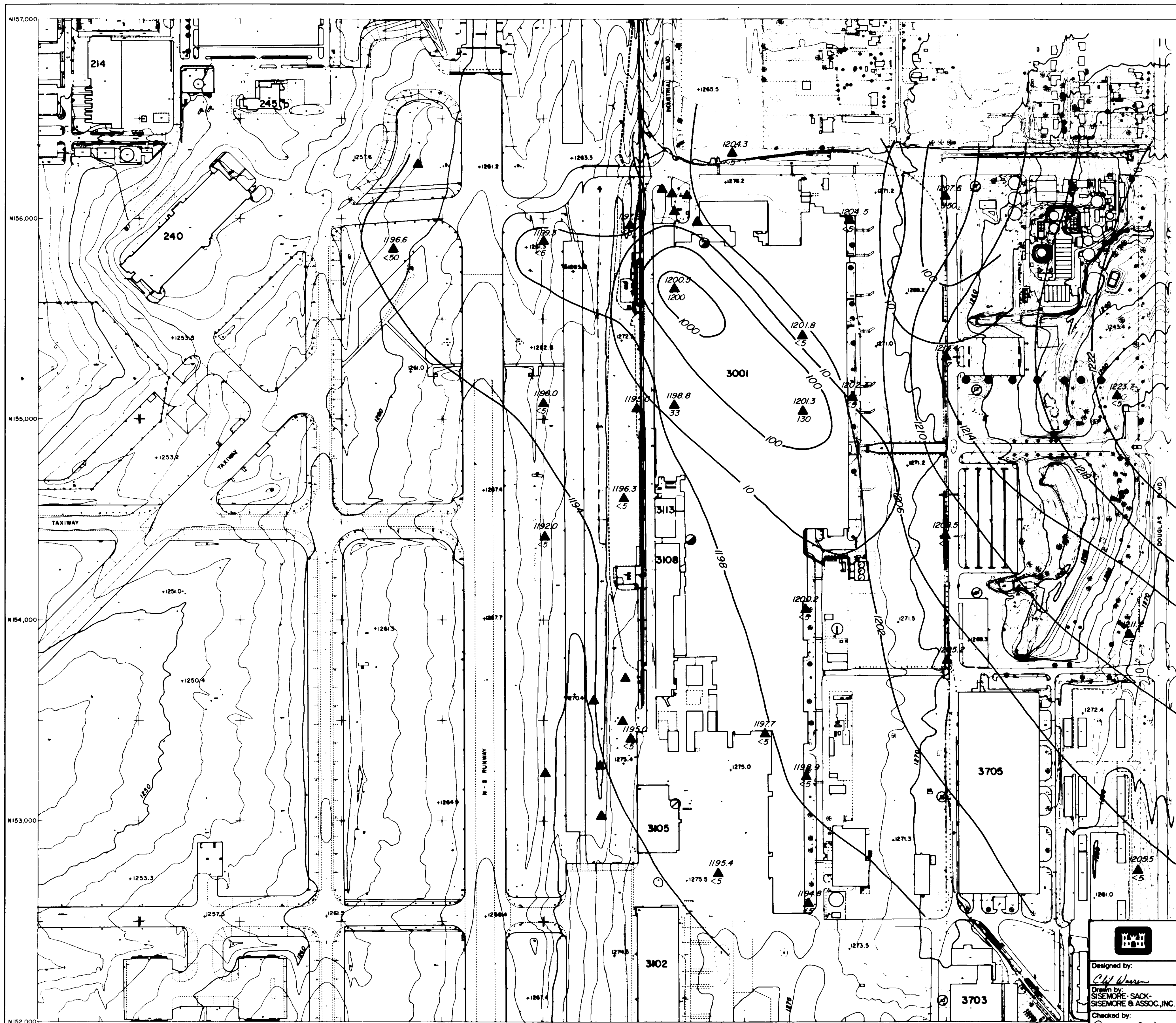
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

TOP OF REGIONAL ZONE

1,2-DCE CONTOURS

Dwg. No. 22

Date: 30 JUNE 1987



LEGEND

▲ Monitoring well cluster

● Piezometer

⊘ - Water supply well

Water supply well plugged

1196.0 Potentiometric surface in top of regional aquifer

— 1202 — Potentiometric contour

7 Tetrachloroethylene (PCE) concentration in monitoring well (ug/l)

— 10 — PCE contour (ug/l)

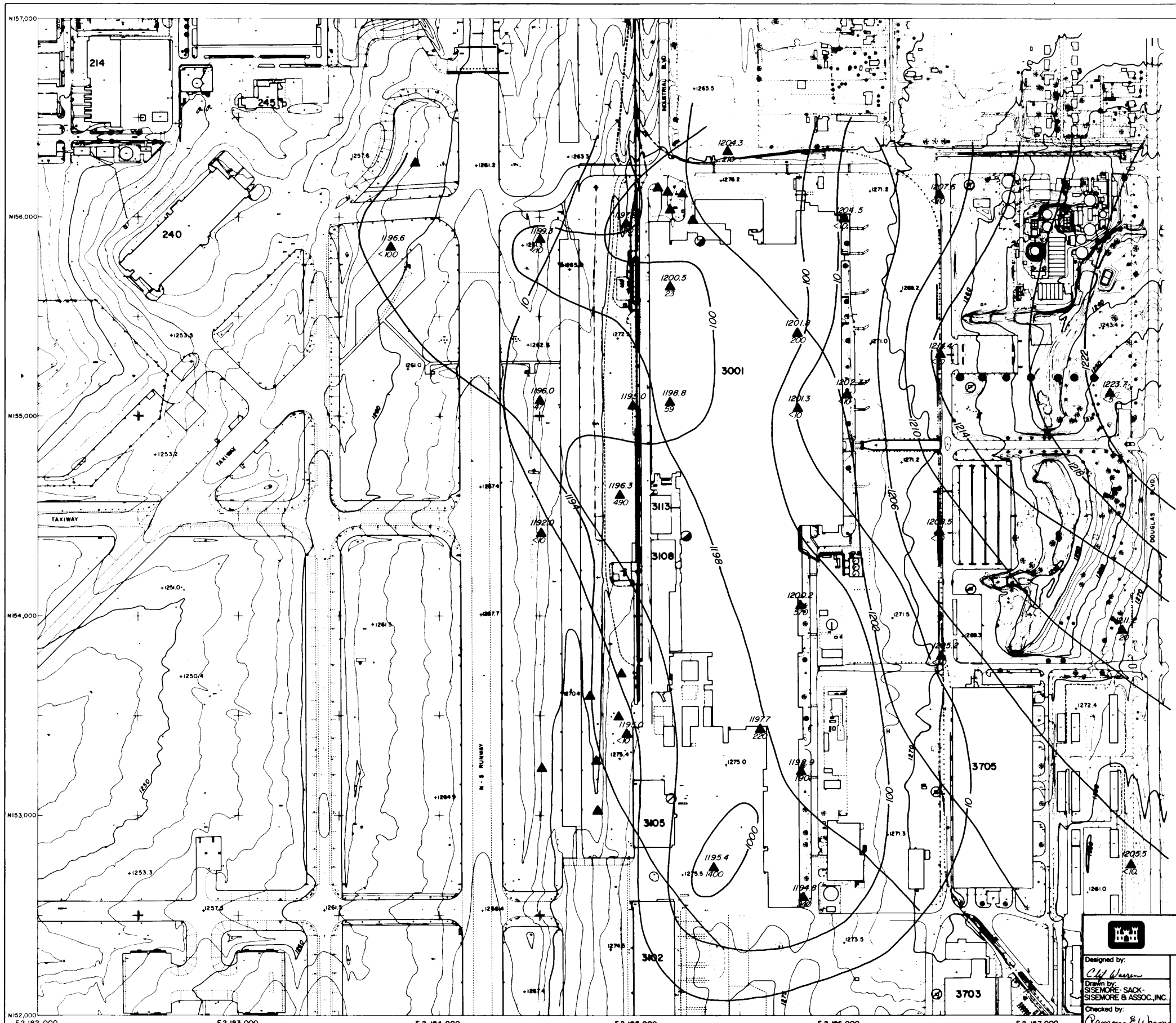
NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE

AIRFIELD ELEVATION 1292 FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: Clif Warren	TINKER AIR FORCE BASE, OKLAHOMA INSTALLATION RESTORATION PROGRAM BUILDING 3001/REMEDIAL INVESTIGATIONS
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.	
Checked by: Ramona E. Wagner	TOP OF REGIONAL ZONE
Submitted by: [signature] Chief, Geotechnical Branch	PCE CONTOURS
Date: 30 JUNE 1987	Dwg. No. 23



LEGEND

- ▲ Monitoring well cluster
- ● Piezometer
- ⊘ Water supply well
- ◪ Water supply well plugged
- 1196.0 Potentiometric surface in top of regional aquifer
- —1202— Potentiometric contour
- 570 Acetone concentration in monitoring well (ug/l)
- —100— Acetone contour (ug/l)

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE
AIRFIELD ELEVATION 1292 FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: Clif Warren
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.
Checked by: Ramona E. Wagner
Submitted by: Chief, Geotechnical Branch

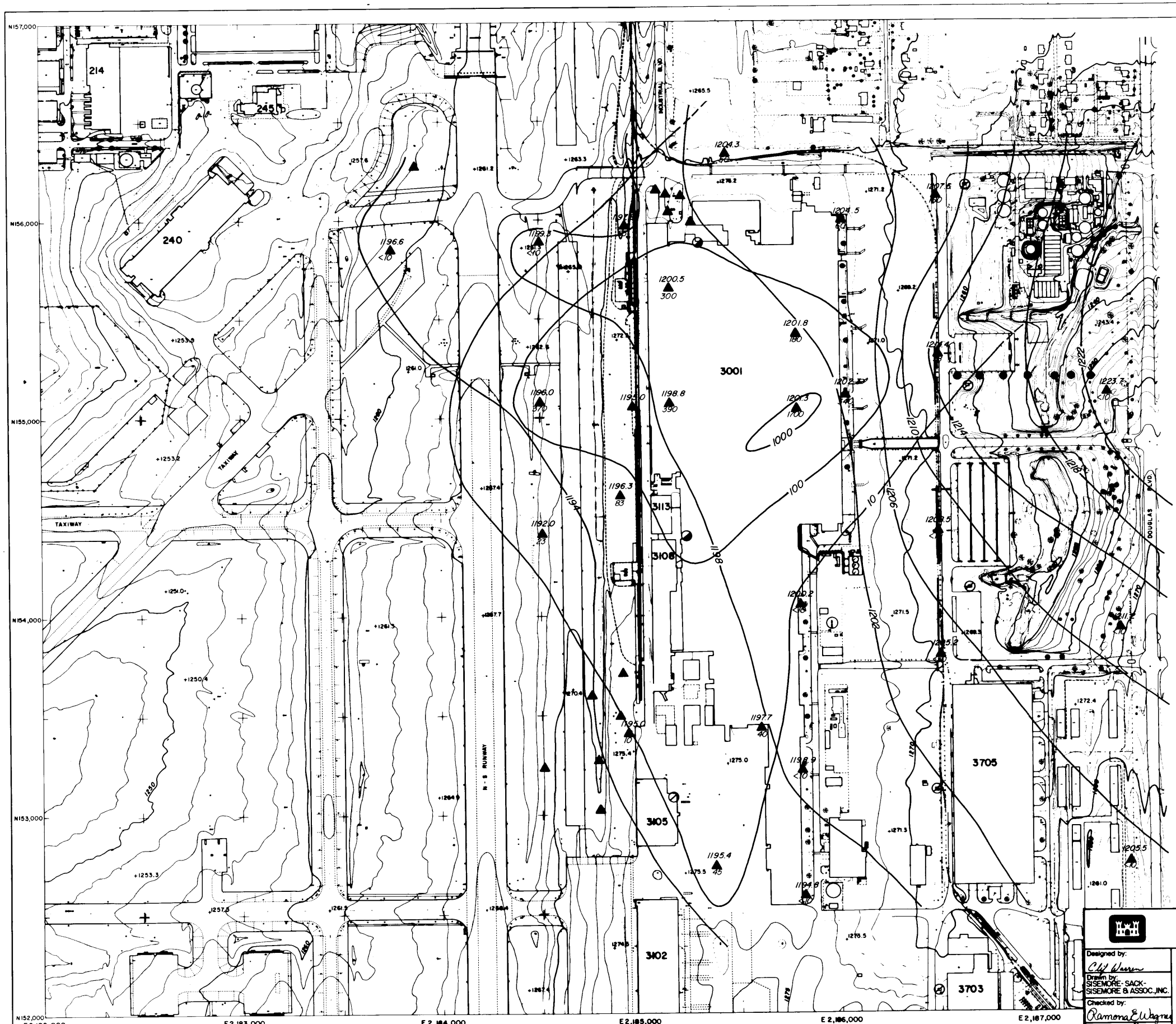
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

TOP OF REGIONAL ZONE

ACETONE CONTOURS

Date: 30 JUNE 1987

Dwg. No. 24



NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE

AIRFIELD ELEVATION 1292 FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: Cliff Warren

Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.

Checked by: Ramona E. Wagner

Submitted by: Chief, Geotechnical Branch

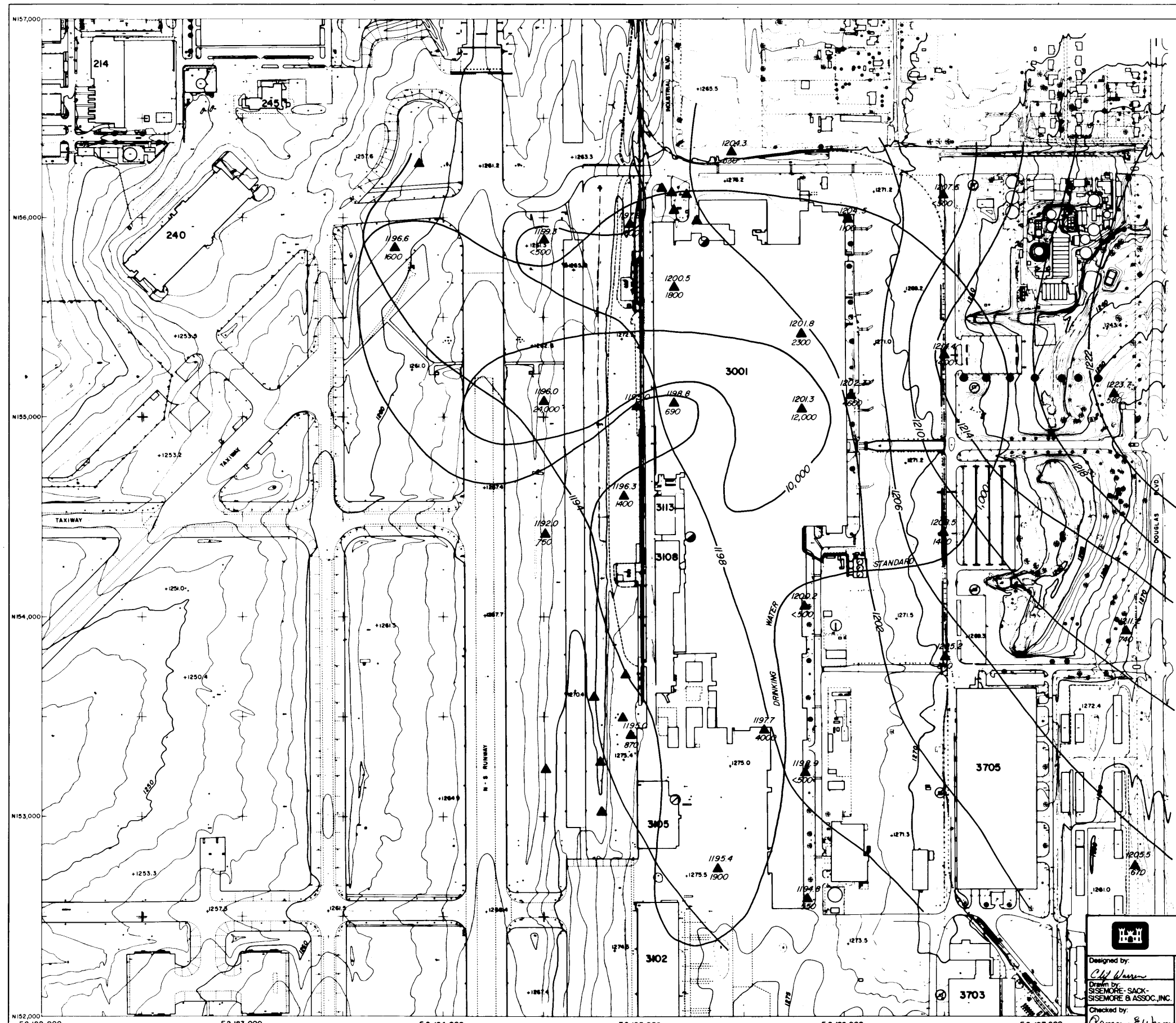
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

TOP OF REGIONAL ZONE

TOTAL CR CONTOURS

Dwg. No. 25

Date: 30 JUNE 1987



N

LEGEND

- ▲ Monitoring well cluster
- ● Piezometer
- ⊘ Water supply well
- ◪ Water supply well plugged

1196.0 Potentiometric surface in top of regional aquifer

—1202— Potentiometric contour

1400 Total barium (Ba) concentration in monitoring well (ug/l)

—1000— Total Ba contour (ug/l)

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE
AIRFIELD ELEVATION 1292 FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: C.H. Warren
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.
Checked by: Ramona E. Wagner
Submitted by: Chief, Geotechnical Branch

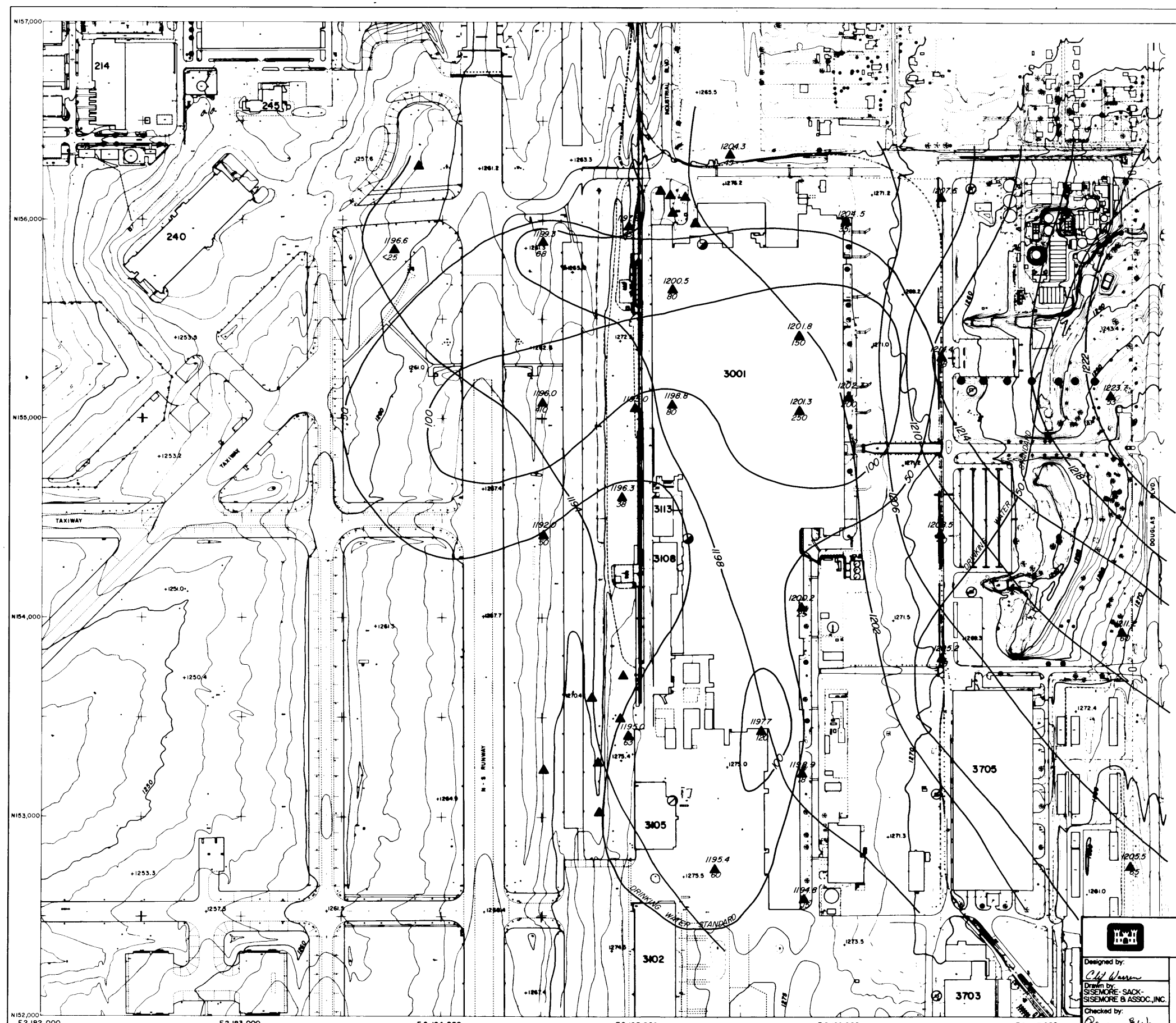
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

TOP OF REGIONAL ZONE

TOTAL BA CONTOURS

Date: 30 JUNE 1987

Dwg. No. 26



U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: Clif Warren
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.
Checked by: Ramona E. Wagner
Submitted by: Chief, Geotechnical Branch

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

TOP OF REGIONAL ZONE

TOTAL PB CONTOURS

Dwg. No. 27

Date: 30 JUNE 1987

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by:

Drawn by:
SISEMORE - SACK -
SISEMORE & ASSOC., INC.

Checked by:

Submitted by:
Chief, Geotechnical Branch

Date: 30 JUNE 1987

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

TOP OF REGIONAL ZONE

TOTAL NI CONTOURS

Dwg. No. 28

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

AIRFIELD ELEVATION 1292 FEET

SCALE
100 0 100 200 300

LEGEND

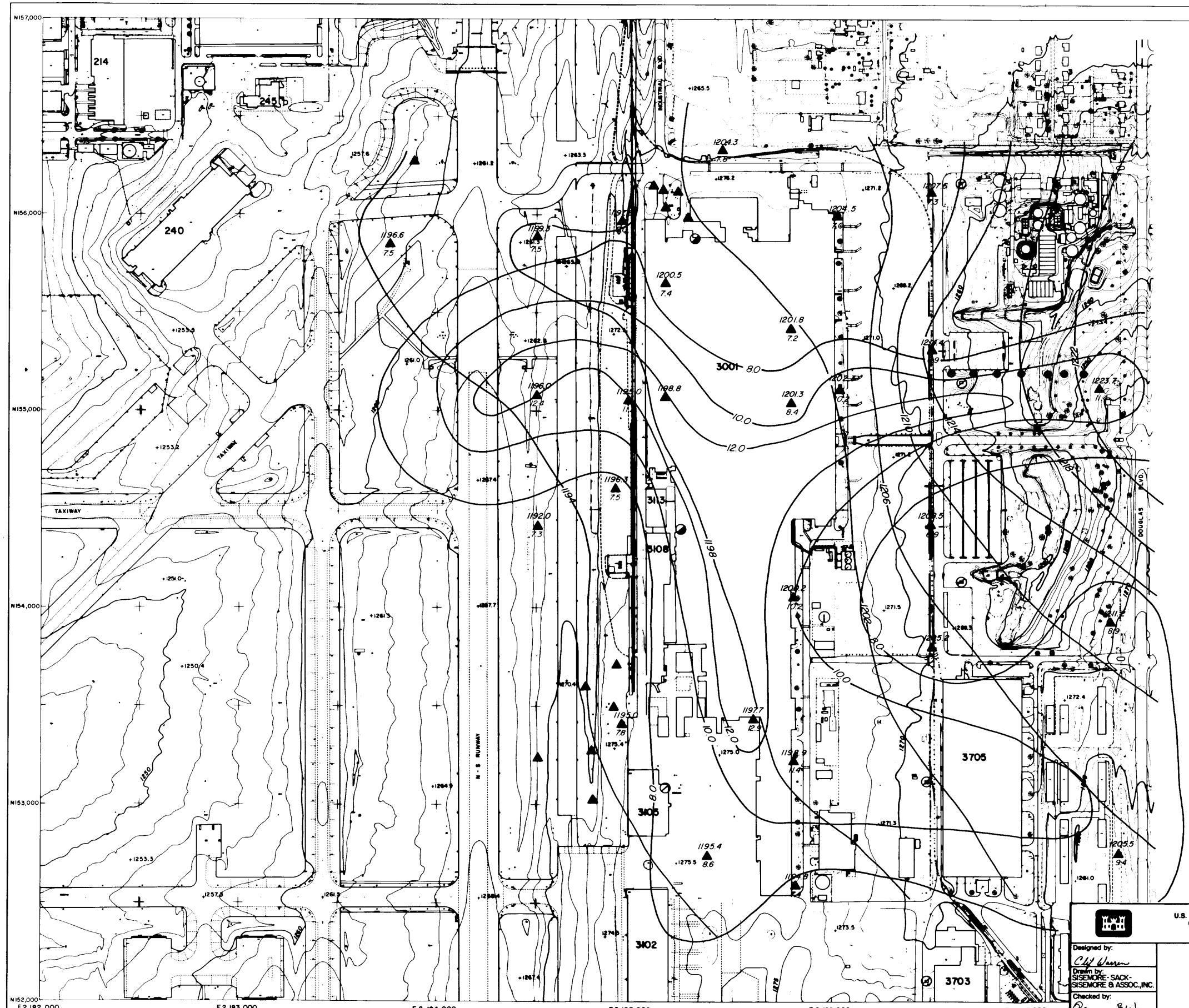
- Monitoring well cluster
- Piezometer
- Water supply well
- Water supply well plugged
- 1196.0 Potentiometric surface in top of regional aquifer
- —120— Potentiometric contour
- 48 Total nickel (Ni) concentration in monitoring well (ug/l)
- —100— Total Ni contour (ug/l)

N

E 2,187,000 E 2,186,000 E 2,185,000 E 2,184,000 E 2,183,000 E 2,182,000

N157,000 N156,000 N155,000 N154,000 N153,000 N152,000

3703 3702 3705 3108 3113 3001 240 214 243



LEGEND

- ▲ Monitoring well cluster
- ● Piezometer
- ⊘ - Water supply well
- ◪ Water supply well plugged

1196.0 Potentiometric surface in top of regional aquifer

—1202— Potentiometric contour

8.4 pH in monitoring well (S.U.)

—10.0— pH contour (S.U.)

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE

AIRFIELD ELEVATION 1292 FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: Clif Warren

Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.

Checked by: Ramona E. Wagner

Submitted by: Chief, Geotechnical Branch

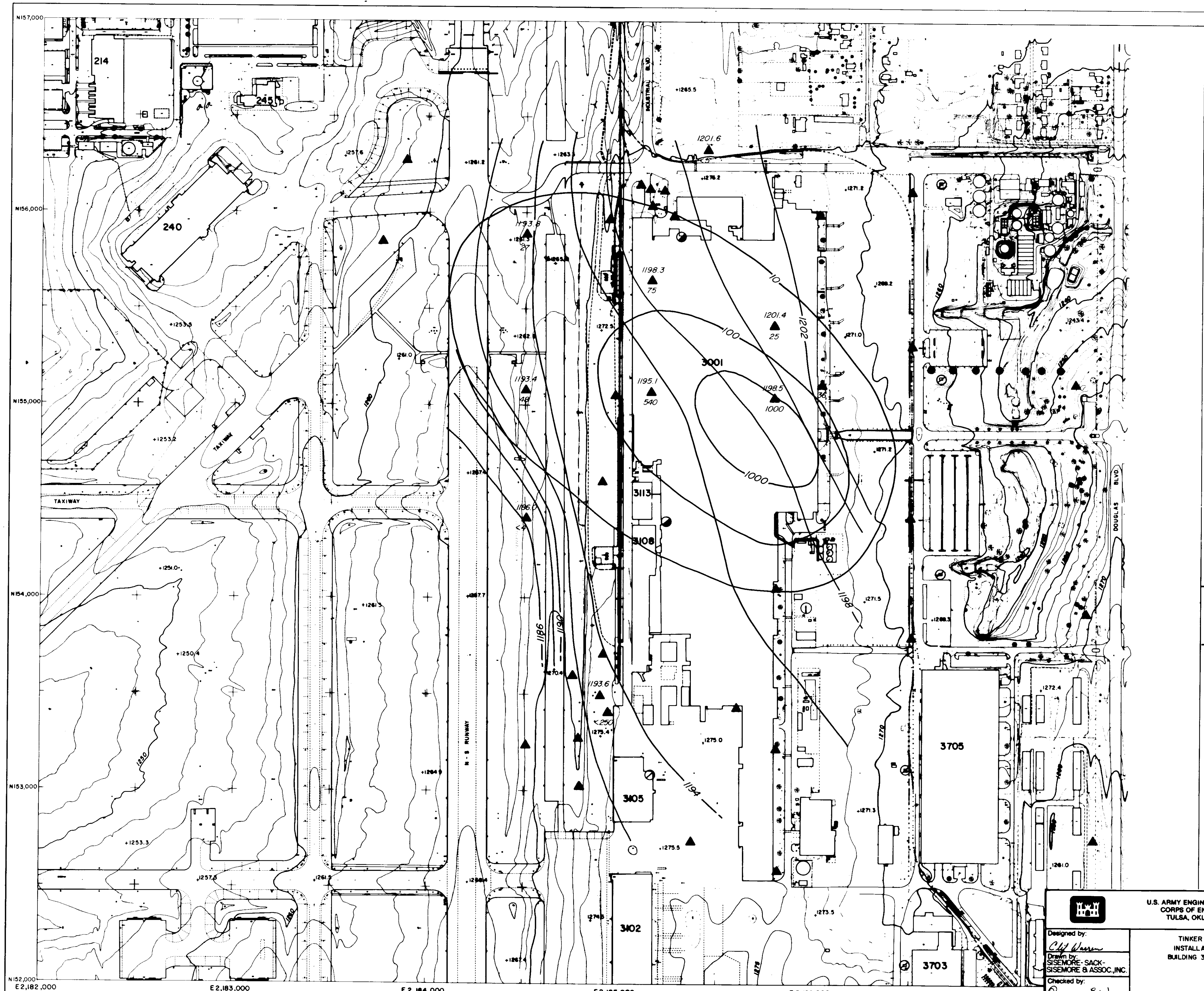
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

TOP OF REGIONAL ZONE

pH CONTOURS

Date: 30 JUNE 1987

Dwg. No. 29



LEGEND

- ▲ Monitoring well cluster
- ● Piezometer
- ⊘ - Water supply well
- ◐ Water supply well plugged
- 1198.5 Elev. of potentiometric surface
- —1200— Potentiometric contour
- 36 Trichloroethylene (TCE) concentration (ug/l) in monitoring well
- —100— TCE contour (ug/l)

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE

AIRFIELD ELEVATION 1292 FEET

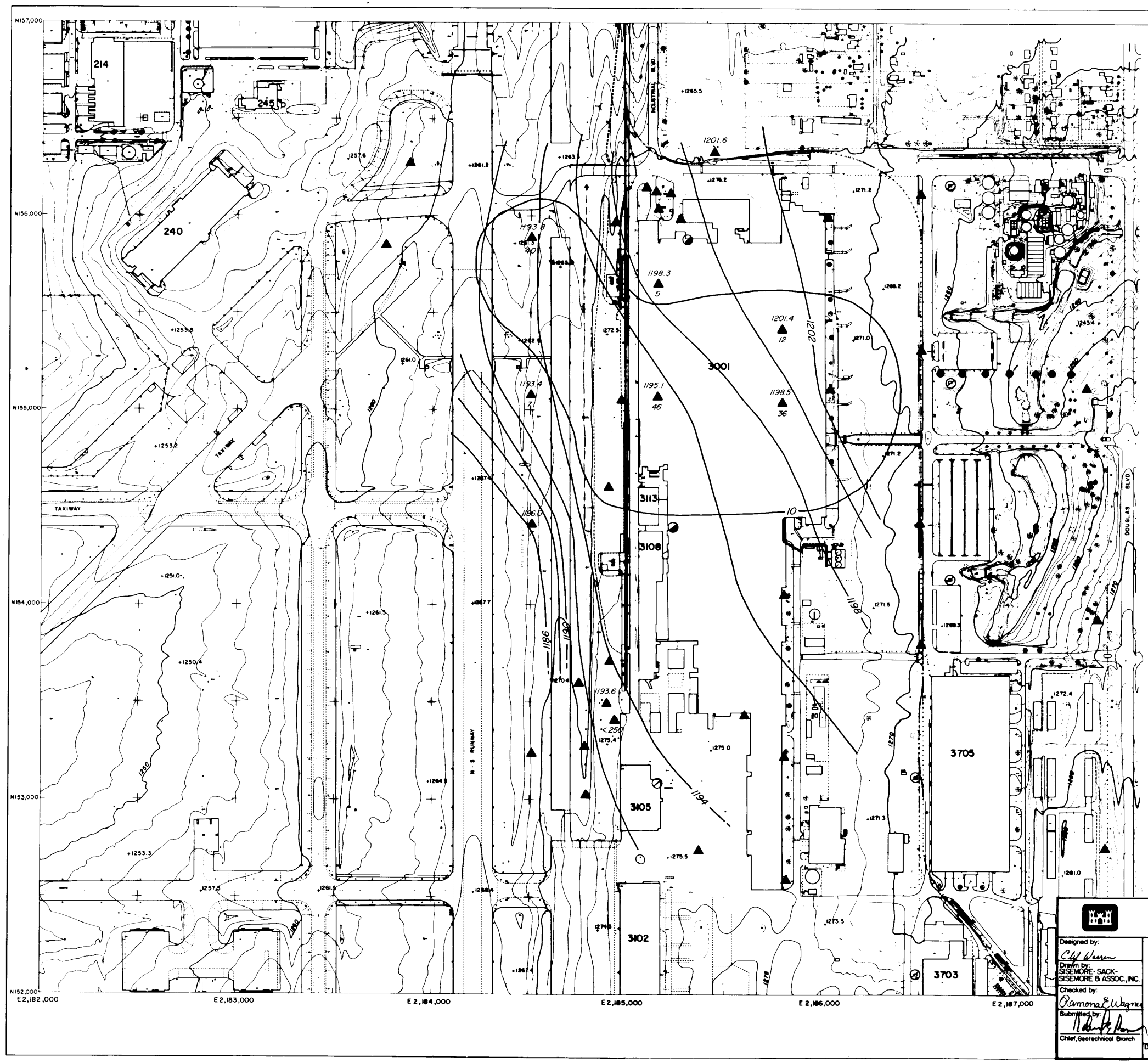
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

REGIONAL ZONE

TCE CONTOURS

Designed by:	[signature]
Drawn by:	SISEMORE-SACK-SISEMORE & ASSOC.,INC.
Checked by:	Ramona E. Wagner
Submitted by:	[signature]
Chief, Geotechnical Branch	
Date:	30 JUNE 1987
Dwg. No.	30



N

LEGEND

- ▲ Monitoring well cluster
- ● Piezometer
- ⊘ Water supply well
- ◪ Water supply well plugged

1198.5 Elev. of potentiometric surface

—1200— Potentiometric contour

12 Trans - 1,2- Dichloroethylene (1,2 - DCE) concentration in monitoring well (ug/l)

—10— 1,2- DCE contour (ug/l)

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE
AIRFIELD ELEVATION 1292 FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by:
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.
Checked by: Ramona E. Wagner
Submitted by:
Chief, Geotechnical Branch

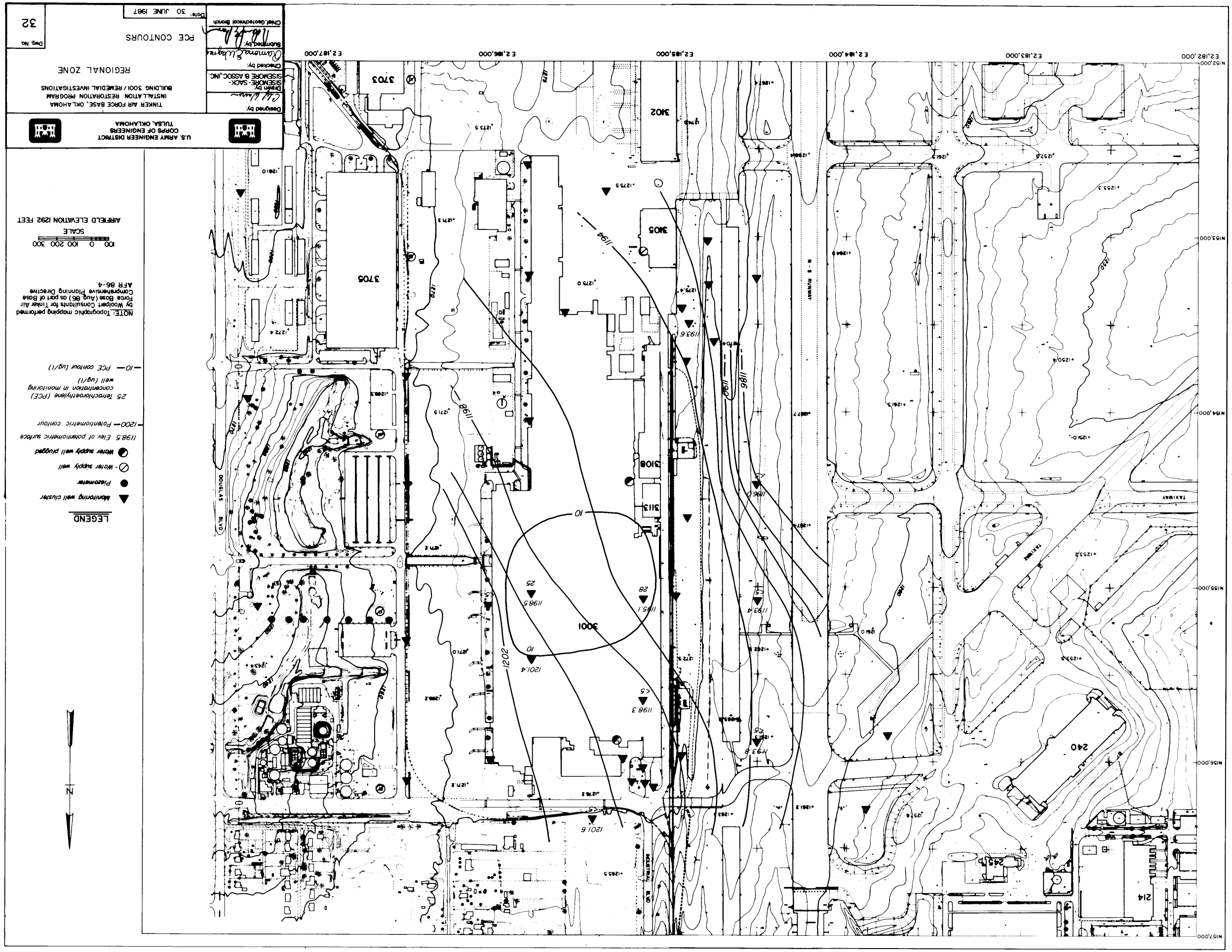
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

REGIONAL ZONE

1,2-DCE CONTOURS

Date: 30 JUNE 1987

Dwg. No. 31



LEGEND

- Monitoring well cluster
- Piezometer
- Water supply well
- Water supply well plugged
- 1198.5 Elev of potentiometric surface
- —1200— Potentiometric contour
- 25 Tetrachloroethylene (PCE) concentration in monitoring well (ug/l)
- —10— PCE contour (ug/l)

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

SCALE
100 0 100 200 300

AIRFIELD ELEVATION 1292 FEET

N

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by:

Drawn by:
SISEMORE - SACK -
SISEMORE & ASSOC.,INC.

Checked by:

Submitted by:
Chief, Geotechnical Branch

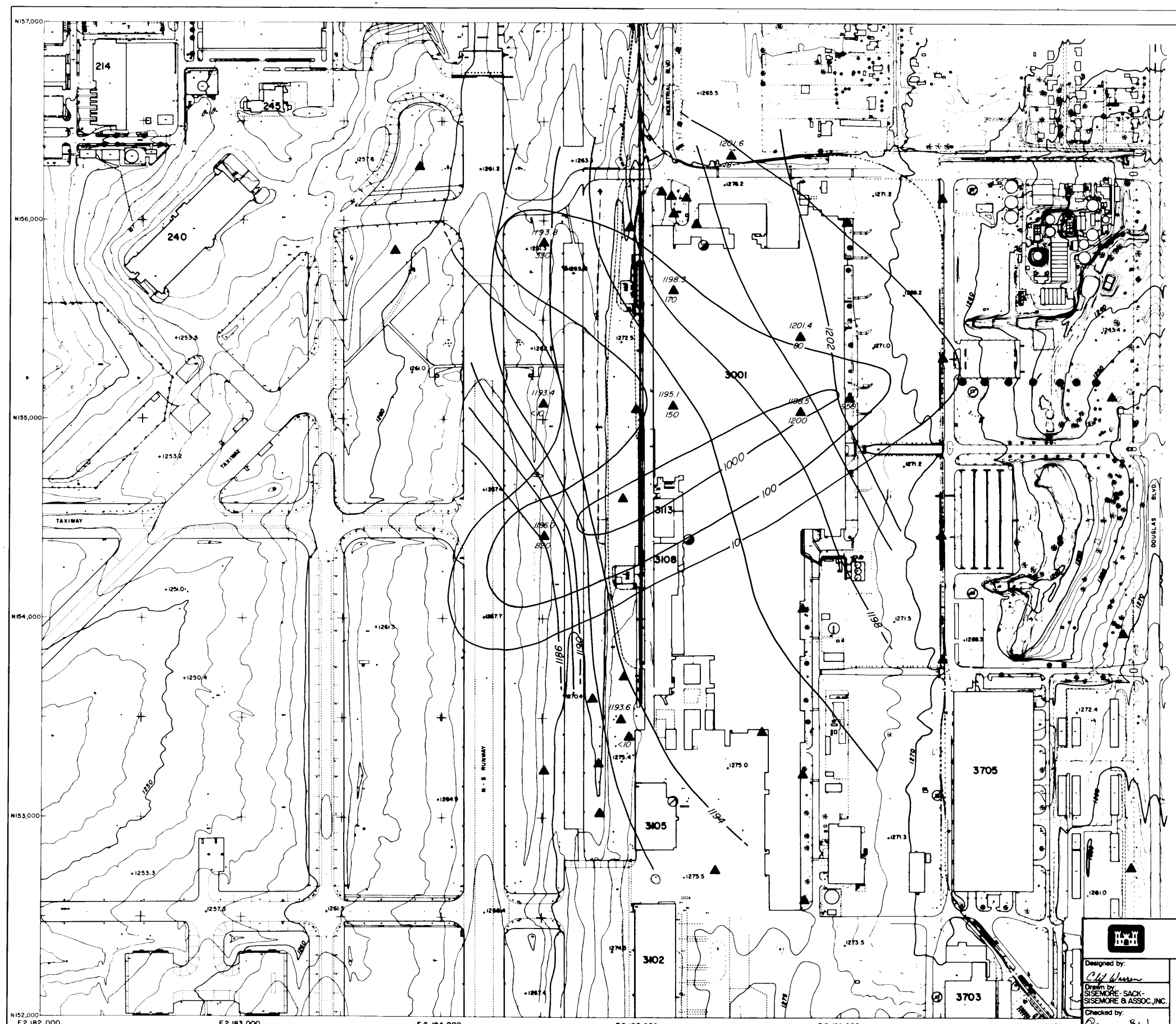
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

REGIONAL ZONE

PCE CONTOURS

Date: 30 JUNE 1987

Dwg. No. 32



LEGEND

- ▲ Monitoring well cluster
- ● Piezometer
- ⊘ - Water supply well
- ◕ Water supply well plugged
- 1198.5 Elev. of potentiometric surface
- 1200 — Potentiometric contour
- 150 Total chromium (Cr) in monitoring well (ug/l)
- 100 — Total Cr contour (ug/l)

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE
AIRFIELD ELEVATION 1292 FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: C.H. Warren
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.
Checked by: Ramona E. Wagner
Submitted by: Chief, Geotechnical Branch

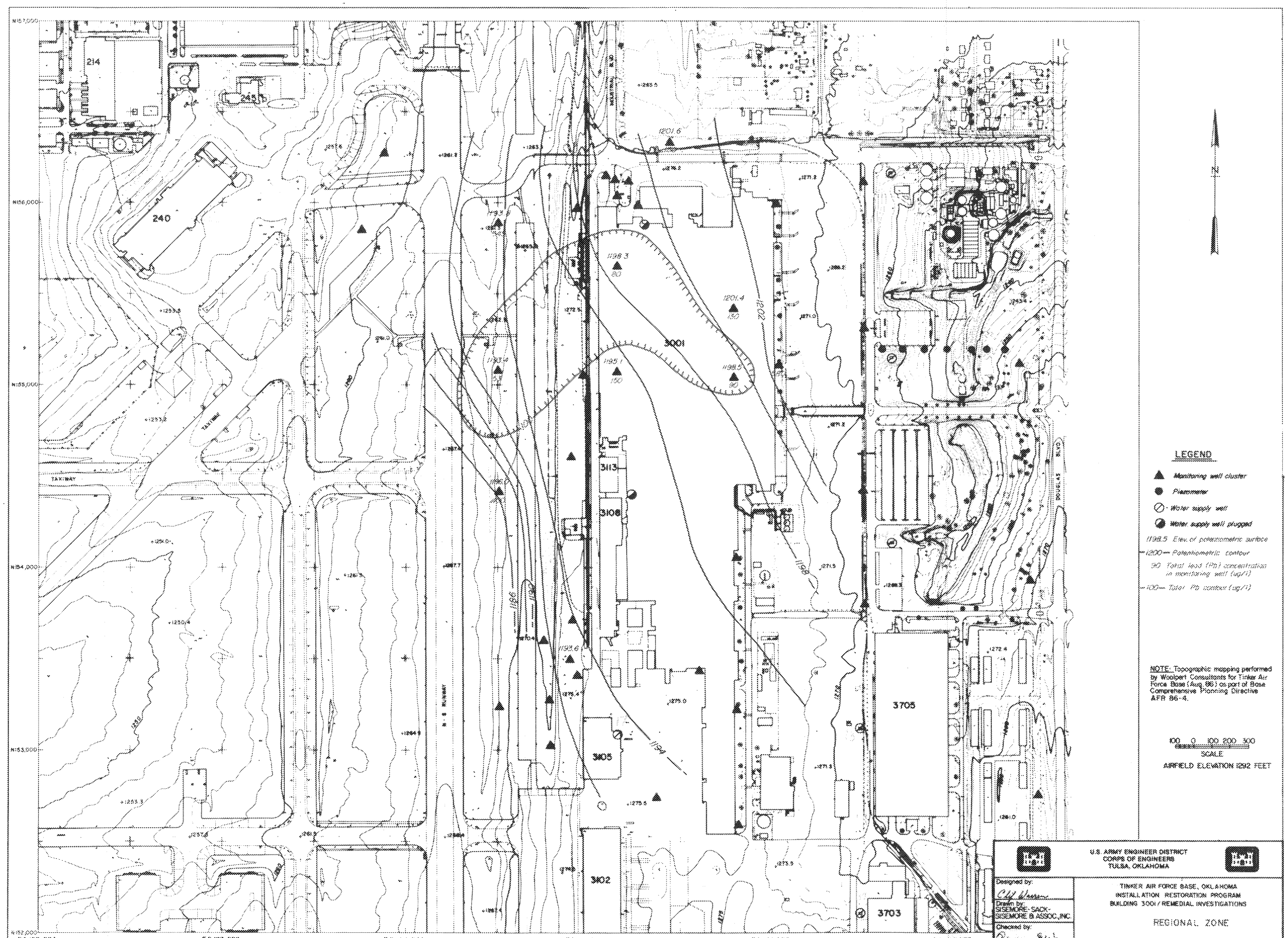
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

REGIONAL ZONE

TOTAL CR CONTOURS

Dwg. No. 33

Date: 30 JUNE 1987



U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by:
Cliff Hansen

Drawn by:
SYDEMORE-SACK-SYDEMORE & ASSOC., INC.

Checked by:
Ramona E. Haynes

Submitted by:
Chief, Geotechnical Branch

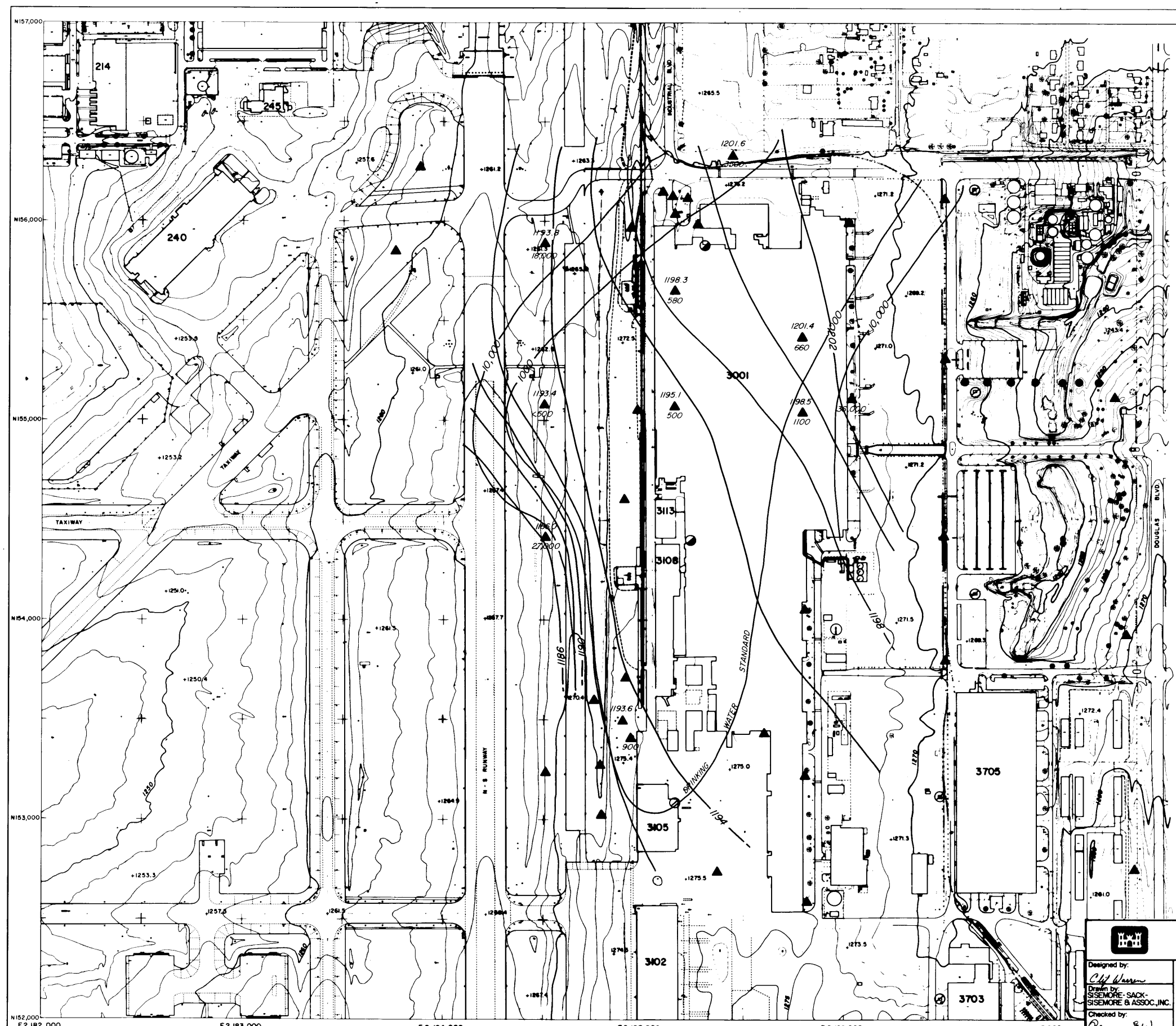
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

REGIONAL ZONE

TOTAL PB CONTOURS

Date: 30 JUNE 1987

Dwg. No. 34



U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: C.W. Warren

Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.

Checked by: Ramona E. Wagner

Submitted by: Chief, Geotechnical Branch

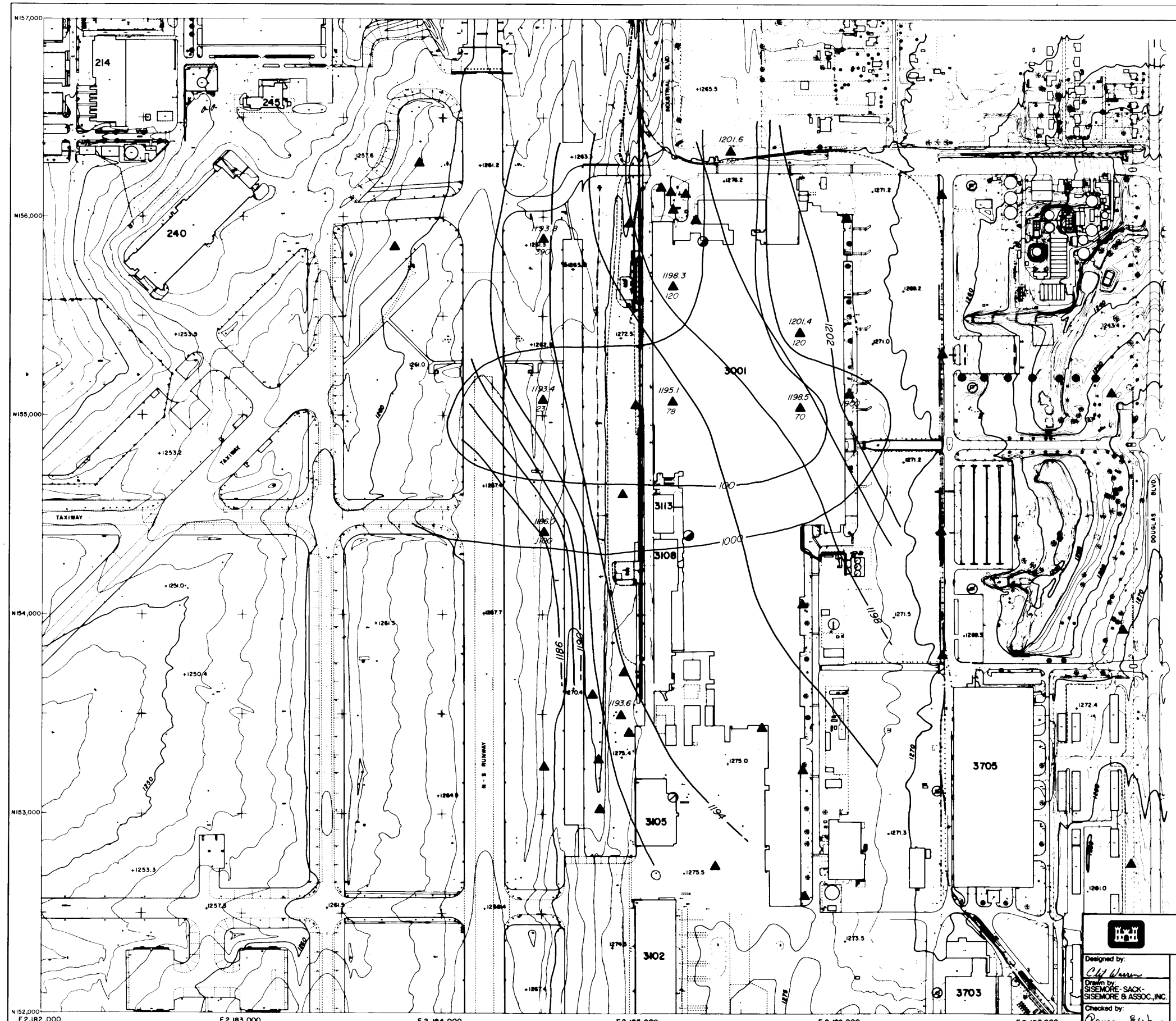
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

REGIONAL ZONE

TOTAL BA CONTOURS

Dwg. No. 35

Date: 30 JUNE 1987



N

LEGEND

- ▲ *Monitoring well cluster*
- ● *Piezometer*
- ⊘ - *Water supply well*
- ◪ *Water supply well plugged*
- *1198.5 Elev. of potentiometric surface*
- *1200 — Potentiometric contour*
- *78 Total nickel (Ni) concentration in monitoring well (ug/l)*
- *100 — Total Ni contour (ug/l)*

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE
AIRFIELD ELEVATION 1292 FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: Clif Warren
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC., INC.
Checked by: Ramona E. Wagner
Submitted by: Chief, Geotechnical Branch

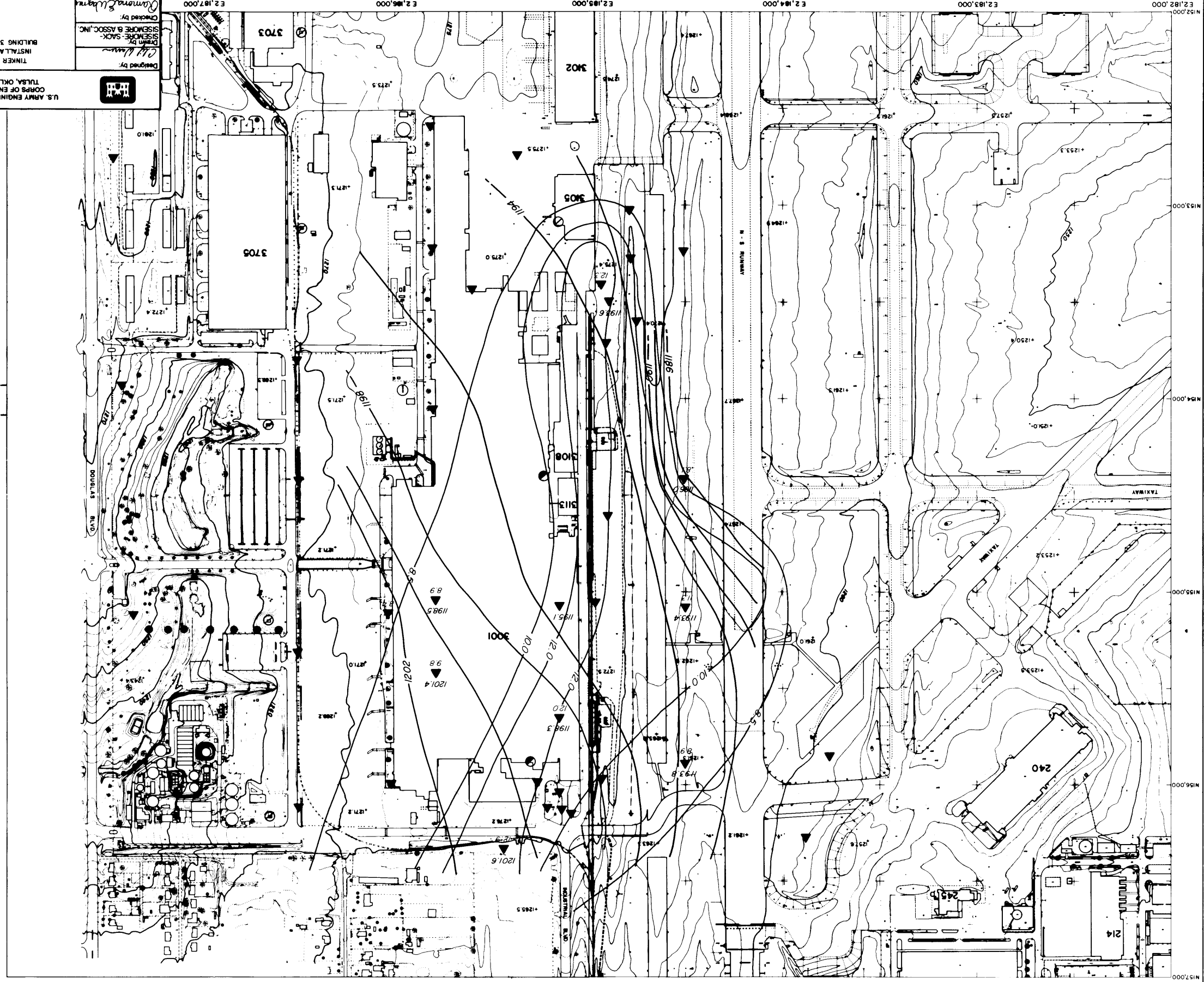
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

REGIONAL ZONE

TOTAL NI CONTOURS

Dwg. No. 36

Date: 30 JUNE 1987



LEGEND

- ▲ Monitoring well cluster
- ● Piezometer
- ⊘ - Water supply well
- ◐ Water supply well plugged
- 1198.5 Elev. of potentiometric surface
- —1200— Potentiometric contour
- 8.9 pH in monitoring well (S.U.)
- —10.0— pH contour (S.U.)

NOTE- Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

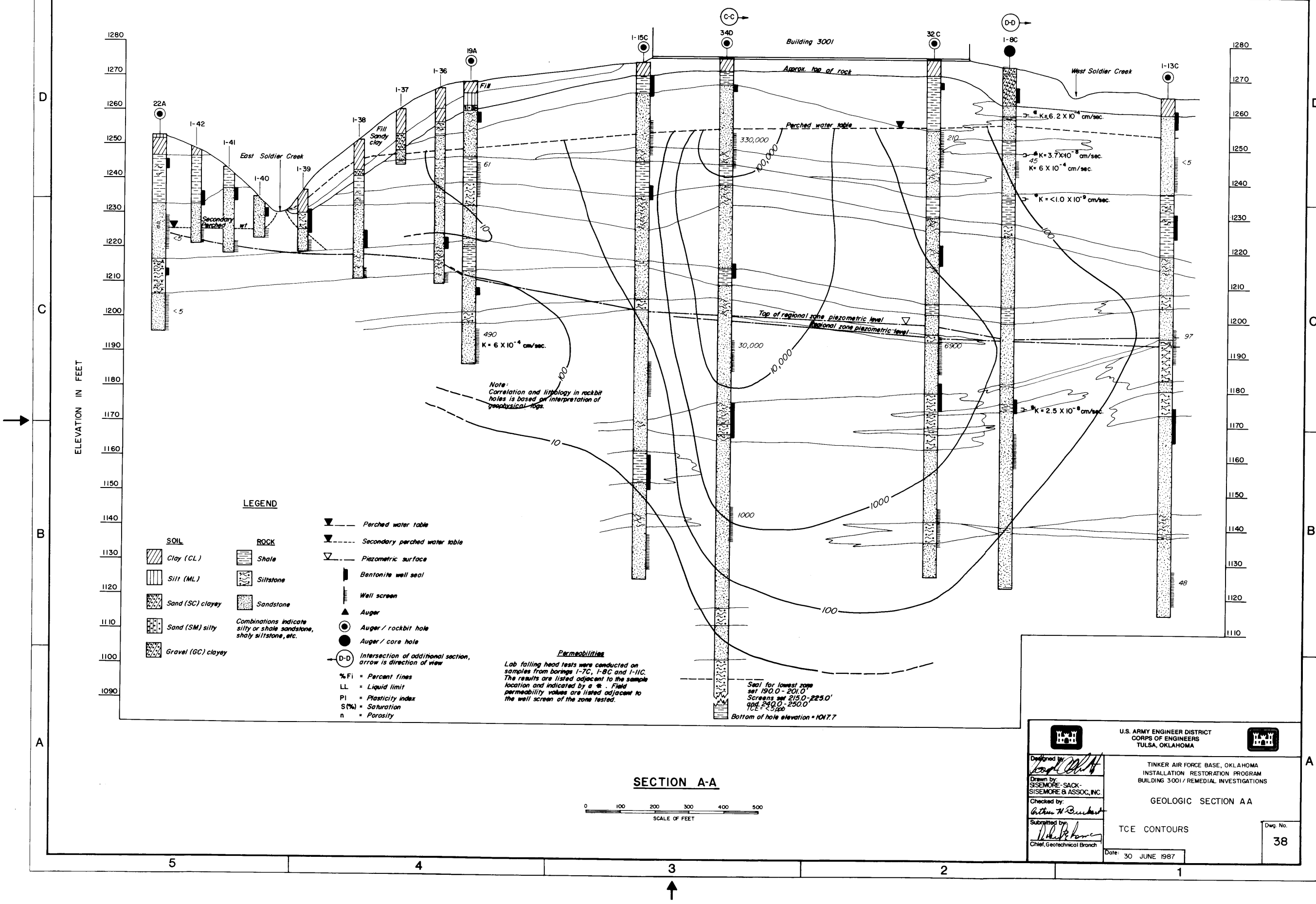
SCALE
100 0 100 200 300

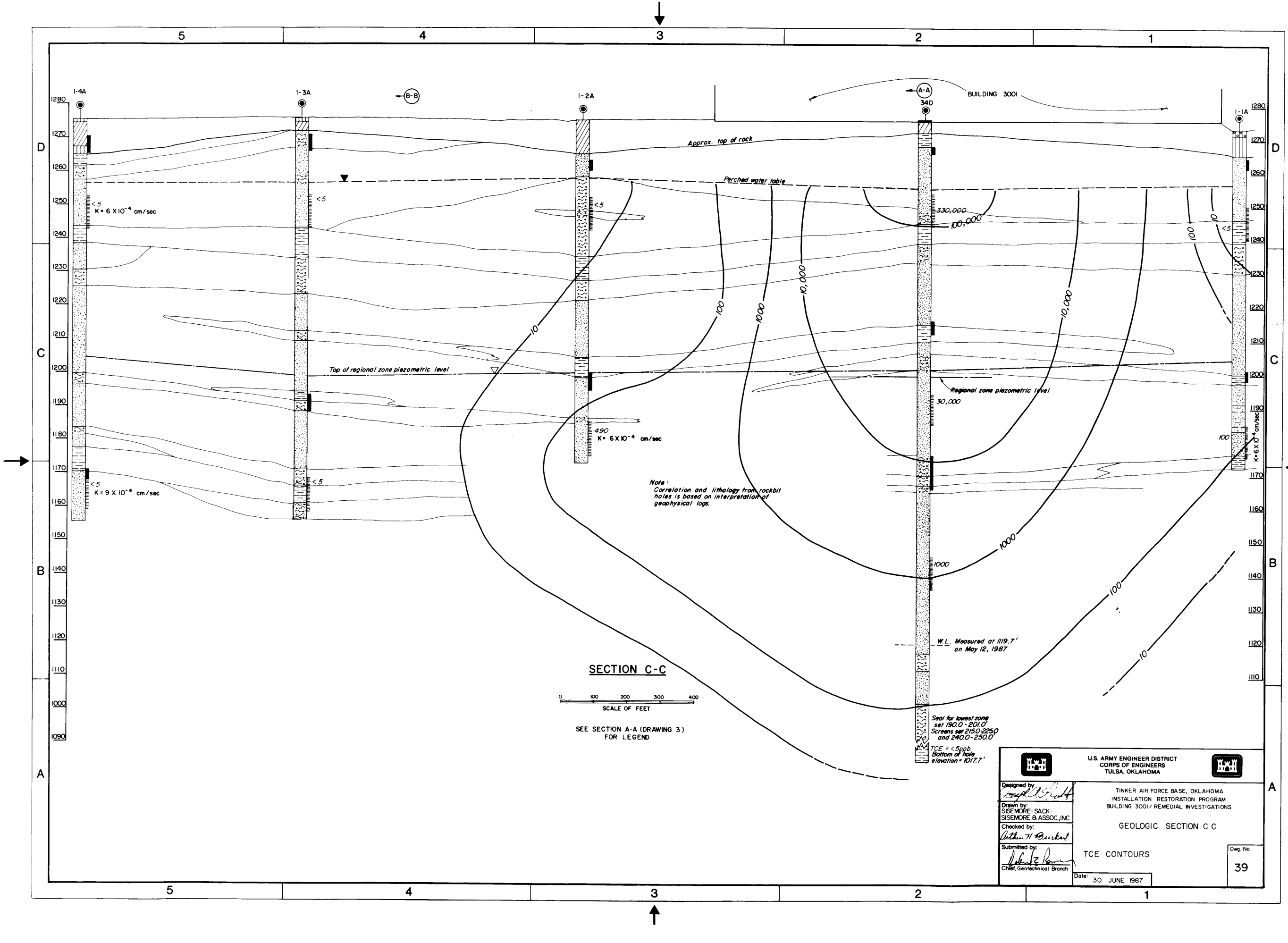
AIRFIELD ELEVATION 1292 FEET

N

Designed by:	TINKER AIR FORCE BASE, OKLAHOMA INSTALLATION RESTORATION PROGRAM BUILDING 3001 / REMEDIAL INVESTIGATIONS
Drawn by: SISEMORE-SAXON, SISEMORE & ASSOC., INC.	REGIONAL ZONE
Checked by:	pH CONTOURS
Submitted by:	Dwg. No. 37
Chief, Geotechnical Branch	Date: 30 JUNE 1987

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA


ELEVATION IN FEET
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
1120
1110
1100
1090
22A
I-42
I-41
I-40
I-39
I-38
I-37
I-36
19A
I-15C
34D
32C
I-8C
I-13C
Fill
Fill Sandy clay
East Soldier Creek
West Soldier Creek
Building 3001
Approx. top of rock
Perched water table
Secondary Perched wt
Top of regional zone piezometric level
Regional zone piezometric level
330,000
30,000
10,000
1000
100
10
61
490
K = 6 X 10⁻⁴ cm/sec.
K≤6.2 X 10⁻⁴ cm/sec.
K= 3.7X10⁻⁸ cm/sec.
45
K= 6 X 10⁻⁴ cm/sec.
K = <1.0 X 10⁻⁹ cm/sec.
K = 2.5 X 10⁻⁸ cm/sec.
210
6900
97
48
<5
Note:
Correlation and lithology in rockbit holes is based on interpretation of geophysical logs.
Seal for lowest zone set 190.0 - 201.0'
Screens set 215.0-225.0' and 240.0-250.0'
TOE = 250.0
Bottom of hole elevation = 1017.7
LEGEND
SOIL
Clay (CL)
Silt (ML)
Sand (SC) clayey
Sand (SM) silty
Gravel (GC) clayey
ROCK
Shale
Siltstone
Sandstone
Combinations indicate silty or shale sandstone, shaly siltstone, etc.
Perched water table
Secondary perched water table
Piezometric surface
Bentonite well seal
Well screen
Auger
Auger / rockbit hole
Auger / core hole
Intersection of additional section, arrow is direction of view
%Fi = Percent fines
LL = Liquid limit
PI = Plasticity index
S(%) = Saturation
n = Porosity
Permeabilities
Lab falling head tests were conducted on samples from borings I-7C, I-8C and I-11C. The results are listed adjacent to the sample location and indicated by a *. Field permeability values are listed adjacent to the well screen of the zone tested.
SECTION A-A
0 100 200 300 400 500
SCALE OF FEET
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA
Designed by:
Drawn by:
SISEMORE-SACK-SISEMORE & ASSOC., INC.
Checked by:
Arthur H. Burchard
Submitted by:
Chief, Geotechnical Branch
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS
GEOLOGIC SECTION A A
TCE CONTOURS
Dwg. No.
38
Date: 30 JUNE 1987



U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by:

Drawn by:
SISEMORE-SACK-
SISEMORE & ASSOC., INC.

Checked by:

Submitted by:
Chief, Geotechnical Branch

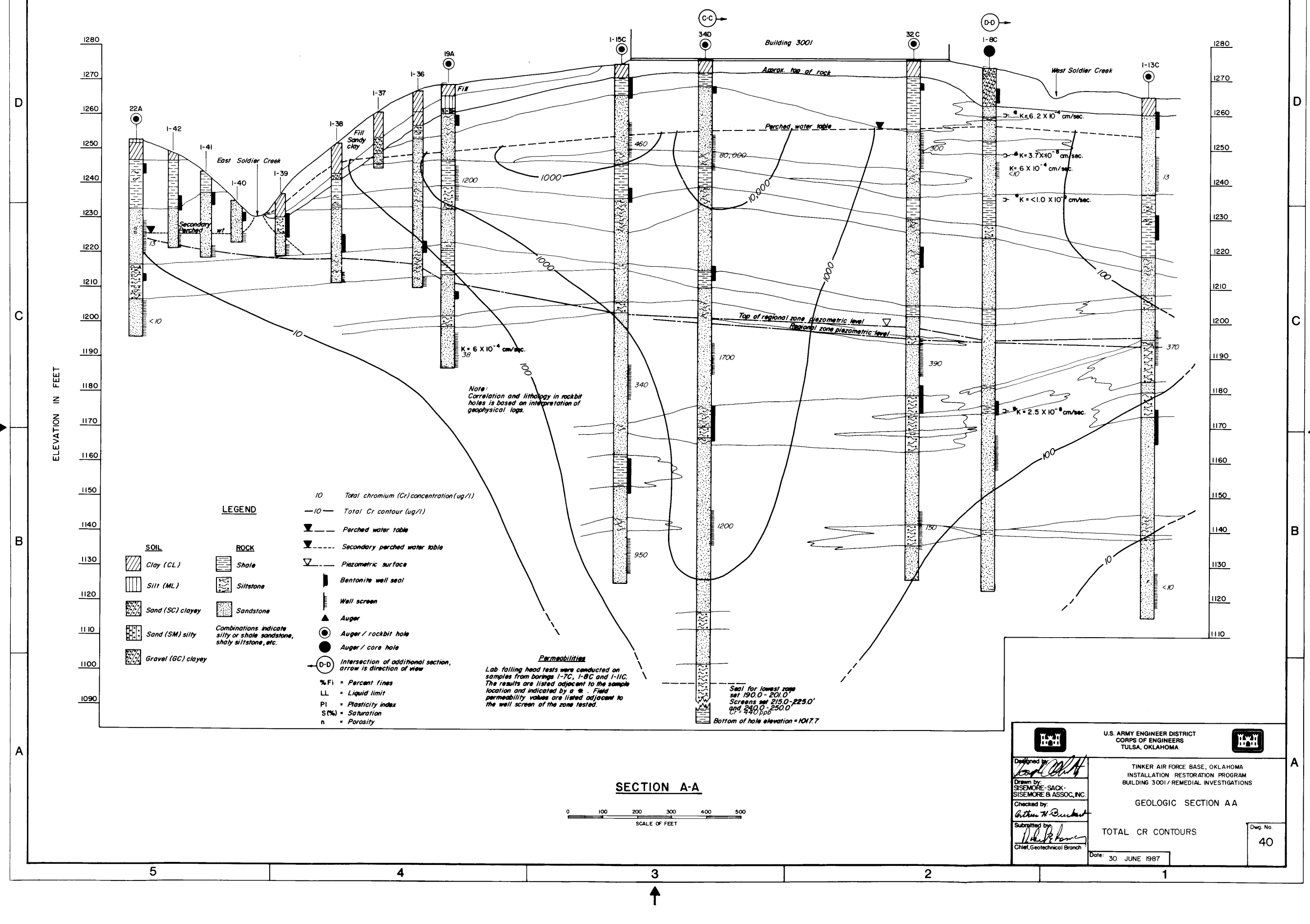
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

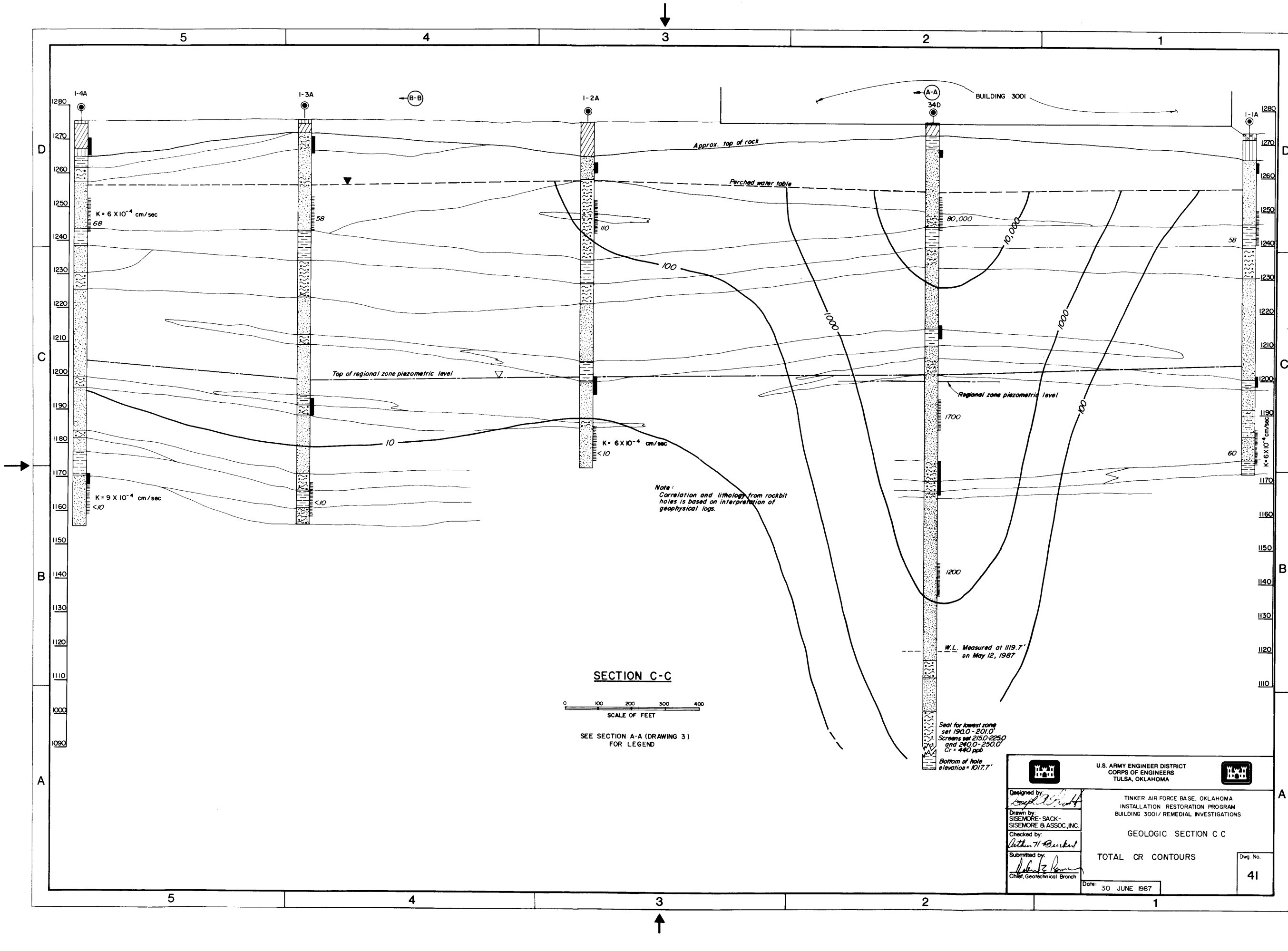
GEOLOGIC SECTION C C

TCE CONTOURS

Dwg. No. 39

Date: 30 JUNE 1987


C-C
D-D
22A
1-42
1-41
1-40
1-39
1-38
1-37
1-36
19A
1-15C
34D
32C
1-8C
1-13C
East Soldier Creek
West Soldier Creek
Fill
Fill Sandy clay
Building 3001
Approx. top of rock
Perched water table
Secondary Perched wt
Top of regional zone piezometric level
Regional zone piezometric level
K= 6 X 10⁻⁴ cm/sec.
K≤6.2 X 10⁻⁴ cm/sec.
K= 3.7X10⁻⁸ cm/sec.
K= 6 X 10⁻⁴ cm/sec.
K = <1.0 X 10⁻⁹ cm/sec.
K = 2.5 X 10⁻⁸ cm/sec.
Note:
Correlation and lithology in rockbit holes is based on interpretation of geophysical logs.
Permeabilities
Lab falling head tests were conducted on samples from borings 1-7C, 1-8C and 1-11C. The results are listed adjacent to the sample location and indicated by a ●. Field permeability values are listed adjacent to the well screen of the zone tested.
Seal for lowest zone set 190.0 - 201.0
Screens set 215.0-225.0' and 240.0-250.0'
U.T. = 440 ppb
Bottom of hole elevation = 1017.7
ELEVATION IN FEET
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
1120
1110
1100
1090
LEGEND
SOIL
Clay (CL)
Silt (ML)
Sand (SC) clayey
Sand (SM) silty
Gravel (GC) clayey
ROCK
Shale
Siltstone
Sandstone
Combinations indicate silty or shale sandstone, shaly siltstone, etc.
10 Total chromium (Cr) concentration (ug/l)
—10— Total Cr contour (ug/l)
Perched water table
Secondary perched water table
Piezometric surface
Bentonite well seal
Well screen
Auger
Auger / rockbit hole
Auger / core hole
D-D Intersection of additional section, arrow is direction of view
%Fi = Percent fines
LL = Liquid limit
PI = Plasticity index
S(%) = Saturation
n = Porosity
SECTION A-A
0 100 200 300 400 500
SCALE OF FEET
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA
Designed by:
Drawn by: SISEMORE-SACK-SISEMORE & ASSOC, INC.
Checked by:
Submitted by:
Chief, Geotechnical Branch
TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS
GEOLOGIC SECTION A A
TOTAL CR CONTOURS
Dwg. No. 40
Date: 30 JUNE 1987



SECTION C-C

0 100 200 300 400
SCALE OF FEET

SEE SECTION A-A (DRAWING 3) FOR LEGEND

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by:

Drawn by:
SISEMORE-SACK-SISEMORE & ASSOC., INC.

Checked by:

Submitted by:
Chief, Geotechnical Branch

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001 / REMEDIAL INVESTIGATIONS

GEOLOGIC SECTION C C

TOTAL CR CONTOURS

Dwg. No. 41

Date: 30 JUNE 1987