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ENGINEERING AND ENVIRONMENTAL SERVICES

DRAFT FINAL REMEDIAL INVESTIGATION REPORT

FOR

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS

PREPARED FOR

U.S. ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT

JOB No. 11-1530-0314
CONTRACT No. DACW41-92-D-9002
DELIVERY ORDER No. 0014

OCTOBER 1993
REVISED APRIL 1994

LAW
ENGINEERING AND ENVIRONMENTAL SERVICES

April 12, 1994

U.S. Department of the Army
Kansas City District, Corps of Engineers
757 Federal Building
601 E. 12th Street
Kansas City, Missouri 64106-2896

Attention: Mr. Rick Van Saun, CEMRK-ED-GN

Subject: **Revisions to the Draft Final RI Report for Southwest Funston Landfill**
Fort Riley, Kansas
Contract No. DACW41-89-D-0124
Delivery Order No. 0032, Modification No. P00013

Dear Mr. Van Saun:

Enclosed please find the Responses to Comments from KDHE and USEPA on the subject Draft Final RI Report and a set of replacement pages for the Draft Final RI Report. The replacement pages incorporate revisions to the document which were made to the report as a result of comments from the regulators. If you have any questions or comments on these submittals, please do not hesitate to contact us at (404) 499-6800.

Sincerely,

LAW ENVIRONMENTAL, INC.

Lee Ann Smith
Principal

Jeff A. Margolin
Project Scientist

LAS/JAM:mlh

Enclosures

1530.M13

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LAW
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October 29, 1993

Mr. Richard Van Saun
U.S. Department of the Army
Kansas City District, Corps of Engineers
757 Federal Building
601 E. 12th Street
Kansas City, MO 64106

Subject: Draft Final RI Report for Southwest Funston Landfill
Fort Riley, Kansas
Contract DACW41-92-D-9002, Delivery Order No. 0014

Dear Mr. Van Saun:

Law Environmental, Inc. is pleased to submit the Draft Final RI Report for Southwest Funston Landfill, Fort Riley, Kansas. This report has been prepared in accordance with the Scope of Work dated 12 August 1993, as clarified during the scoping meeting held in Kansas City on 20 August 1993.

The report distribution list is attached for your convenience. The Draft RI Report Responses to Comments are also enclosed, under separate cover, with this submittal.

If you have any questions or comments on this submittal, please do not hesitate to call. We can be reached at (404) 499-6800.

Sincerely,

Lee Ann Smith

Lee Ann Smith
Project Manager

Arthur J. Whallon, P.G.
Principal

LAS:mlh

1530.M12

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COMMENT RESPONSES

Draft Final Remedial Investigation Report
Southwest Funston Landfill (SFL)
Fort Riley, Kansas

Commentor: USEPA

Note: The USEPA did not provide numbered comments in their December 1, 1993, letter regarding the subject report. The comments cited below are from the second and third paragraphs of the referenced letter.

1. We find insufficient information presented in the report to support your assertion that Threemile Creek acts as a hydraulic boundary to groundwater flow from the landfill. Similarly, we are unable to concur that off-site transport of groundwater contaminants may occur solely via Three-Mile Creek or the Kansas River.

   R: The description of the site hydrogeology in the revisions to the Draft Final RI Report was modified to reflect the possibility of intermittent groundwater flow under Threemile Creek (Sections 3.6.2.2, 3.6.2.2.7, 3.6.2.3, 5.4.2.6, 7.1, and 7.2). The transport of SFL contaminants is more fully evaluated in Section 5.6 (new) that addresses similarities and differences in the concentrations and types of chemical constituents detected in the Camp Funston wells and their potential relationship to the chemical constituents detected in the SFL monitoring wells. A description of other potential sources of the chemical constituents is also included in the Report (Section 4.4).

2. We find significant deviations in the presentation of hydrogeologic information in comparing the Draft Final RI Report with the Draft RI Report. We are unable to find additional supporting data to rationalize these deviations.

   R: The presentation of the hydrogeologic information on the potentiometric maps in the Draft Final RI Report was modified from that presented in the Draft RI Report to represent the hydraulic condition formed by Threemile Creek and to reflect the impact of Threemile Creek and the Kansas River on the groundwater flow system in the SFL area. The presentation was modified upon analysis of groundwater level data from wells in the Camp Funston area. These data were not available during preparation of the initial conceptual model of the groundwater system in the SFL area. Because of the revised interpretation resulting from these additional data, the initial potentiometric maps of the SFL given in the Draft RI Report differ from the figures presented in the Draft Final RI Report (Figures 3-14, 3-15, 3-16, 3-17, 3-18, and 3-18a).

COMMENT RESPONSES

Draft Final Remedial Investigation Report
Southwest Funston Landfill (SFL)
Fort Riley, Kansas

Commentor: KDHE

General Comments

1. The text does not discuss analytical results of the Camp Funston off-site sampling in detail.

   R: The Draft Final Remedial Investigation Report has been revised to include an expanded analysis addressing similarities and differences in the concentrations and types of chemical constituents detected in the Camp Funston wells and their potential relationship to the chemical constituents detected in the Southwest Funston Landfill monitoring wells (Section 5.6).

   Volatile organic compounds were detected at six of the eleven Camp Funston wells sampled and analyzed for organics. Semi-volatile organic compounds were also detected at three of the eleven wells. Metals were detected at all 12 of the Camp Funston wells sampled and analyzed for inorganic constituents. Based on a comparison of constituents and concentrations detected, and considering the fate and transport processes affecting the detected constituents, it is unlikely that common anthropogenic sources exist for the inorganic compounds detected at both SFL and Camp Funston. A similar analysis for the organic compounds detected at both SFL and Camp Funston was inconclusive.

2. The argument for Threemile Creek acting as a boundary condition is partially contingent upon the reliability of the river stage data and the creek stage data for Threemile Creek which is questionable. The ground water system at SFL is complex and dynamic and the interpretation that a questionable shallow ground water "boundary" affects all flow (including deeper flow) within the aquifer is not plausible without additional hydrologic data off-site.

   R: The river stage data for the SFL area are considered to be reliable. The data were derived from stage data at the USGS Kansas River gage (USGS No. 06879100) using the calculations (Van Saun, 1993) presented in Appendix S of the Draft Final RI Report. The surveyed river elevations near SFL93-301 (referenced in the aforementioned calculations) were obtained with a standard survey level and stadia rod, using the previously surveyed datum elevation for

SFL92-301 as a control elevation. Elevation data for Threemile Creek were available only for the September 7, 1993 monitoring event, and were not necessary for other events for the presentation of Threemile Creek as a hydraulic boundary condition. While we concur that the groundwater system at SFL is complex and dynamic, the presentation of Threemile Creek as a hydraulic boundary condition for groundwater flow from the SFL site was based on consistent interpretation of measured groundwater elevations, measured surface-water elevations, and inferred surface-water elevations.

It is recognized that due to the effects of transient conditions in Threemile Creek and the Kansas River, groundwater flow under Threemile Creek could possibly occur under certain circumstances. However, it is highly likely that any such flow under Threemile Creek would subsequently be toward the Kansas River. Based on regional patterns of groundwater discharge to the Kansas River, it is unlikely that groundwater flow under Threemile Creek would continue for a substantial distance parallel to the Kansas River toward Ogden.

Sections 3.6.2.2, 3.6.2.2.7, 3.6.2.3, 5.4.2.6, 7.1, and 7.2 of the Draft Final RI Report were modified to acknowledge the possibility of groundwater flow under Threemile Creek.

3. Potentiometric maps drawn from data included in the Draft RI Report are incompatible with the maps drawn from the same data in the Draft Final. Figure 3-11 in the Draft does display the "boundary condition" illustrated in the potentiometric map of the same event (23 July 1992) utilizing the same data. No explanation is given for the discrepancy, nor is any reference made to the Draft map or conclusions. It appears the contours have been redrawn on the Draft Final map simply to corroborate the "boundary" interpretation of Threemile Creek. Data from the intermediate and deeper wells of clusters should also be presented for comparisons in the text for each event.

R: The presentation of the hydrogeologic information on the potentiometric maps was modified to represent the hydraulic boundary condition formed by Threemile Creek and to reflect the impact of Threemile Creek and the Kansas River on the groundwater flow system in the SFL area. The presentation was modified upon analysis of groundwater level data from wells in the Camp Funston area. These data were not available during preparation of the initial conceptual model of the groundwater system in the SFL area. Because of the revised interpretation resulting from these additional data, the initial potentiometric maps of the SFL given in the Draft RI Report differ from the figures presented in the Draft Final RI Report (Figures 3-14, 3-15, 3-16, 3-17, 3-18, and 3-18a).

The presentation of the site hydrogeology has been revised to incorporate a discussion of water levels measured in each well cluster and their significance in the interpretation of groundwater flow in the SFL area (Section 3.6.2.2). The groundwater level data in the well clusters do not reveal marked differences in hydraulic head, such as might be observed in multiple wells screened in differing unconfined, semi-confined, or confined aquifers. The lack of hydraulic head differences suggests common flow patterns among shallow and deeper sections of the aquifer system.

4. Regardless of Threemile Creek, off-site sampling at Camp Funston has shown that during a prolonged period of "reverse-flow" within the alluvial aquifer, no appreciable concentrations of constituents from the SFL appear to be moving towards Ogden. The hydraulic assessment of Threemile Creek as a boundary condition is not the crucial issue; rather whether or not constituents can or are being transported off-site towards potential receptors. The upshot of this conclusion (that potential ground water flow may be towards Ogden) is that future remedial actions should include continued off-site monitoring of the Camp Funston wells as an assurance that off-site migration is not occurring. Deeper monitoring wells off-site may be needed to monitor the deeper portions of the aquifer in which the Ogden public water supply wells are screened.

   R: Future groundwater monitoring is included as an alternative in the Feasibility Study. The components of that monitoring program will be defined, as necessary, in a separate monitoring plan document. No changes to the text of the Draft Final RI Report were made on the basis of this comment.

Specific Comments

1. Page 3-38. The text acknowledges that no confirmatory hydraulic characterization data exists for the streambed of Threemile Creek. Thus the relation of base flow to surface flow to the stream flow (whether the stream is gaining from or losing to the shallow ground water table) is unknown. It is difficult to determine the baseflow (ground water to surface water discharge) or loss (surface water loss to ground water) component relative to the surface water flow if no streambed hydraulic data exists.

   R: We concur that the magnitude of stream flow loss or gain is difficult to determine without streambed hydraulic characteristics. In addition, releases from upstream reservoirs to the Kansas River and releases by Fort Riley to the Threemile Creek drainage basin (such as wastewater discharges) interfere with stream flow measurements, making determination of baseflow or loss impractical. Of greater importance than the magnitude of flow through the streambed is the potential direction (i.e., stream flow loss or gain), which can be inferred from elevation differences between the stream and aquifer water levels. In a meeting held in Kansas City with representatives of CEMRK, LAW, KDHE, EPA, the U.S. Army, and the USGS in attendance, a USGS representative presented results of modeling which demonstrated that Threemile Creek could serve as a hydraulic boundary condition based on elevations even if the hydraulic conductivity of the streambed was lower than the hydraulic conductivity of the porous media of the shallow aquifer by a factor of 10. As the factor of 10 is believed to be a conservative estimate (i.e., a substantial conductivity divergence compared to conditions expected in the field), the presentation of Threemile Creek as a hydraulic boundary condition is considered to be reasonable. Therefore, no changes to the text of the Draft Final RI Report were made on the basis of this comment.

2. Page 3-40. The hydrologic assessment of SFL including Threemile Creek does not consider deeper aquifer flow; the recharge/discharge characteristics of Threemile Creek are representative of the shallow water table conditions. In many alluvial aquifer systems semi-discrete stratified sections display almost pseudo-confined conditions because of different flow patterns within coarser, deeper sections of the aquifer overlain by finer sediments with differing hydraulic properties.

   R: An examination of the groundwater level elevations observed in the well clusters does not reveal marked differences in hydraulic head, such as might be observed in multiple wells screened in differing unconfined, semi-confined, or confined aquifers. The lack of hydraulic head differences suggests common flow patterns among shallow and deeper sections of the aquifer system, and supports the interpretation that distinct aquitards or aquicludes are not present in the alluvial aquifer system. Revisions to Section 3.6.2.2 of the Draft Final RI Report include an examination of the groundwater level elevations.

3. Page 3-47. The use of 8 as a "fudge factor" in determining SFL elevations from the gage height is not explained. The "unpublished studies" referred to are not presented in the text or verified in any way. It is unclear whether the gage heights given in the text are surveyed to a similar degree of precision as the monitoring wells. Several of the potentiometric maps in the text are contingent on the reliability of the river stage data in contouring of the maps.

   R: As explained previously, the river stage data for the SFL area are considered to be reliable (see the Response to KDHE General Comment 2 for a description of the survey methods used to determine gage heights). The calculations (Van Saun,

1993) supporting the use of 8 as a factor in determining river elevation in the SFL area have been added to the Draft Final RI Report as Appendix S.

4. Figure 3-15. Again, this map, as Figure 3-14, diverges from the map presented in the Draft RI report for the same sampling event without any explanation.

   R: See the Response to KDHE General Comment 3.

DRAFT FINAL
REMEDIAL INVESTIGATION REPORT

FOR

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS

Prepared for:

U.S. Army Corps of Engineers
Kansas City District
601 East 12th Street
Kansas City, Missouri 64106

Prepared by:

Law Environmental, Inc.
Government Services Division
114 TownPark Drive
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OCTOBER 1993
REVISED APRIL 1994

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LIST OF ACRONYMS AND ABBREVIATIONS

AEHA	Army Environmental Hygiene Agency
AKAL	Alternate Kansas Action Level
AKNL	Alternate Kansas Notification Level
ARAR	Applicable or Relevant and Appropriate Requirements
ARCOM	Army Reserve Command
ASTM	American Society for Testing and Materials
AWQC	Ambient Water Quality Criteria
BCF	Bioconcentration Factor
BGS	Below Ground Surface
BOD	Biological Oxygen Demand
CAL	Corrective Action Levels
CEMRK	Corps of Engineers-Missouri River Division, Kansas City District
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
cfs	Cubic feet per second
CLP	Contract Laboratory Program
cm^2	Centimeter squared
cm/sec	Centimeters per second
CREAMS	Chemicals, Runoff and Erosion from Agricultural Management Systems
CSF	Carcinogenic Slope Factor
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DEH	Directorate of Engineering and Housing

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

DNAPL	Dense, Non-aqueous phase liquid
DOD	Department of Defense
DOT	Department of Transportation
DPDO	Defense Property Disposal Office
DQCR	Daily Quality Control Report
DQO	Data Quality Objectives
DRMO	Defense Reutilization and Management Office
ECD	Electron Capture Detector
EM	Electromagnetic
ER-L	Effects Range - Low
ER-M	Effects Range - Median
°F	Degrees Fahrenheit
FEMA	Federal Emergency Management Agency
FFA	Federal Facility Agreement
FID	Flame Ionization Detector
FS	Feasibility Study
FSP	Field Sampling Plan
GC	Gas Chromatograph
GC/ECD	Gas Chromatograph/Electron Capture Detector
GC/MS	Gas chromatography/mass spectrometry
gpm	Gallons per minute
HEAST	Health Effects Assessment Summary Tables
HELP	Hydrologic Evaluation of Landfill Performance
HRS	Hazard Ranking System
HSSWDS	Hydrologic Simulation on Solid Waste Disposal Sites
IAG	Interagency Agreement

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
K	Hydraulic Conductivity
KAL	Kansas Action Level
KDHE	Kansas Department of Health and Environment
KNL	Kansas Notification Level
kg	Kilogram
KGS	Kansas Geological Survey
KSNG	Kansas National Guard
Law	Law Environmental, Inc., Government Services Division
LENL	Law Environmental National Laboratory
LNAPL	Light, Non-aqueous Phase Liquid
m	Meter
MAAF	Marshal Army Air Field
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDL	Method Detection Limit
mg	Milligram
mg/L	Milligrams per Liter
msl	Mean Sea Level
MS/MSD	Matrix Spike/Matrix Spike Duplicate
n	Average Porosity in Percent
NCP	National Contingency Plan
ND	Not Detected (Above Method Detection Limits)
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List (Superfund List)

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

NTU	Nephelometric turbidity unit
O.D.	Outside diameter
PCBs	Polychlorinated biphenyls
PID	Photoionization Detector
ppb	Parts per billion
PPE	Personal Protective Equipment
ppm	Parts per million
PQL	Practical Quantitation Limit
PRC	Planning Research Corporation
PSF	Pesticide Storage Facility
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
RDA	Recommended Daily Allowance
RfC	Reference Concentration
RfD	Reference Dose
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RME	Reasonable Maximum Exposure
RPD	Relative Percent Difference
SARA	Superfund Amendments and Reauthorization Act of 1986
SCS	Soil Conservation Service
SFL	Southwest Funston Landfill
SM	Standard Method(s)
SOC	Site Operation Center
SWLO	Southwest Laboratory of Oklahoma

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

SWRRB	Simulator for Water Resources in Rural Basins
TBC	To Be Considered
TC	Top of Casing (Monitoring Well Casing)
TIC	Tentatively Identified Compounds
TKN	Total Kjehldal Nitrogen
TOC	Total Organic Carbon
TRPH	Total Recoverable Petroleum Hydrocarbons
UCL	Upper Confidence Limit
μg/kg	Microgram Per Kilogram
μg/L	Microgram Per Liter
USACA	U.S. Army Correctional Activity
USACE	U.S. Army Corps of Engineers
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USCS	Unified Soil Classification System
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UST	Underground Storage Tank
V	Velocity
VOC	Volatile Organic Compound
WWTP	Waste Water Treatment Plant
XRF	X-Ray Fluorescence

EXECUTIVE SUMMARY

Law Environmental, Inc. Government Services Division has been tasked by the United States Army Corps of Engineers to evaluate the nature and extent of suspected contamination associated with past operation of the Southwest Funston Landfill, Fort Riley, Kansas, and to prepare Remedial Investigation and Feasibility Study Reports for this site. This report is the Remedial Investigation which describes the field activities and selected physical site characteristics, results of the field activities and analytical results, the nature and extent of contamination, fate and transport of site-related constituents, and potential risks to human health and the environment from site-related constituents.

Southwest Funston Landfill is approximately 120 acres in size and is situated adjacent to the Kansas River and Camp Funston cantonment area. The landfill operated through a state of Kansas permit (No. 570) from the mid 1950s until its approved closure in 1981. The landfill handled domestic refuse generated as a result of activities at the Fort Riley military installation. Hazardous material, substances and wastes were also reportedly disposed in the Southwest Funston Landfill.

On August 30, 1990, Fort Riley was included on the National Priorities List. As a result of this listing, the Department of the Army, United States Environmental Protection Agency, and State of Kansas entered into a Federal Facilities Agreement designed to facilitate compliance of site investigations and remedial activities with the Comprehensive Environmental Response, Compensation, and Liability Act. The Federal Facilities Agreement required that a Remedial Investigation and Feasibility Study be conducted at the Southwest Funston Landfill.

Study Area Investigation

The Remedial Investigation field activities included geophysical surveys, soil gas survey, groundwater monitoring well installation and sampling, surface and subsurface soil sampling, and surface water and sediment sampling. The groundwater, soil, surface water, and sediment samples were analyzed by a Corps of Engineers' approved laboratory for volatile organics, semi-volatile organics, pesticides, polychlorinated biphenyls, herbicides, explosives, metals, total recoverable petroleum hydrocarbons, and selected inorganic analytes.

Hydrogeology

The Southwest Funston Landfill site hydrogeology consists of a shallow aquifer system within alluvial deposits of sand and gravel, with interbedded silts and clays, overlying shales and limestones. Water levels in the alluvial deposits fluctuate in response to seasonal variations in regional recharge, local conditions of infiltration, and variation of water levels in adjacent surface water systems. Groundwater levels at the site are generally at least 10 to 30 feet below land surface, depending on location, with periodic fluctuation in the range of about 5 to 10 feet.

The average direction of groundwater flow at the Southwest Funston Landfill site is toward the south-southeast and toward Threemile Creek and the Kansas River. However, widely variable flow directions have been observed during high river stages. The most likely pathway for off-site release of site-related constituents is via groundwater discharge to these stream features. Based on interpreted gradients and flow velocities, residence time within the site area is expected to range from seven years to hundreds of years.

Nature and Extent of Contamination

Organic constituents in the groundwater were detected in each of the eight monitoring well clusters during the four rounds of groundwater sampling. Most organic constituents were detected during the baseline sampling and were not detected in subsequent sampling events. Maximum Contaminant Levels and/or Kansas Action Levels were exceeded by detected concentrations of vinyl chloride, benzene, 1,1,2-trichloroethane, 1,1,2,2-tetrachloroethane, cis-1,3-dichloropropane, and 1,2-dichloroethane.

Metal constituents which were detected in the groundwater at concentrations that exceeded the secondary Maximum Contaminant Levels include manganese, iron, and aluminum. Antimony was the only metal constituent detected in excess of primary Maximum Contaminant Levels; it was detected once in the first quarterly sampling and once in the second quarterly sampling in different wells. The concentrations of manganese and iron detected in the groundwater at the Southwest Funston Landfill were comparable to naturally occurring concentrations of these constituents in alluvial wells throughout the Kansas River valley. Therefore, it is probable that these are not site-related constituents.

The surface water and sediment results indicate that the Southwest Funston Landfill is not contributing any organic constituents to either Threemile Creek or the Kansas River. Metals were detected in both upstream and downstream samples at comparable levels which are consistent with historical data for the Kansas River. Therefore, the landfill does not appear to be impacting these streams.

Fate and Transport

The dominant transport pathways of importance at the Southwest Funston Landfill include 1) groundwater movement towards the Kansas River and Threemile Creek and any episodic, high river-stage event that temporarily reverses groundwater flow away from the river or the creek along the southern and eastern boundary of the landfill; and 2) infiltration of rainwater through underlying waste and soils which would lead to the generation of leachate and contribute to groundwater contamination.

Metals and volatile organics in the groundwater result from percolation of rainwater through the landfill cover and underlying waste material as well as the upward migration of groundwater into additional waste material not normally saturated except during high water conditions in the river or aquifer. Migration of constituents off-site occurs primarily via groundwater discharge to the adjacent surface water bodies. However, there are no discernible, site-wide, contaminant plumes in the groundwater.

Baseline Risk Assessment

The site is an inactive, closed landfill which lies entirely within the 50- and 100-year floodplain of the Kansas River. Therefore, the only receptors expected to be on or adjacent to the site are occupational or recreational receptors. The risks to these receptors (utility worker, ground maintenance worker, and recreational hunters) are within the acceptable range of risks, as defined by the National Contingency Plan, for both noncarcinogenic and carcinogenic effects.

Future residential development of the site is not probable because the site lies within the floodplain and is located on an active military installation. However, because the state of Kansas considers the aquifer beneath the landfill to be a potential future potable water source, the potential risks to future residential users of this groundwater were estimated. The potential risks estimated for residential use of the groundwater were unacceptable (hazard index of 16 for adults; cancer risk of 5×10^{-4}). The primary site-related constituents contributing most to this risk are vinyl chloride, 1,1,2,2-tetrachloroethane, arsenic, and beryllium. Neither arsenic nor beryllium were detected at concentrations greater than their respective Maximum Contaminant Levels. It should be noted that, consistent with the Environmental Protection Agency's guidance for risk assessments at Superfund sites, the risk estimates for the groundwater pathways are very conservative and will tend to overestimate the potential risks.

Negative impacts on the flora and fauna of the area from site-related constituents are not readily apparent at this time. The only site-related constituents which were detected in Threemile Creek at concentrations greater than the Ambient Water Quality Criteria for the protection of aquatic life were iron and chloride. Potential adverse impacts on aquatic or terrestrial species utilizing this creek are expected to be minimal. Based on the flow rate within Threemile Creek, downstream surface water impacts are also not expected.

Conclusions

Based on the results of the Remedial Investigation and the Baseline Risk Assessment, it was determined that remedial actions to address the low-levels of volatile organics in the shallow, alluvial aquifer at Southwest Funston Landfill may be warranted. Several volatile organics were detected at concentrations greater than the Maximum Contaminant Levels and the risk assessment indicated potentially unacceptable risks if the groundwater were ever to be used as a potable water supply.

Remedial actions to address the metals in the groundwater at the landfill are not warranted because 1) none of the metals which contribute to the unacceptable risk estimates, except antimony, are present at concentrations which exceed primary Maximum Contaminant Levels, and 2) the levels of iron and manganese detected, which exceed secondary Maximum Contaminant Levels, are consistent with historical data for naturally-occurring metals in the alluvial groundwater of the Kansas River valley. Antimony was only detected once in two of the four groundwater sampling events in different monitoring wells (i.e., detected in less than five percent of the samples). Therefore, it is questionable whether antimony is a widespread, site-related constituent that warrants remediation. Continued monitoring to confirm the presence or absence of antimony in the groundwater may be warranted.

1.0 INTRODUCTION

Law Environmental, Inc., Government Services Division (Law) has been tasked by the United States Army Corps of Engineers (USACE) to evaluate the nature and extent of suspected contamination associated with past operation of the Southwest Funston Landfill (SFL), Fort Riley, Kansas, and to prepare Remedial Investigation/Feasibility Study (RI/FS) reports for this site.

Pursuant to Section 105 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Fort Riley was proposed for inclusion on the National Priority List (NPL) on July 14, 1989. Two sites at Fort Riley, the SFL and the Pesticide Storage Facility (PSF), were aggregated as one site by the U.S. Environmental Protection Agency (USEPA). The USEPA reasoned both contaminant sources potentially affected the same shallow aquifer and target populations. These two sites were finalized on the NPL on August 30, 1990, and were assigned a combined score of 33.79 on the USEPA's Hazard Ranking System (HRS) (USEPA, 1988c).

Subsequent to the NPL listing, the Department of the Army - Fort Riley, the USEPA, and the State of Kansas entered into a Federal Facility Agreement (FFA), also known as the Inter Agency Agreement (IAG), effective June 28, 1991. Under Section IX A, paragraph 2 of the agreement, the SFL is specifically addressed as a contaminant source (FFA, 1991). The objectives of the agreement are to:

- Ensure sites such as the SFL are investigated and appropriately remediated.
- Establish procedures and schedules.
- Develop, implement, and monitor appropriate response actions in accordance with federal and state laws.
- Facilitate cooperation and participation of the parties in the agreement.

1.1 PURPOSE OF REMEDIAL INVESTIGATION

The purpose of this project was to perform a Remedial Investigation (RI) that evaluated the nature and extent of chemical contamination consistent with Feasibility Study (FS) objectives. The RI program involved a sampling and analysis effort that will lead to the development of remedial action alternatives during the FS phase. The RI process encompassed several key elements necessary for selecting an appropriate remedial action.

The key elements necessary for selecting an appropriate remedial action include:

- Identification of federal and state Applicable or Relevant and Appropriate Requirements (ARARs).
- Development of Data Quality Objectives (DQOs) consistent with the ARARs and achievable with acceptable field and analytical procedures.
- Performance of a field investigation in one or more stages to collect sufficient information for evaluating contaminant movement and pathways and to support development of remedial action alternatives described in CERCLA and the National Contingency Plan (NCP).
- Evaluation of the direction and seepage velocity of groundwater movement in the vicinity of the landfill, especially in the context of characterizing the recharge/discharge relationship between the Kansas River and the shallow aquifer system.
- Evaluation of potential hazards by quantifying the impact on receptors through the pathways of surface water, groundwater, biota, and soil, and incorporating the exposure and risk assessment as required under CERCLA, the NCP, and the Superfund Amendments and Reauthorization Act of 1986 (SARA), and as defined in the USEPA's "Risk Assessment Guidance for Superfund."
- Identification of sites where the results of the field investigation and risk assessment indicate no significant threat to human health or welfare or to the environment and preparation of a decision document identifying any necessary control measures, or no need for further action.

1.2 SITE BACKGROUND

This section contains a description of the SFL site as follows:

- Installation and SFL site description
- A brief history of Fort Riley
- Site-specific history of the SFL site
- A discussion of previous investigations

1.2.1 Site Description

The Fort Riley Military Installation is situated along the north bank of the Kansas and Republican Rivers in Riley and Geary counties in north central Kansas (Figure 1-1), near the cities of Manhattan, Ogden, Junction City and Grandview Plaza, Kansas. Respective populations of Fort Riley and these cities are as follows:

COMMUNITY	POPULATION	SOURCE
Fort Riley	17,164	1990 Economic Impact Survey
Manhattan	37,712	Assistant Director of Planning, Manhattan
Ogden	1,500	City Clerk, Ogden
Junction City	21,000	Deputy City Clerk, Junction City
Grandview Plaza	1,266	City Clerk, Grandview Plaza

The installation comprises about 150 square miles (101,000 acres) and is located between two major surface water reservoirs: Tuttle Creek Lake constructed in 1962 and Milford Lake constructed in 1965. Troop housing and support facilities are in the southern portion of Fort Riley and consist of the Main Post, Camp Forsyth, Custer Hill, Camp Whitside, Camp Funston, and Marshall Army Air Field. The remainder of the installation consists of troop/family housing, numerous training areas, gunnery complexes, small arms firing ranges, drop zones, tank trails, and an impact area used for live fire artillery.

The SFL is in the southern portion of Fort Riley, adjacent to the southwest corner of the Camp Funston cantonment area (Figure 1-1). The inferred limits of the SFL extend from the north bank of the Kansas River north to near Well House Road, and east from the old Kansas River Channel to just west of Threemile Creek (Figure 1-2). The two landfill boundaries shown on Figure 1-2 are similar though derived from different sources. The Army landfill boundary (approximately 118 acres) is shown on correspondence in Ft. Riley's Directorate of Engineering and Housing (DEH) files from 1980. The boundary inferred from the magnetometer survey (approximately 123 acres) represents the limits of metallic debris. The magnetometer survey is discussed in Sections 2.1.4.1 and 3.4.1. The nearest surface-water impoundment to the SFL is Whitside Lake, an oxbow lake located about 0.5 miles northwest of the SFL site. This oxbow lake was part of the Kansas River channel prior to the 1951 flood which changed the course of the Kansas River. When the Kansas River flooded, it bypassed the channel segment now known as Whitside Lake.

The landfill is presently covered with vegetation and displays little topographic relief compared to the surrounding land surface. In some areas, surface erosion is exhibited as rills and channels, resulting in partial removal of soil cover material. The landfill may have up to 2 feet (0.6 meter) of soil cover, a portion of which is comprised of backfill soil obtained from rifle ranges just north of the site.

FIGURE 1-1

SOUTHWEST FUNSTON LANDFILL LOCATION MAP

FORT RILEY, KANSAS

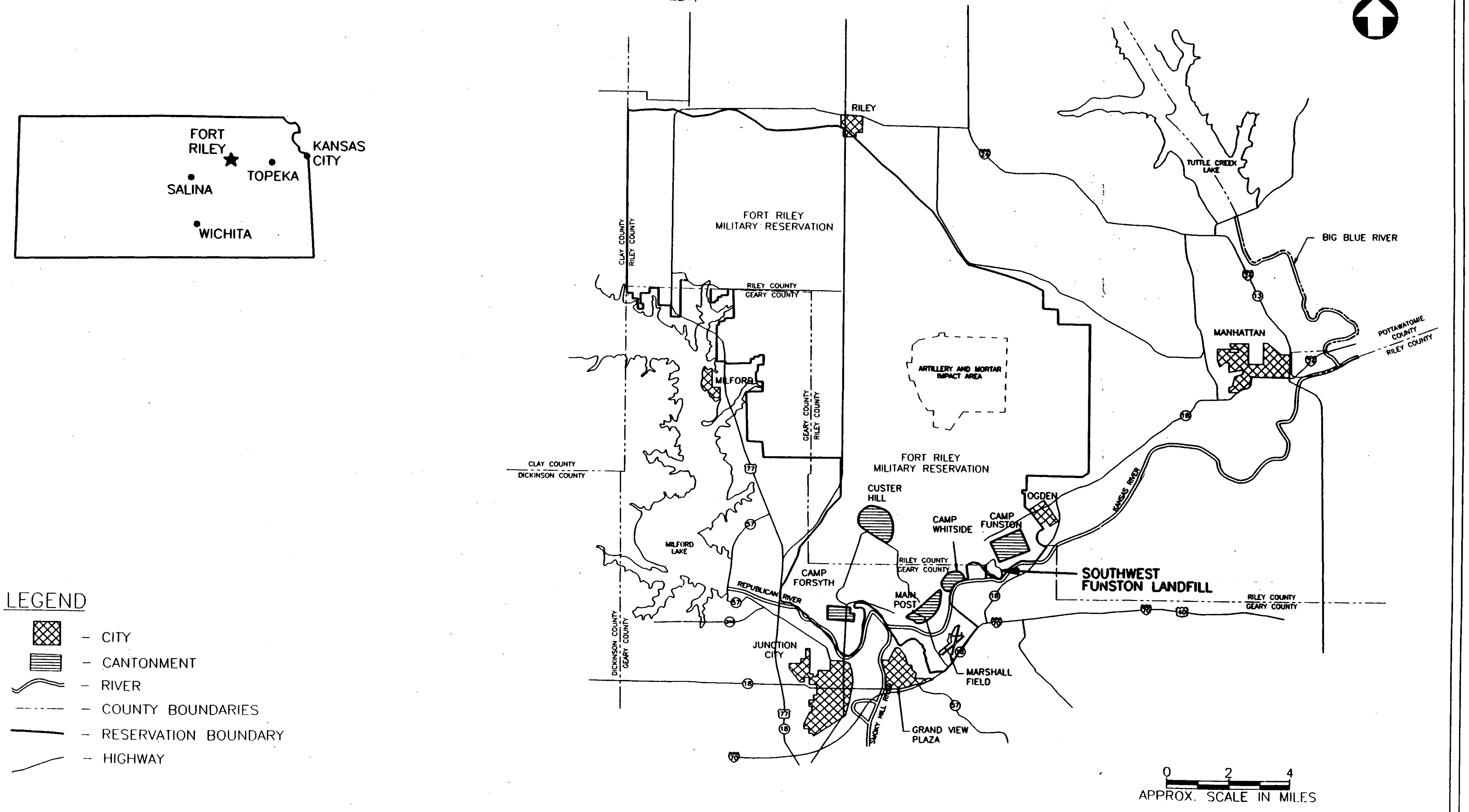
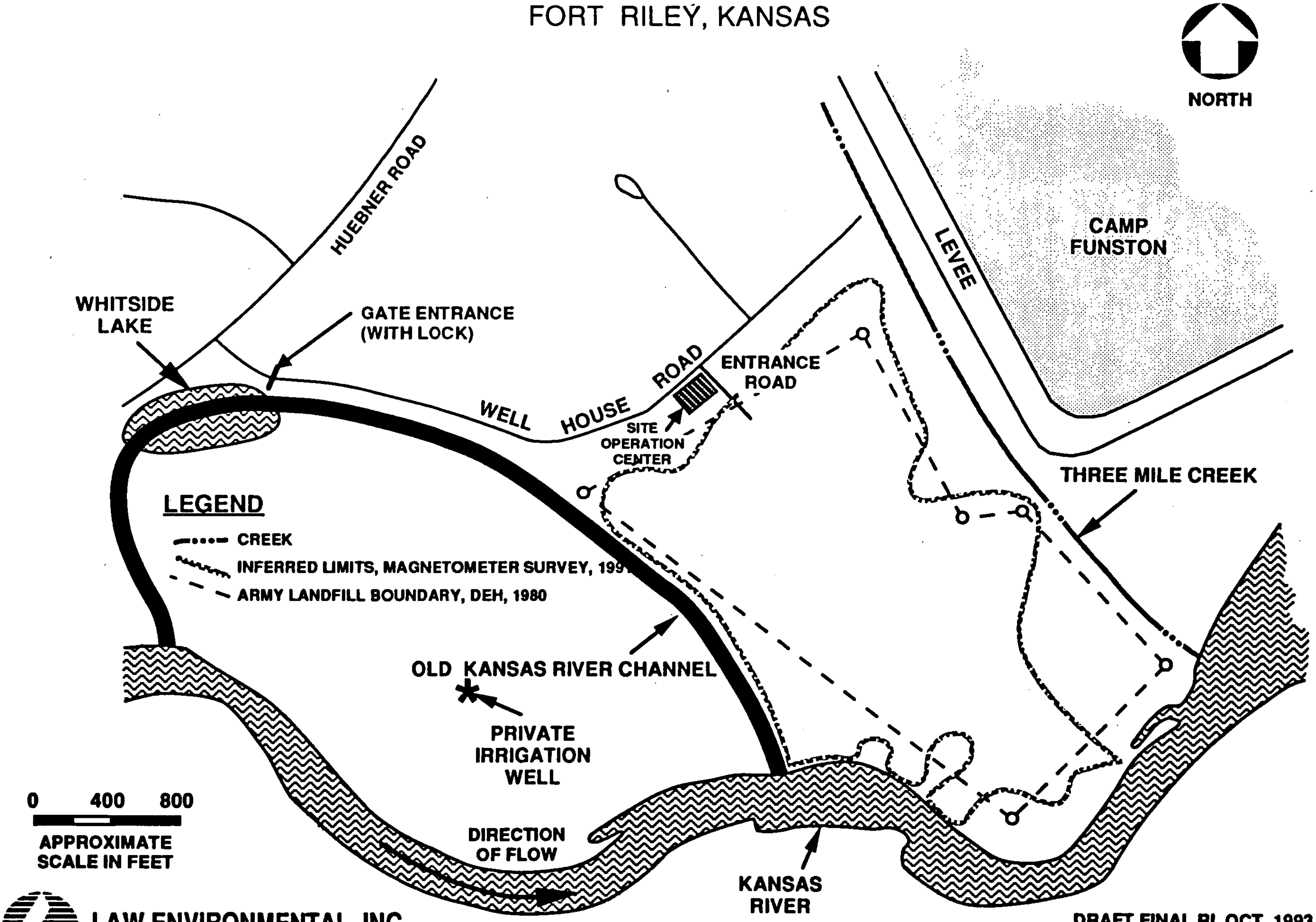


FIGURE 1-2

GENERAL VICINITY MAP

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS



During a site visit in March 1990, construction debris was observed on the surface of the landfill and along the banks of the Kansas River. Construction debris was also visible through the cover material. Depressions of up to 1.5 feet were observed and are assumed to be the result of settlement of soil cover at some of the former disposal trenches. Surface water has been observed in some of these depressions and no predominant drainage pathways exist at the site. Numerous holes, approximately 6 inches in diameter, presumably dug by small animals, have also been observed in and adjacent to the now filled-in but depressed trenches.

Access to the SFL area is restricted by a locking gate on Well House Road, a short distance south of Huebner Road (Figure 1-2), but pedestrian entry to the site may be gained by walking around the gate. Although the area north of Well House Road is officially designated for training, recent use is not evident. A small, occasionally-used borrow area (soil excavation) is northeast of Well House Road, a short distance inside the gate. Hunting has previously been allowed in this area but was restricted in 1991. However, the area north of Well House Road was reopened for deer hunting in the fall of 1992 (DEH, 1992c).

1.2.2 Site History

A site history investigation of the installation, including a literature search and research of the landfill's history, was performed. The results of this study are described in this section. The study included review of readily accessible, existing file information and interviews with selected former and current installation staff, Fort Riley contractors, and private individuals, who possessed specific knowledge concerning the SFL site. During this task, it was noted that general file maintenance procedures require periodic purging of files and therefore existing files contained very little historical data.

1.2.2.1 Installation History - In response to the need for military protection resulting from westward expansion of civilian populations in the 19th Century, Fort Riley was established in 1852 as a small outpost near the confluence of the Republican and Smokey Hill rivers. The development and growth of Fort Riley proceeded in response to the evolution of the American military mission, including development of tactics and acquisition of equipment during the Indian conflicts of the last half of the 1800s, the Spanish American War, World Wars I and II, and the Korean, Vietnamese, and Persian Gulf engagements.

Since its inception, Fort Riley has continually served as a major center of military education and readiness, at times comprising a population of more than 20,000 military residents and civilian employees. The Fort Riley reservation has historically functioned both as a small municipality and light industrial complex. Solid waste disposal (landfilling), wastewater treatment and discharge, facilities maintenance and construction, pesticide and herbicide usage, and electrical equipment installation, storage, and repair, are among the environmentally significant municipal activities at Fort Riley. Fort Riley's function as a military training, equipment supply, and maintenance center has historically required management and disposal of wastes associated with these activities. Maintenance activities associated with rotary and fixed-wing aircraft, and tracked and wheeled vehicles have occurred at the Fort Riley installation.

1.2.2.2 Landfill History - The SFL operated from the mid-1950s until 1981 under a "grandfathered" Kansas Department of Health and the Environment (KDHE) permit (No. 370). Documented landfill operations ceased in 1981. A KDHE letter dated October 25, 1983, states "... closure plan (F5-00157-1-J) was approved on August 9, 1982." This letter is provided in Appendix A. No record of an approved final report has been located (KDHE, Wilson and Company, 1992). However, the KDHE letter also states that SFL was "... closed in an acceptable manner" (KDHE, 1983). The plan included installation of six groundwater monitoring wells, topographic regrading, and the application of a continuous soil cover (KDHE, Wilson and Company, 1992).

The SFL is one of seven documented landfills at Fort Riley. Waste generation at Fort Riley reflects installation activities from the Civil War to the present. Most of the information regarding the sources and quantities of waste delivered to the SFL was obtained from two previous studies: (1) Installation Assessment Report [U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), 1984] and (2) Hazardous Waste Management Consultation [U.S. Army Environmental Hygiene Agency (USAEHA), 1989].

Many operations exist at Fort Riley. Military operations and support activities at the installation which generated waste during the SFL period of operation include, but are not limited to:

- Vehicle maintenance shops
- Vehicle wash racks
- Aircraft maintenance shop
- Print shop
- Furniture restoration shop
- Painting facilities
- Pathology, radiology, veterinary, and dental clinics
- Photography laboratories
- Oil analysis laboratory
- Pesticide/herbicide storage and preparation
- Laundry and dry cleaning facilities
- Former Fire Training Area
- Wastewater Treatment Plants
- Troop housing
- Family housing

- Administrative functions
- Commissary/PX stores
- Supply/Warehousing

Large volumes of typical municipal wastes such as domestic garbage and construction debris, and probably material normally found in waste streams of the various military and support activities were also disposed in the SFL. Most wastes generated and disposed on post were domestic refuse and sewage sludge from the wastewater treatment facilities. However, increasing mechanization of the Armed Forces caused an increase in the amount of petroleum products and solvents used and disposed in the landfill. According to the Installation Assessment Report, liquid wastes generally were not segregated in the landfill (USATHAMA, 1984). Spent solvents were mixed with waste oils and contaminated fuels and were disposed by dumping them into the SFL. Also, solvent soaked rags and containers from the furniture stripping shop and print shop and paint stripping sludge and containers were disposed in the landfill. As noted in an informal communication with Fort Riley (IRP Manager, 1992) material stored/disposed of on the surface of the SFL included: neatly stacked drums (no size estimate noted), scrap metal(s), and construction material debris. This communication further states that the "southwest side [is the] location of a lot of roofing/building materials - potentially containing asbestos."

Although wastes were not always segregated in the landfill, field observations and review of historical photographs suggest that material conducive to erosion control (such as construction debris and discarded heavy appliances) were segregated and placed along the bank of the Kansas River. On occasion, material was burned in the trenches, sometimes creating below grade fires (President, Harris Refuse Company, 1992). Additional information from the Section Chief, Environmental Division, DEH indicates trash and wood wastes were also burned in windrows (DEH, 1992d). The combustible waste consisted of building construction waste, tree stumps, trunks and limbs, wooden ammunition boxes, etc. These wastes/residue, once burned, were placed into trenches and covered with soil. Interviews did not provide information as to the frequency of these burnings.

Scrap metal that was brought to the SFL rather than the Defense Reutilization and Management Office (DRMO) [formerly Defense Property Disposal Office (DPDO)] was placed in a large pile (DEH, 1993f). The DPDO at times would conduct a spot sale of this scrap metal. The material not sold was placed in trenches and covered with soil. Finally, during the SFL period of operation (mid 1950's to 1981), waste oil was sold by the DPDO to a contractor who picked it up and hauled it away (DEH, 1993f).

The President of Harris Refuse Company, Salina, Kansas, stated in a personal interview that during the first 15 years of operation, the SFL was managed by a private contractor. Both landfarming and trench disposal methods were used in the landfill during this time. Trenches were excavated approximately 16 feet below ground surface (President, Harris Refuse Company 1992). A preliminary report issued by the Army Environmental Hygiene Agency (AEHA), issued May 11, 1977, states:

> "Landfill contractor personnel reported that water [groundwater] occasionally seeps into the working trenches at a depth of about 20 feet when the river [Kansas] is high. To minimize production of leachate which could pollute the groundwater, trench depths should be reduced to 12 to 15 feet."

In 1970, Harris Refuse Company was under contract to manage and operate the SFL. Harris Refuse Company continued to manage the SFL until January 1981 (President, Harris Refuse Company, 1992). No specific data exists which record the waste types disposed in the landfill during this time. Trucks hauling "trash" were not weighed before or after dumping. All trucks belonging to Harris Refuse Company were assumed to be of a certain cubic yardage capacity. The weight was then estimated by multiplying the capacity by a conversion factor. The weight of non-contractor trucks was also estimated in this fashion. In addition, no documentation exists to identify or manifest the waste type (DEH, 1993f).

Aerial photographs of the SFL site have been reviewed and indications of landfilling activities noted. An undated photograph, presumed to have been taken before the 1951 flood, shows the main channel of the Kansas River forming a bend which runs north to south along the western border of the present SFL (Figure 1-3). During the 1951 flood, the Kansas River formed a cut-off channel which isolated the bend (oxbow) from the main flow. The old channel has since filled with sediments and revegetated. Water bodies (oxbow lakes) were seen in the photograph (Figure 1-3) which may represent remnant channel locations from even earlier events. Linear features running both north-south and east-west are also prevalent. These features appear to be related to surface activities, such as mowing or grading. The four Funston well houses can also be seen on pre-1951 photographs.

A December 1954 aerial photograph (flight altitude approximately 6,000 feet) showed numerous signs of surface activities, including roads, cleared areas, a building, and a water-filled pit possibly related to a sand pit operation (Figure 1-4). There is no indication that this apparent pit is related to any landfilling operations. Granular materials (sand and gravel) were present in the well log for closure well no. 2 (Appendix C), which is located near this pit. The surface features north of Well House Road are presumed to be associated with tracked vehicle military training activities. No signs of landfilling related activities were seen in the 1954 photograph.

A March 1960 aerial photograph (flight altitude approximately 6,000 feet) displayed a developed road in the northern portion of the SFL site, leading to the southwest corner of the landfill and terminating at an area of activity possessing a single open trench (Figure 1-5). The signs of activity north and south of Well House Road previously described for the 1954 photograph were obscured by vegetation, indicating lack of usage. Also seen on the photograph are five northwest-southeast oriented excavation features. The sites of these excavations were visually inspected during a November 1991 reconnaissance and no visible evidence of landfilling activity was present at that time. Personal communications with DEH personnel suggest that these features may have been formed from local personnel excavating soil for private use.

FIGURE 1-3

PHOTOGRAPHIC INTERPRETATION-CIRCA 1951

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS

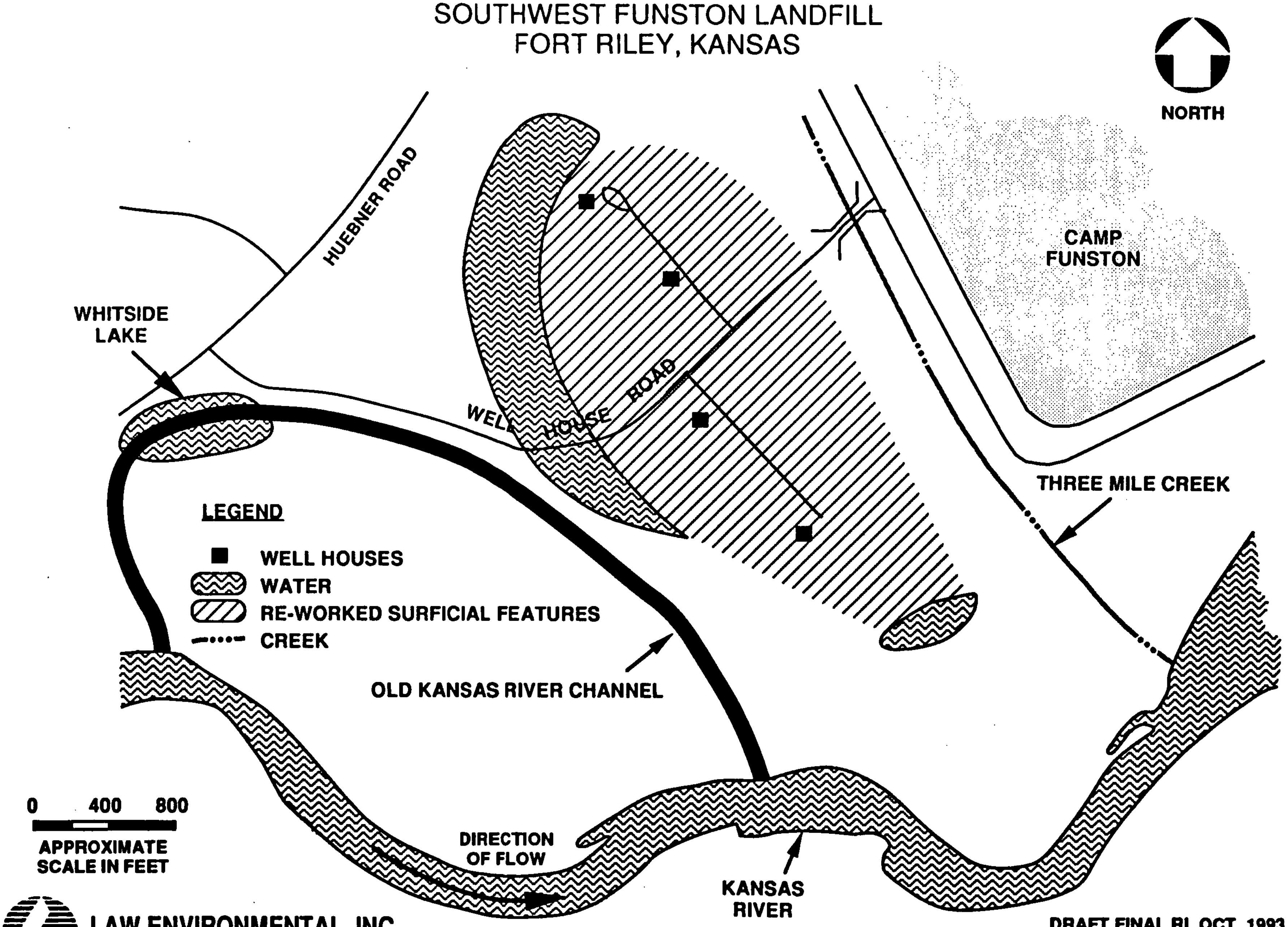


FIGURE 1-4

PHOTOGRAPHIC INTERPRETATION-1954

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS

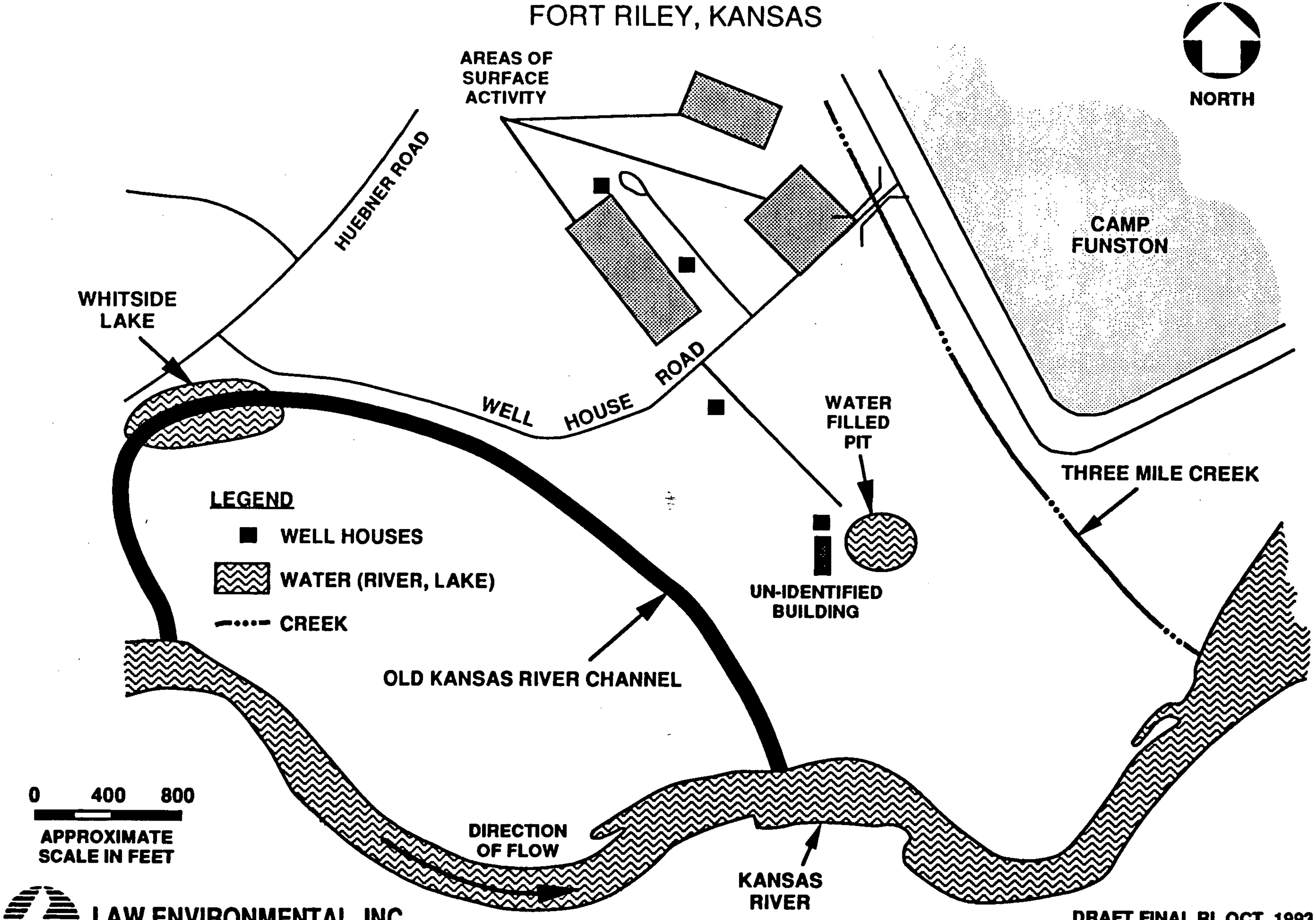


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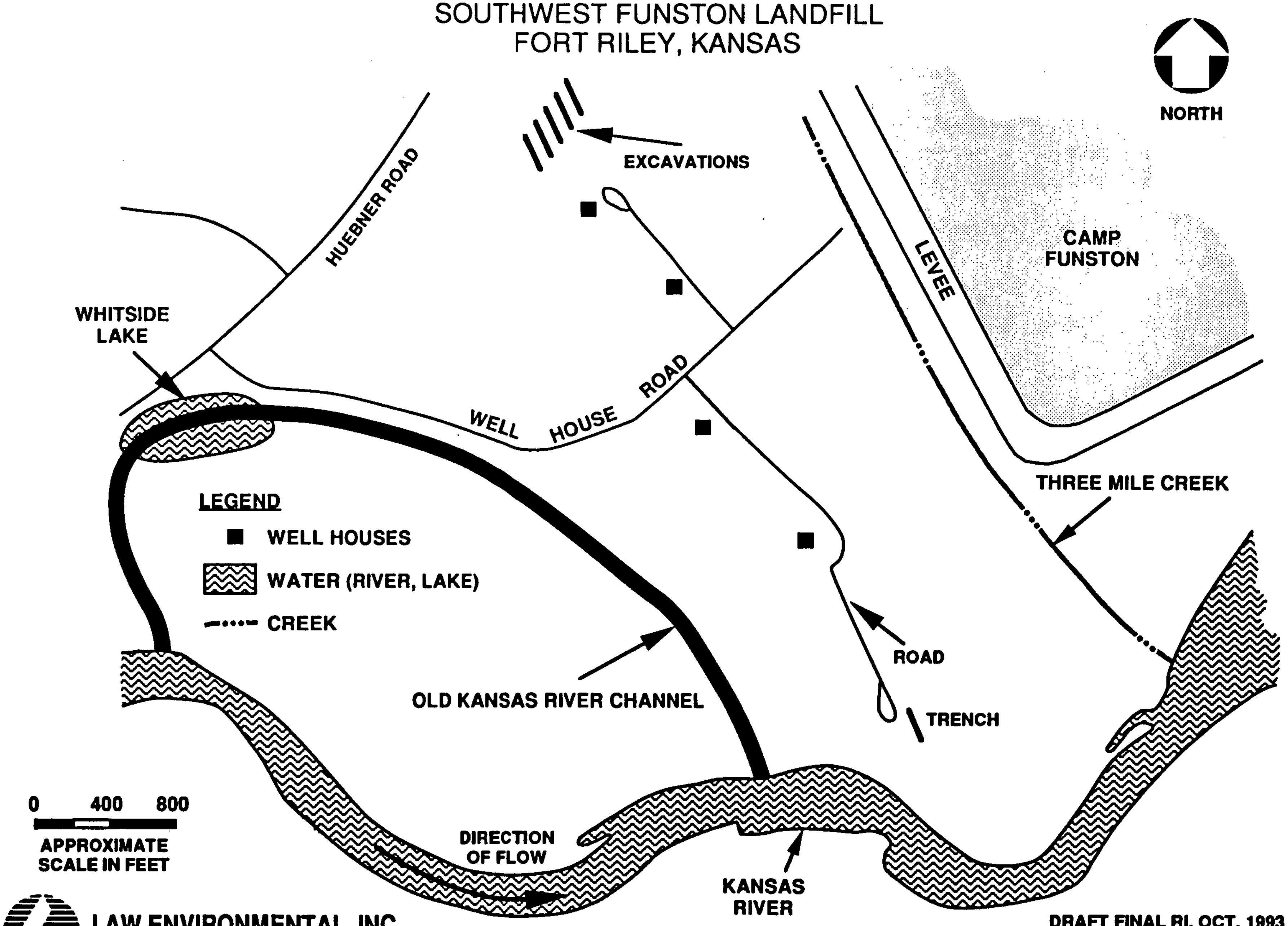
FIGURE 1-5

PHOTOGRAPHIC INTERPRETATION-1960

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS



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Several trenches could be seen in a March 1971 aerial photograph (Figure 1-6). These trenches were located in the west-central to east-central portions of the landfill. Another trench could be seen near the southern border of the SFL adjacent to the river bank. Apparent debris piles were situated along the banks of the old channel near its confluence with the Kansas River. Fire training pits were observed adjacent to Well House Road at Threemile Creek. A building, identified as a gas chamber training building, was located north of the trenches in the west-central portion of the landfill. The Installation Assessment Report for Fort Riley does not specifically state that a gas chamber training building was located at the SFL, however, file drawings from the DEH (drawing no. 18-02-05, Dec. 1970) do identify a gas chamber building on the SFL as shown on Figure 1-6. The report mentions the use of o-chloro-benzyliodene malononitrile (tear gas) in the gas chamber training areas. Existing documentation does not describe how often these training chambers were used nor the operating procedures. Typical gas chamber operating procedures encompass releasing tear gas in the building and having personnel enter the building wearing gas masks, remove the gas masks once in the building, and then leave the building after the eyes tear.

From a series of low altitude aerial photographs taken in February 1972, at least six open trenches were seen in an area adjacent to the river bank in the southwest portion of the landfill. According to documentation provided with the photographs and personal communications with a former Wastewater Treatment foreman, these trenches contained oil and grease. Several debris piles, generally less than 500 square feet in area, were scattered throughout the southern portion of the landfill.

A July 1976 aerial photograph (flight altitude approximately 6,000 feet) displayed large areas of barren ground landfilling activity in the northwest corner of the SFL area and in an additional area extending in a band (approximately 200 feet wide) from the center of the landfill to the east boundary. The former Fire Training Area also displayed signs of surface activity (Figure 1-7).

1.2.3 Previous Investigations

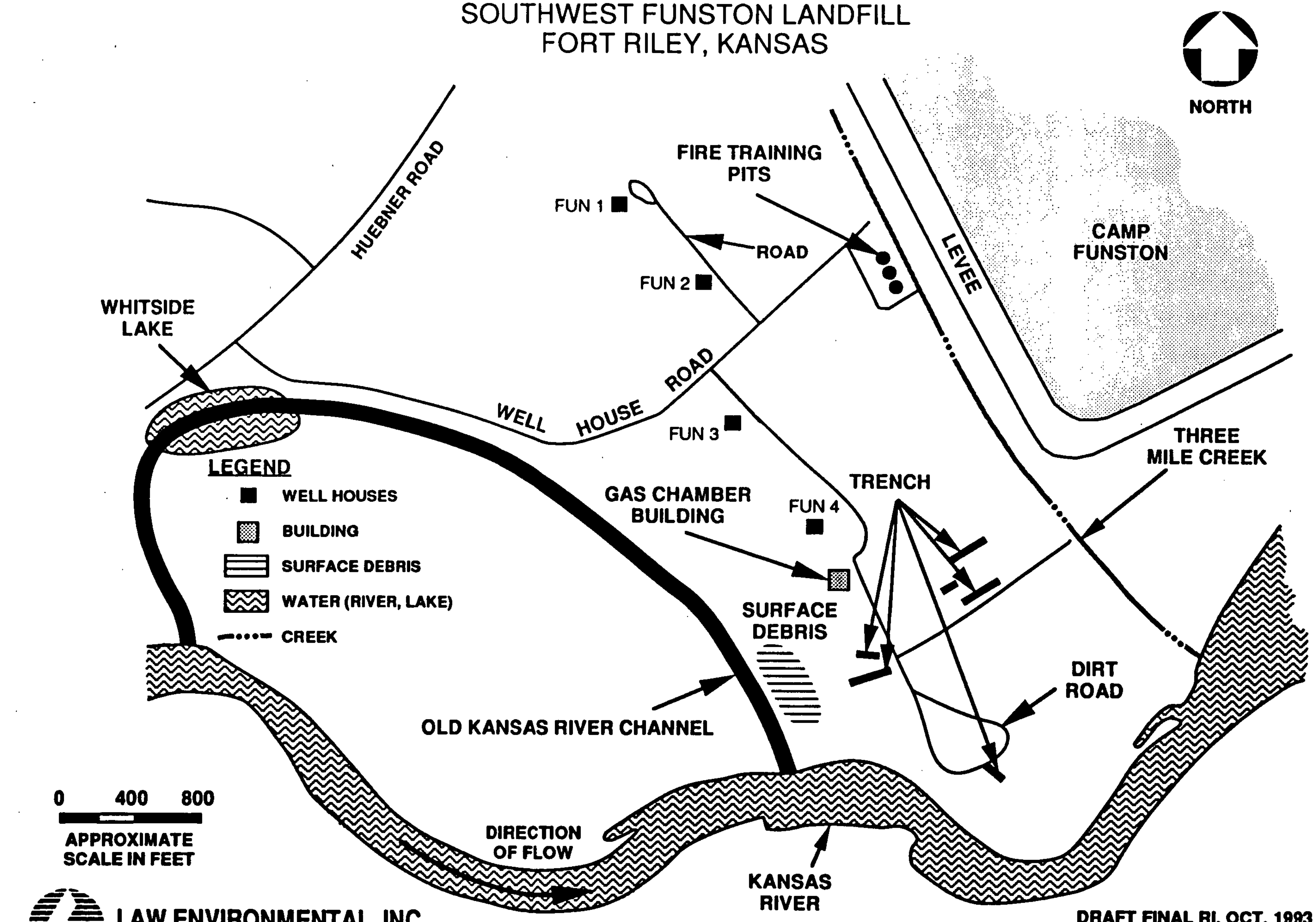
A review of data generated from previous investigations (and summarized in Section 4.0) has been performed. These investigations were examined for:

- Field methodology and procedure
- Accuracy and completeness of field records
- Laboratory data, methodology, and Quality Assurance/ Quality Control (QA/QC)
- Physical and chemical field data
- Comparability of data
- Recommendations and conclusions

FIGURE 1-6

PHOTOGRAPHIC INTERPRETATION-1971

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS



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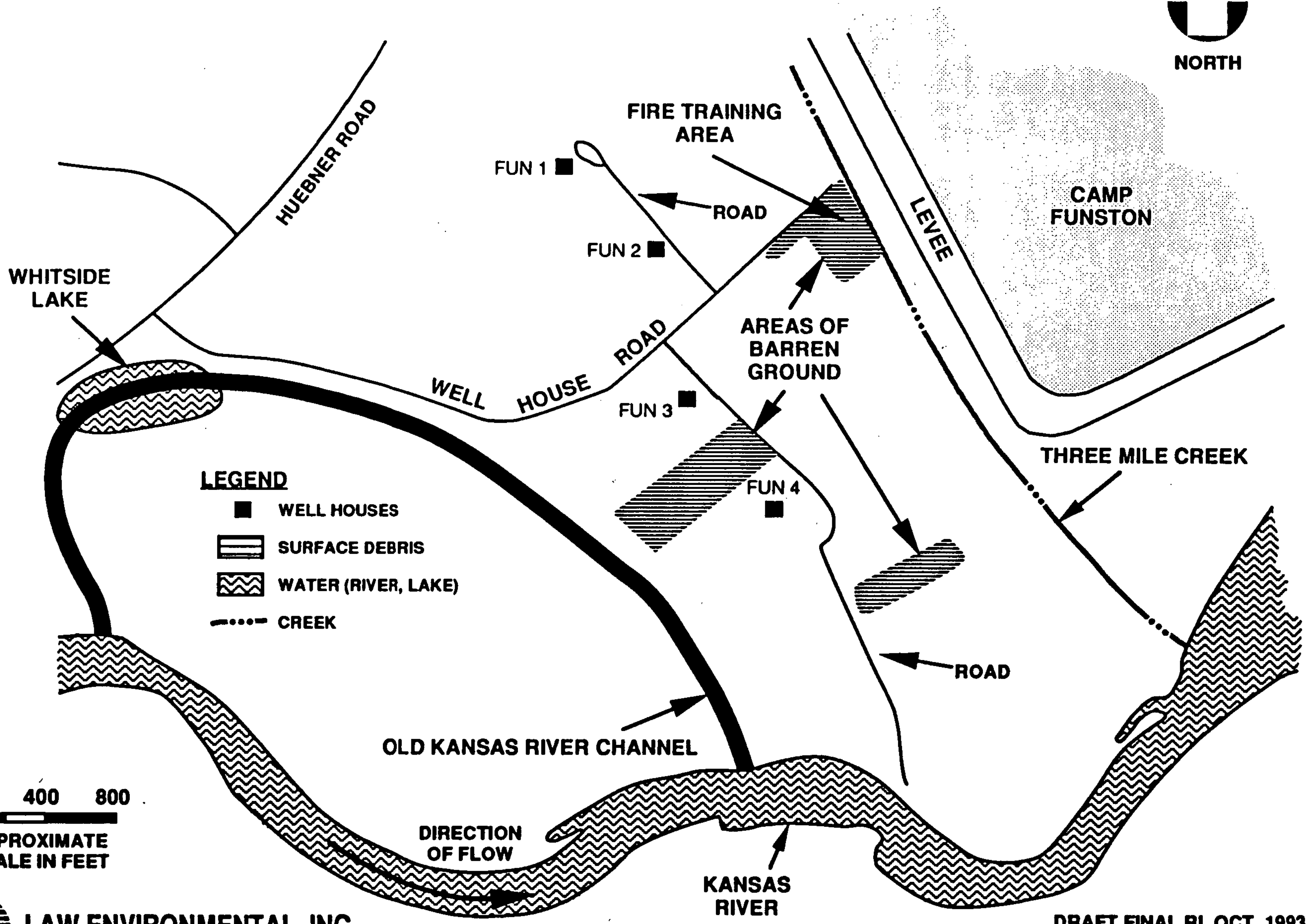
DRAFT FINAL RI, OCT. 1993 1530.75

FIGURE 1-7

PHOTOGRAPHIC INTERPRETATION-1976

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS



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The intent of reviewing the data from previous investigations was to assess the overall data quality, develop a confidence in these data, and compile a data set for past efforts that can be resourced in assessing remedial decisions concerning the site.

Six monitoring wells were installed at the landfill in May 1983 as part of the July 1982 approved closure plan requirements for the SFL (see Figure 2-3). Groundwater samples have been periodically collected from these six monitoring wells. Results of these sampling events are summarized in Appendix B. Detailed well construction information is provided in Appendix C. These monitoring wells were installed using glued casing joints (Water Well Record Form WWC-5 KSA 82a-1212). Glue from the joints can introduce constituents such as vinyl chloride to groundwater samples. Previous results have shown detectable concentrations of arsenic, cadmium, copper, lead, nickel, and zinc, and high levels of iron in the monitoring wells. Arsenic concentrations ranged from 5.1 to 17 micrograms per liter (μg/L), lead from 13.7 to 25.1 μg/L, and iron from 55 to 14,900 μg/L. Petroleum hydrocarbons were found in all wells in 1984 in the range 2.62 to 11.9 μg/L (USATHAMA, 1984).

From 1984 to 1986, the six closure monitoring wells were sampled once per year; from 1987 to 1990, the wells were sampled between one and three times per year, resulting in a total of 11 data points per well. Available records indicate at least two separate groups sampled these wells, Environmental Science & Engineering, Inc. and AEHA. Analytical parameters for Chemical Oxygen Demand, Total Organic Carbon, and Total Halogenated Organics were chosen as indicators of general chemical constituency for comparison to carcinogenic organic compounds that had been reportedly found in some or all of the wells at various times (see preceding paragraph).

According to the DEH at Fort Riley, the accepted procedure for purging groundwater monitoring wells may not have been followed properly before sample collection from the six closure monitoring wells. The accepted procedure involves removal of at least three to five well volumes and/or purging until groundwater field readings for pH, conductivity, and/or temperature stabilize within ±10 percent. The inconsistent purging may account for the differences in reported analytical results for specific compounds from one sampling event to another and from one analytical laboratory to another. Other possible sampling related causes for the variability in data are improper sample collection techniques and improper handling of samples after collection.

Another problem concerning previous sampling is that the six monitoring wells installed as part of the 1984 landfill closure plan were screened at three distinct intervals within a single well bore. The wells were purged and sampled without isolating discrete water-bearing zones; therefore, the purged water was predominantly produced from the most permeable screened zone and any contamination may have been diluted by water from less contaminated zones. To obtain useful information from these wells, each zone would have required sealing with a packer, purging of that isolated well section, and subsequent sample collection.

The concentrations of certain contaminants varied by one to two orders of magnitude among analytical laboratories (raw data tables of Appendix B). These variations may be related to differences between analytical methods used by each laboratory. An increase in Total Organic Carbon occurred when the change to the Quality Analytical Services Laboratory for the May 1988 sampling event was made. The Total Organic Carbon returned to previous levels when Quality Analytical Services Laboratory was discontinued and the QWAL Laboratory was used, but the Total Halogenated Organics increased dramatically for some wells following the last change in laboratories.

Specific Volatile Organic Compounds were detected by the AEHA laboratory in measurable quantities on several sampling occasions. When private laboratories were contracted, no Volatile Organic Compounds or priority pollutants were detected, though detection limits are stated as the same for each of the laboratories. Vinyl chloride was detected at a maximum of 53 μg/L in 1986. Trichloroethene, dichloroethene, vinyl chloride, benzene, and ethylbenzene were detected in the initial testing performed in 1984 and in 1987. In 1988, the Quality Analytical Services Laboratory did not test for Total Halogenated Organics or Volatile Organic Compounds or content because these parameters were removed from the KDHE testing requirements.

In 1984, total recoverable petroleum hydrocarbons (TRPH) were detected in the six existing monitoring wells. Subsequent analysis for TRPH in the six closure wells was not performed. Dissolved and colloidal (total) iron were detected in concentrations above background. Also found were detectable concentrations of arsenic and zinc.

Use of three potable water supply wells (FUN 1 through 3) located about 200 to 3,000 feet north of the landfill (Figure 1-7) was discontinued around 1975 because of deteriorating taste and aesthetic characteristics of the water (DEH, 1992d). Well abandonment records are included in Appendix C. An additional potable water supply well (FUN 4) in the landfill area (Figure 1-7) was apparently removed from service between 1962 and 1970. Well records at KDHE do not include abandonment documentation for this well. It is unknown why this well was abandoned. Groundwater analyses from well FUN 1 in the mid-1970s reported specific conductance values in the 900-1000 μmhos/cm range. Trace organic analysis was not performed. According to the Installation Assessment Report, analytical data from these wells indicated levels of iron and total dissolved solids above background conditions (USATHAMA, 1984). However, this report did not state (specifically) that the abandonment of these wells was due to these concentrations. This report also stated that these wells had not been sampled for organic constituents. In March 1990, all pumping equipment was removed from wells FUN 1 through 3, and the well casings were grouted to the surface in each well. The wells were abandoned according to procedures required by the State of Kansas (Article 30-K.A.R. 28-30-7-b).

Presently, the nearest water supply well in operation is an irrigation well located a quarter mile west of the SFL and owned and operated by a private individual. There are no structures (homes, barns, outbuildings) on or near the irrigated field, and therefore a potable water supply is not necessary. This irrigation well is approximately 60 feet deep and is completed in the alluvium of the Kansas River. The alluvium is the source of groundwater for this well.

There are three public water supply wells located in the city of Ogden, approximately 3.6 miles northeast of the SFL (USGS, 1982). These wells were constructed in 1941 (Well 2), 1973 (Well 7), and 1979 (Well 8). These wells not only serve the city of Ogden, they also provide potable water for the Riley County Rural Water District and the town of Keats on the west side of the Tuttle Creek Reservoir (Ogden City Hall, 1993). Previously active supply wells 1, 3, 4, 5, and 6 are not locatable according to public works staff at the City of Ogden. Well log and water chemistry files at KDHE and City of Ogden were reviewed and copies made of available information (Appendix C). Only one well log was available for well 8, along with a well plugging record for well 3. Multiple water chemistry analyses were available for each active well dating back to about 1983.

Well 8 is the most recently constructed public supply well (1979). The completed well depth is 51 feet and the borehole diameter is 24 inches. The upper 30 feet consisted of topsoil, clay and sand, and the lower 21 feet was reported to be predominantly coarse sand and pea gravel. Bedrock was apparently not encountered. The well was constructed using 14-inch steel blank casing to a depth of 41 feet and a stainless steel, 80 slot, Johnson wire-wrapped well screen from 41 to 51 feet. The static water level following well completion was 21 feet below land surface. The well was tested with a 50 hp turbine pump at about 520 gallons per minute for three hours. The water level in the well was about 27 feet below land surface during this test. According to the City of Ogden public works staff, each of the three wells pumps about 250 to 300 gpm on an intermittent daily schedule to maintain adequate hydraulic pressure in the city's 50,000-gallon water tower. Additional information on the well log forms and water analyses reports are provided in Appendix C.

1.3 REPORT ORGANIZATION

This report was prepared in accordance with the U.S. Army Corps of Engineers' "Draft Revision of Engineering and Design Chemical Data Quality Management for Hazardous Waste Remedial Activities," ER 1110-1-263, dated October 1, 1990, and USEPA's "Guidance on Conducting Remedial Investigation and Feasibility Studies under CERCLA," OSWER Directive 9355.3-01, October 1988.

The organization of this RI report is as follows:

- Section 1.0 presents a general overview and description of the SFL site and provides historic and previous studies information.

- Section 2.0 describes the study area investigation which includes details of the performed field activities, both physically and chemically, associated with site characterization.

- Section 3.0 describes the physical characteristics of the study area which include the results of the field investigation as described in Section 2.0.
- Section 4.0 addresses the sources, nature, and extent of contaminants as obtained in Section 2.0.
- Section 5.0 addresses the Contaminant Fate and Transport mechanisms at the SFL.
- Section 6.0 presents the Baseline Risk Assessment.
- Section 7.0 provides a summary of Sections 4.0, 5.0, and 6.0. Project conclusions are also presented in Section 7.0.

2.0 STUDY AREA INVESTIGATION

A study area investigation was performed at the SFL site to characterize the site and accomplish objectives for selecting an appropriate remedial action. Specific field tasks performed at the SFL and objectives for these activities are discussed in the following sections and are summarized in Table 2-1. Included are discussions of a surface feature investigation which includes general topography and mapping, a contaminant source investigation and surface-water and sediment investigations, a geological investigation, and an ecological investigation along with an endangered species survey.

2.1 SITE CHARACTERIZATION ACTIVITIES

Field investigations at the SFL included:

- Surface features survey
- Surface geophysical survey
- Soil gas survey
- Installation of 20 monitoring wells and groundwater sampling
- Collection of soil samples from each of 8 deep well borings
- Collection of 7 surface water and 7 sediment samples
- Sampling of a private irrigation well
- Quarterly groundwater sampling

Log books were compiled and filled out each day detailing the daily activities of the field investigation. Daily Quality Control Reports (DQCRs) were prepared by the site manager and submitted to the US Army Corps of Engineers, Kansas City District (CEMRK) Project Manager and are also included in the QCSRs. The DQCRs summarized the daily activities and included general and specific information regarding the number and types of samples taken, field instruments used, and problems encountered during the field work. The approved December 1991 Draft Final Work Plans (Law, 1991) and the September 1992 Modified Draft Final Work Plans (Law, 1992a) (hereafter jointly referred to as the Work Plans) provide a list of the field equipment used for sample collection, description of the field instruments and calibration, description of sample collection devices, and discussion of decontamination and sample shipment procedures.

Field work was performed in approved modified level D personal protective equipment (PPE). During the field investigation, decontamination water, purge water, drill cuttings, development water, and discarded PPE clothing were stored in 55-gallon Department of Transportation (DOT) approved liquid and solid waste drums. The drums were labeled to facilitate identification,

TABLE 2-1

PROJECT ACTIVITIES AND OBJECTIVES
Southwest Funston Landfill
Fort Riley, Kansas

ACTIVITIES	OBJECTIVES
Surface Feature Survey	Delineate topography, surface drainage, and erosion features
Geophysical Survey	Establish landfill boundaries and aid in the placement of monitoring wells
Soil Gas Survey	Delineate volatile contaminant plume and aid in the placement of monitoring wells
Install 20 monitoring wells in 8 cluster locations and perform ground-water sampling	Evaluate vertical and horizontal extent of ground-water contamination
Collect soil samples from each of 8 deep well borings	Evaluate vertical extent of soil contamination
Collect 7 surface water and 7 sediment samples (including Benthic and Endangered Species Survey)	Evaluate extent of contamination and impact of contamination on aquatic macroinvertebrate community
Sample private irrigation well	Evaluate if contamination exists and impact of contamination
Perform quarterly ground-water sampling	Determine contaminant fluctuations due to seasonal changes in the aquifer

including type of material, date, and location of waste. The drums were then transported and staged at the Site Operation Center (SOC) located in the northern portion of the SFL site. Details of the SOC and its construction are described in the Work Plans (Law, 1991; Law, 1992a).

2.1.1 Surface Features Investigation

Topographic survey (Plate 1) and sampling location maps were developed for the SFL site to provide data necessary to evaluate potential contaminant migration pathways. These include surface water flow patterns, topographic slopes, and groundwater flow direction and gradient. These data are critical in evaluating the potential hazards and risks associated with past and/or current site activities.

Law contracted with a local survey company in Kansas City, Missouri, to conduct a topographic survey at the SFL site as described in the Work Plans. After installation of the monitoring wells and sample collection tasks were completed, the elevations and horizontal locations of the newly installed wells and sampling stations were determined. This included surveying background (upgradient) sampling locations and elevations. Location coordinates were surveyed to the closest 0.1 foot and referenced to the Lambert Coordinate System. Elevations were determined to within 0.01 foot, to the top of the polyvinyl chloride (PVC) well casing, the top of the protective casing, and the brass survey marker for each monitoring well. A 3.5-inch diameter, domed brass survey marker was permanently set in the concrete pad surrounding each new monitoring well and was stamped to display the following information:

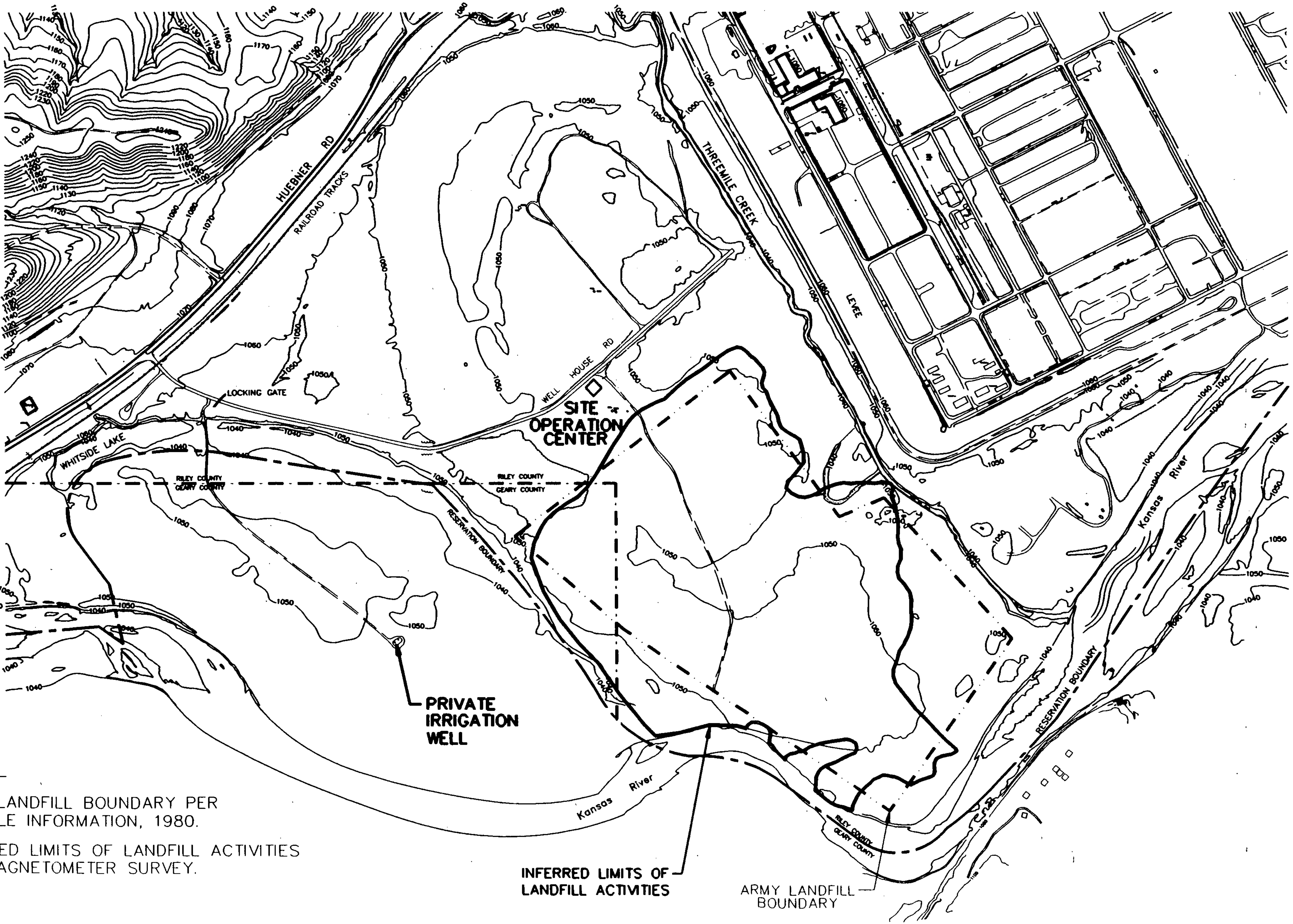
- Date
- USA-ED-TP-KCMO
- Northing
- Easting
- Elevation (top of PVC casing)
- Well Identification Number

A topographic contour map of the SFL site was produced in November 1991 with 2-foot contour intervals, referenced, at the direction of the CEMRK, to the Lambert Coordinate System. The limits of the map were bound to the north just beyond Well House Road, to the south at the north bank of the Kansas River, to the east on the west bank of Threemile Creek, and to the west on the east bank of the old channel which borders the open field adjacent to the landfill (Plate 1). Figure 2-1 provides a site location map showing the approximate areal extent of landfill activities based on file information from Fort Riley (118 acres) and the magnetometer survey (123 acres). Surface water and sediment sampling points, as well as the benthic survey sampling points, are shown on Figure 2-2. An attempt to "stake out" and survey the surface water and sediment sampling locations was made. However, a high river stage event washed

FIGURE 2–1

SITE LOCATION MAP
SOUTHWEST FUNSTON LANDFILL

FORT RILEY, KANSAS



LEGEND

1050 LAND SURFACE ELEVATION CONTOUR INTERVAL (10 ft)

+++++ RAILROAD TRACKS

0 800 1600

APPROXIMATE SCALE IN FEET

NOTES

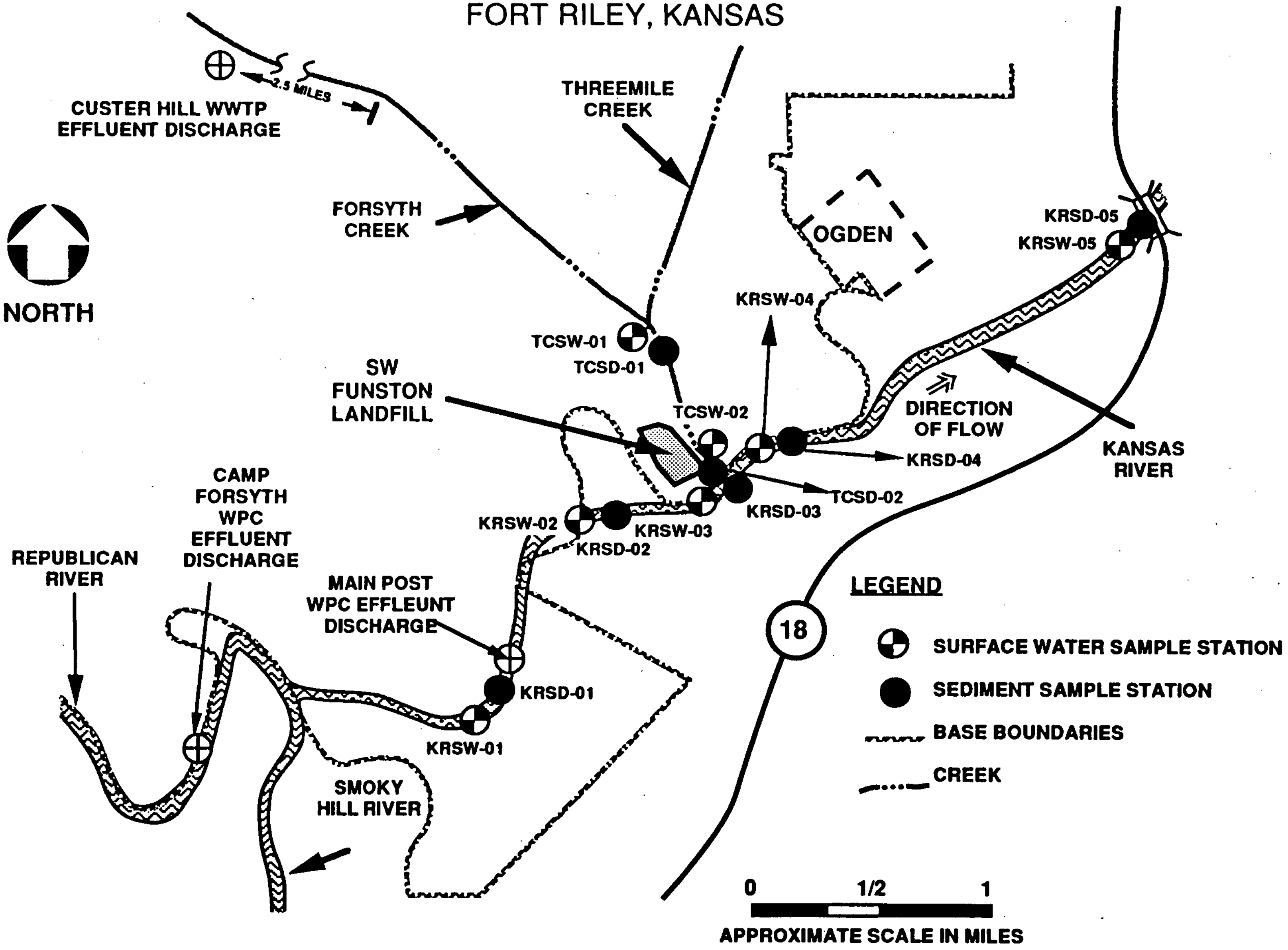
– · – ARMY LANDFILL BOUNDARY PER DEH FILE INFORMATION, 1980.

—— INFERRED LIMITS OF LANDFILL ACTIVITIES PER MAGNETOMETER SURVEY.

FIGURE 2-2

SURFACE WATER AND SEDIMENT SAMPLING STATIONS

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS



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away three of these staked locations before the survey. The locations of the other sampling points were determined using landsurvey instruments. The locations of the three unstaked sampling points were estimated based upon field notes taken during sampling. Monitoring well and soil sampling locations are shown in Figure 2-3.

A tabulated list of the monitoring wells and survey markers, including their coordinants and elevations, field books, and computation sheets were submitted previously to CEMRK with copies furnished to Fort Riley. Table 3-1 lists survey data for surface water, sediment, soil and groundwater sample locations.

2.1.2 Contaminant Source Investigation

The contaminant source investigation of the SFL site considered the inclusion of wastes from a broad range of diverse sources. As stated in the Work Plans and in Section 1.2.2.2, the types and quantities of wastes disposed at the SFL are poorly documented. However, based upon analysis of samples collected from the landfill closure wells, assumptions were made concerning the types and concentrations of constituents expected to be present in the groundwater at the SFL.

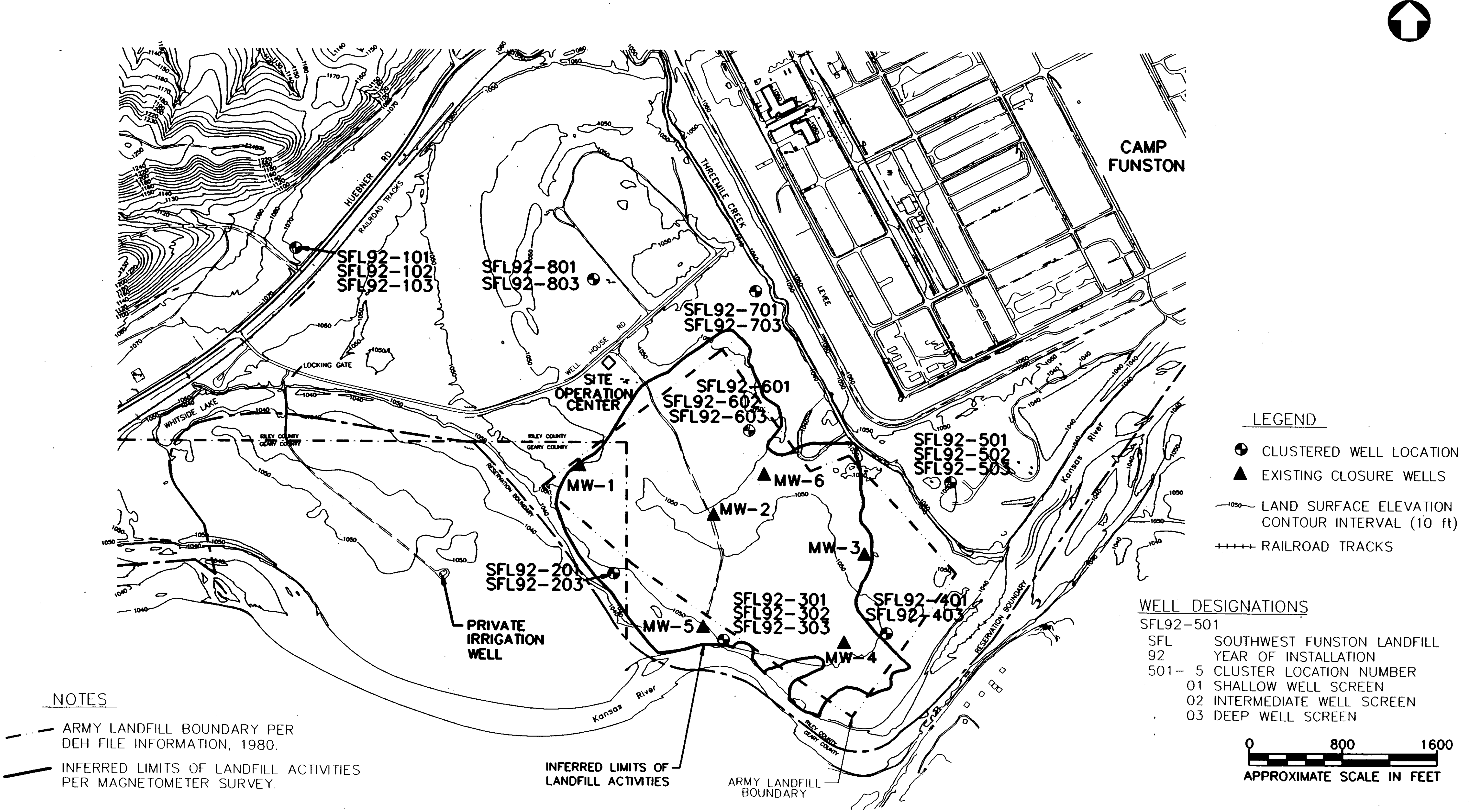
Historically, Fort Riley disposed solid wastes in landfills from the Civil War to the present. Waste oils, solvents, waste water and paint sludge, heavy metals, pesticides, and potential asbestos-containing construction debris have also been disposed in landfills. Known wastes disposed at the SFL include drummed, metal-containing waste oils mixed with spent degreasing solvents and dried sludge from the wastewater treatment plants. In addition, large volumes of domestic trash and construction debris have been disposed at the SFL. Increased mechanization of the armed forces resulted in an increase in the amount of petroleum products and solvents used and disposed in the landfill. Additional historical data regarding waste disposal are presented in Section 1.2.2.2 and the Work Plans.

West of the SFL site lies an open field with an irrigation well which was sampled during the baseline sampling event. This field is currently used for agriculture. Normal operation of crop fields usually entails the use of pesticides and herbicides for insect and weed control. The field and well are privately owned. The owner of the irrigation well is contacted before each quarterly sampling event so that a sampling of the well can be scheduled (if not winterized).

2.1.3 Surface Water and Sediment Investigation

The objective of the surface water and sediment investigation was to evaluate whether selected samples contained chemical constituents at concentrations exceeding remedial action levels.

FIGURE 2-3
MONITORING WELL LOCATION MAP
SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS



Surface water and sediment samples were collected from seven separate locations. Five surface water and sediment samples were obtained from the Kansas River, and two were obtained from Threemile Creek. Table 2-2 contains the locations and descriptions of each sampling location, and Figure 2-2 illustrates the approximate location of each sampling station. Table 2-2 also includes the locations and descriptions of the seven macroinvertebrate sampling locations, which are further discussed in Section 2.1.8.1. The surface water and sediment samples were analyzed for chemical constituents contained in the abbreviated Resource Conservation and Recovery Act (RCRA) Appendix IX list and are summarized below. Surface water samples were analyzed for:

- Volatile and semi-volatile organics
- Pesticides/Polychlorinated biphenyls (PCBs)
- Metals (total and dissolved)
- Organophosphorus pesticides
- Herbicides
- Inorganic anions

The sediment samples were analyzed for the same parameters as specified for the surface water, excluding inorganic anions. During the surface water and sediment sampling, samples for volatile compound analyses were collected first and remaining samples were then obtained. Specific rationale for sampling locations, analyses, and corresponding analytical methods is further described in Section 4.0.

The surface water samples were collected in higher-flow areas to represent dynamic conditions, while the sediment samples were obtained in lower-flow areas representing areas of sediment accumulation. At each sampling location, the surface water samples were obtained first, downstream of the sediment location, to avoid cross contamination. Each of the surface water samples was collected using a pre-cleaned stainless-steel beaker and placed in appropriately labeled sampling containers.

After collecting the surface water samples at each sampling station, the sediment samples were collected in the general location of the surface water samples near the river/stream bank. The sediment samples were collected using pre-cleaned stainless steel hand augers with extensions and placed in appropriately labeled sampling containers.

Surface water data were obtained from the U.S. Geological Survey (USGS) to evaluate stage and river flow characteristics for the Kansas River between the Marshal Army Air Field (MAAF) and the SFL. The river elevation at SFL was measured with a standard survey level and stadia rod near well cluster series 300 using the well control datum as a local benchmark elevation. Comparing the field measurement of the river elevation to the river gage elevation resulted in a difference of approximately eight feet (see Section 3.6.2.3).

TABLE 2-2

SEDIMENT, SURFACE WATER AND MACROINVERTEBRATE SAMPLING LOCATIONS

Location ID	Body of Water	Location/Description
KRSD-01 KRSW-01 KRB-01	Kansas River (background site)	Upstream from the Main Post Waste Water Treatment Plant discharge
KRSD-02 KRSW-02 KRB-02	Kansas River	Bridge (Henry Drive) upstream from landfill site
KRSD-03 KRSW-03 KRB-03	Kansas River	Immediately adjacent to landfill site
KRSD-04 KRSW-04 KRB-04	Kansas River	500 feet downstream of landfill site and Threemile Creek
KRSD-05 KRSW-05 KRB-05	Kansas River	Approximately 1 mile downstream of landfill on upstream side of Hwy. 18 bridge
TCSD-01 TCSW-01 TCB-01	Threemile Creek (background site)	Upstream from landfill site and downstream from confluence with unnamed tributary
TCSD-02 TCSW-02 TCB-02	Threemile Creek	100 feet upstream of Threemile Creek/Kansas River confluence

Note: Figure 2-2 shows the approximate location of these samples.

Daily rainfall data were provided by the 1st Weather Group, Detachment 8, at MAAF to observe the relationship between precipitation events and changes in river elevation at the SFL. It was assumed that rainfall amounts at the SFL (approximately 4 miles east of the MAAF) were the same as at the MAAF.

The infiltration potential through the SFL cap soils and through natural, undisturbed soils, adjacent to the landfill area was not measured with field tests. Section 3.6.2.4 estimates the infiltration potential based on analysis of the available data using the HELP (Hydrologic Evaluation of Landfill Performance) model.

2.1.4 Geological Investigation

The objective of the geological investigation was to characterize the soil stratigraphy and depth to bedrock beneath the SFL site. The initial investigation included a review of existing geological data (including data obtained from the six closure wells at SFL), a literature search, and personal interviews, as described in Section 1.0.

Geophysical surveys were performed, prior to soil sampling and monitoring well installation, to locate areas of buried metallic debris as well as non-metallic anomalies. Results of the geological investigation are discussed in Section 3.4. The following sections describe the field activities associated with this investigation.

2.1.4.1 Geophysical Surveys - Before beginning subsurface sampling, geophysical surveys were conducted from late October to early November 1991. These surveys were performed to help evaluate the lateral boundaries of the SFL site.

Two geophysical techniques, magnetometer and electromagnetic (EM) conductivity surveying, were employed. Magnetic surveying is useful in locating buried metallic objects, since such objects create local disturbances to the earth's magnetic field which are detectable with a magnetometer. The EM surveys measure changes in the electrical conductivity of subsurface materials. Such changes can result from the presence of buried metallic objects, which are generally detectable with a magnetic survey, but also may result from electrically conductive features such as clayey lenses or conductive contaminants in groundwater. Locations of the geophysical survey lines and base lines are shown in Figure 3-7. Location control for the magnetic and EM surveys was obtained by measuring with a cloth tape from north-south survey base lines established by a land surveyor.

The magnetometer survey consisted of 25 profile lines totalling 24,680 linear feet. The survey was performed using GEM Systems, Inc. Model GSM-19 magnetometer/gradiometer which measures both the total magnetic field and the magnetic gradient (change in the field with vertical distance) at a given point. Measurements were obtained at linear intervals of 10, 25, 50, or 100 feet, depending upon proximity to known or suspected anomalies. Quality control was maintained by:

- Checking instrument functions prior to each survey loop.
- Taking two or more magnetometer readings at each measurement station.
- Recording both the magnetic total field and gradient at each station.
- Performing loop closures to assess diurnal drift.

The loop closures indicated that the instrument drift was small (<20 nanoTeslas) compared to the magnetic anomalies (100s to 1000s of nanoTeslas); therefore, no drift corrections were performed prior to plotting and interpreting the magnetometer data.

The magnetometer survey was to consist of a series of traverses across the SFL area. However, initial results of the magnetometer survey indicated that much of this area (i.e., the area bounded by Threemile Creek, the Kansas River, the Old Channel, and Well House Road) was yielding data indicative of buried metallic debris. Accordingly, the survey configuration for this area was modified to include a survey around the perimeter of this area (designated Line P), and several radial lines (designated Lines R1 through R12). The perimeter survey was performed to identify areas around the perimeter which, based upon the magnetometer data, did not appear to have buried debris. Radial surveys were then performed beginning within these non-anomalous sections of the perimeter and progressing inward toward the center of the survey area until anomalous readings were recorded. The point along the radial survey line at which readings changed from non-anomalous to anomalous was interpreted to be at the edge of the subsurface metallic debris area. By connecting such points, a map showing the inferred extent of subsurface metallic debris (Figure 3-8) was created. The features of this map are described in Section 3.4.1.

Magnetometer survey lines were also performed north of Well House Road (Figure 3-7). The data from these survey lines were used to locate possible buried metallic objects within the northern portion of the study area, where historical data indicated that some dumping may have occurred.

The EM survey consisted of two profiles totalling 7800 linear feet (Figure 3-7). The survey was performed with a Geonics Limited Inc. Model EM-31D with an analog (continuous readout) recorder. The EM survey provided a check on anomalous areas indicated by the magnetometer survey (since both instruments respond to the presence of buried metal) and provided electrical conductivity data in areas which did not produce magnetic anomalies. Quality control was maintained by:

- Checking instrument functions prior to each survey line.
- Adjusting the instrument compensation controls prior to each survey line.
- Recording both the quadrature phase (a measure of the subsurface electrical conductivity) and in-phase (an indication of subsurface metallic objects) readings.

Results of the Magnetic and EM surveys are provided in Section 3.4.1 and shown on Figure 3-8. Appendix J contains field data from the geophysical surveys.

2.1.4.2 Monitoring Well Installation - From March 1992 to May 1992, 20 monitoring wells were installed at the SFL. These wells were installed in the alluvium at eight clustered locations as shown on Figure 2-3. These locations were selected based on soil gas field analytical data (Section 3.5.1) and geophysical survey data (Section 3.4.1). Four of the eight locations (clusters 1, 3, 5, 6) contain three wells: one shallow well screened above and below the water table; one intermediate well screened halfway between the water table and bedrock; and one deep well screened at the lower 10 feet of the alluvial aquifer. The other four locations (clusters 2, 4, 7, 8) consist of a shallow well and a deep well. Location 4 was initially scheduled to have three wells in the cluster, however, due to shallow bedrock, only two wells were installed.

Figure 2-4 illustrates the typical well and screen placement for the well clusters. Shallow wells were installed to monitor light, nonaqueous contaminants which float on the water column, such as fuel products. Intermediate wells were installed to monitor dissolved contaminants within the saturated zone between the shallow and deep intervals. Deep wells were installed to monitor dense nonaqueous contaminants that sink through a water column as well as dissolved constituents. During the drilling and well installation activities at the SFL, the boring and breathing zones were monitored for organic vapor content using a photoionization detector (PID).

The well locations were selected based on soil gas results, geophysical survey data and groundwater flow toward the Kansas River, as this was the expected flow direction. In some instances, well locations were selected inside of the inferred extent of magnetic anomalies because of access considerations for drilling equipment. The well location rationale is presented below.

Location 1 was chosen to provide background data for groundwater. This location was anticipated to be upgradient of the SFL and the abandoned water supply wells.

Location 2 was chosen to evaluate the area of the most recent landfill activities (up to 1981) and monitor potential contaminants at the periphery of SFL in the area of visible surface debris (Figure 1-6). This location was also selected based on the positive soil gas survey results in the soil gas survey.

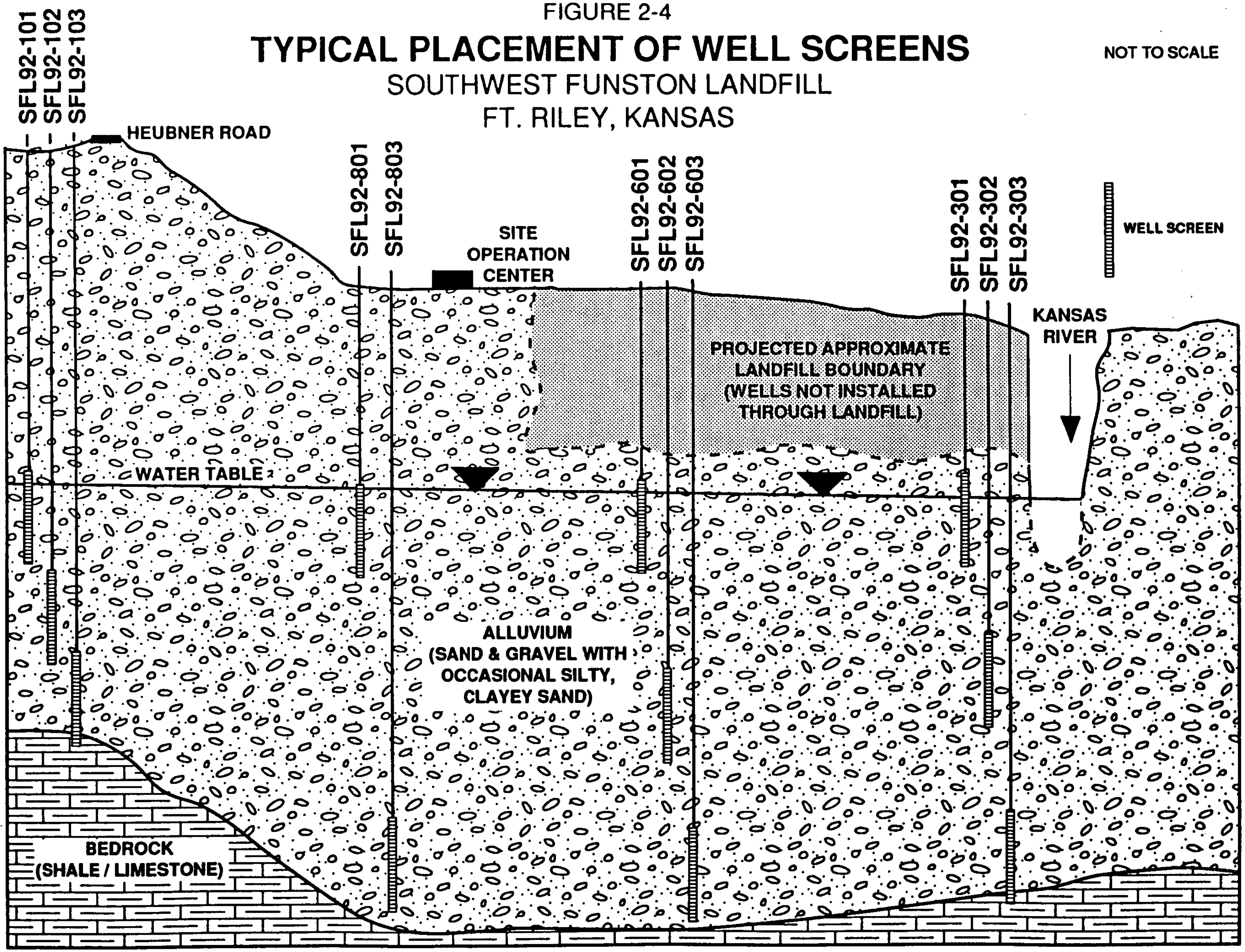
Locations 3 and 4 were selected to detect contaminants migrating from the landfill into the Kansas River. Locations 3 and 4 were assumed to be hydrologically downgradient of suspected contaminant sources and were located in the general proximity of positive soil gas results.

Location 5 was selected to detect contaminants which may have traveled off the SFL to the east of Threemile Creek. However, results of this investigation indicate that Threemile Creek acts

FIGURE 2-4

TYPICAL PLACEMENT OF WELL SCREENS

SOUTHWEST FUNSTON LANDFILL
FT. RILEY, KANSAS



as a hydraulic boundary to groundwater flow during periods of fluctuating river stages, between the SFL and Camp Funston (see Section 3.6.2). Therefore, this cluster may not be affected by SFL but may be influenced by groundwater migrating from Camp Funston and the Kansas River.

Locations 6 and 7 were chosen to monitor the eastern boundary of the SFL along Threemile Creek. Location 7 was selected to provide a groundwater monitoring site just downgradient of the former Fire Training Area. Location 8 was selected to monitor groundwater in an area apart from the main landfill but in an area possibly containing subsurface metallic debris. In addition, locations 6, 7, and 8 were located near areas within the landfill which exhibited positive soil gas results.

The initial shallow monitoring wells were drilled and installed using hollow-stem augers with a wooden plug inserted into the lead auger. The wells were subsequently abandoned by grouting with a tremie pipe from the bottom of the well to at least 1 foot below grade. The well riser pipe was then cut below grade and covered with clean fill. The remaining wells were drilled and installed using 10-inch outside diameter (O.D.) hollow-stem augers. Each of the deep and intermediate wells were drilled using mud rotary techniques (with a 6-inch O.D. roller cone bit). Initially, the deep wells were drilled using 10-inch hollow-stem augers, but sand filled the inside portion of the auger and prevented the installation of the 2-inch PVC wells. A technical memorandum dated March 30, 1992, was submitted to modify the Work Plans and to change the drilling and construction methods for the intermediate and deep wells at the SFL. The technical memorandum is provided in Appendix Q.

The soils in the deep monitoring wells at each location were continuously sampled and logged. The soils in the wells were sampled for geotechnical and chemical analyses using 2-inch and 3-inch outside diameter samplers. Samples were collected for geotechnical (2 inch split spoons) and chemical analyses (3 inch continuous sampler) as described in Section 2.1.5. A geologist performed the borehole logging activities and supervised construction of the monitoring wells as described in the Work Plans. After total depth of each deep monitoring well was confirmed (top of bedrock), the borehole was flushed with potable, non-chlorinated water, and a 2-inch PVC well (screen and riser pipe) was installed and constructed, including the sand pack, well seal, cement-grout, and well pad. The protective posts and casings surrounding the wells along Huebner Road were painted brown, in accordance with the request of CEMRK and DEH. The protective casing and posts for the remaining SFL wells were painted bright orange. The monitoring well test boring records are included in Appendix D. The "as-built" well installation diagrams for these wells are included in Appendix E.

The drill rig and down hole equipment (augers, rods, etc.) were steam-cleaned before beginning any drilling activities for each well. A decontamination pad area was constructed north of the SFL site. Each time the drill rig and equipment were cleaned, the decontamination water was captured on plastic sheeting and pumped into 55-gallon DOT-approved drums. The drummed liquids were labeled and transported to the SOC for storage.

Because of the design of the six closure wells at the SFL, they were to be abandoned after the monitoring well installation field activities. However, based on conversations with the CEMRK, USEPA, KDHE, and Fort Riley, it was decided to defer this abandonment activity so that additional hydrogeologic information could be obtained from these wells (such as groundwater elevations, feasibility uses, etc.). This decision, in effect, converted these wells from monitoring wells to piezometers.

2.1.5 Soil and Vadose Zone Investigations

The objective of the soil and vadose zone investigations is to evaluate and identify the presence of selected chemical constituents in various soil media at the SFL. A soil gas survey was performed to collect vadose zone (unsaturated soil) information. Subsurface soil samples (vadose and saturated soils) were collected from the deep monitoring wells for chemical and geotechnical testing, and shallow surface soil samples from the landfill cover were collected for selected metals testing. The monitoring well borings were not located on the landfill proper but were advanced in areas bordering the SFL where it is estimated that limited source material would be present. Soil samples from these borings were collected to evaluate if there have been contaminant releases from the landfill. The subsurface soil samples from these borings characterize the periphery of the SFL and not the SFL source(s). Characterization and classification of these soils are described and presented in Section 3.5.2 of this report. The nature and extent of chemical constituents in the soil media are discussed in Section 4.2.3.

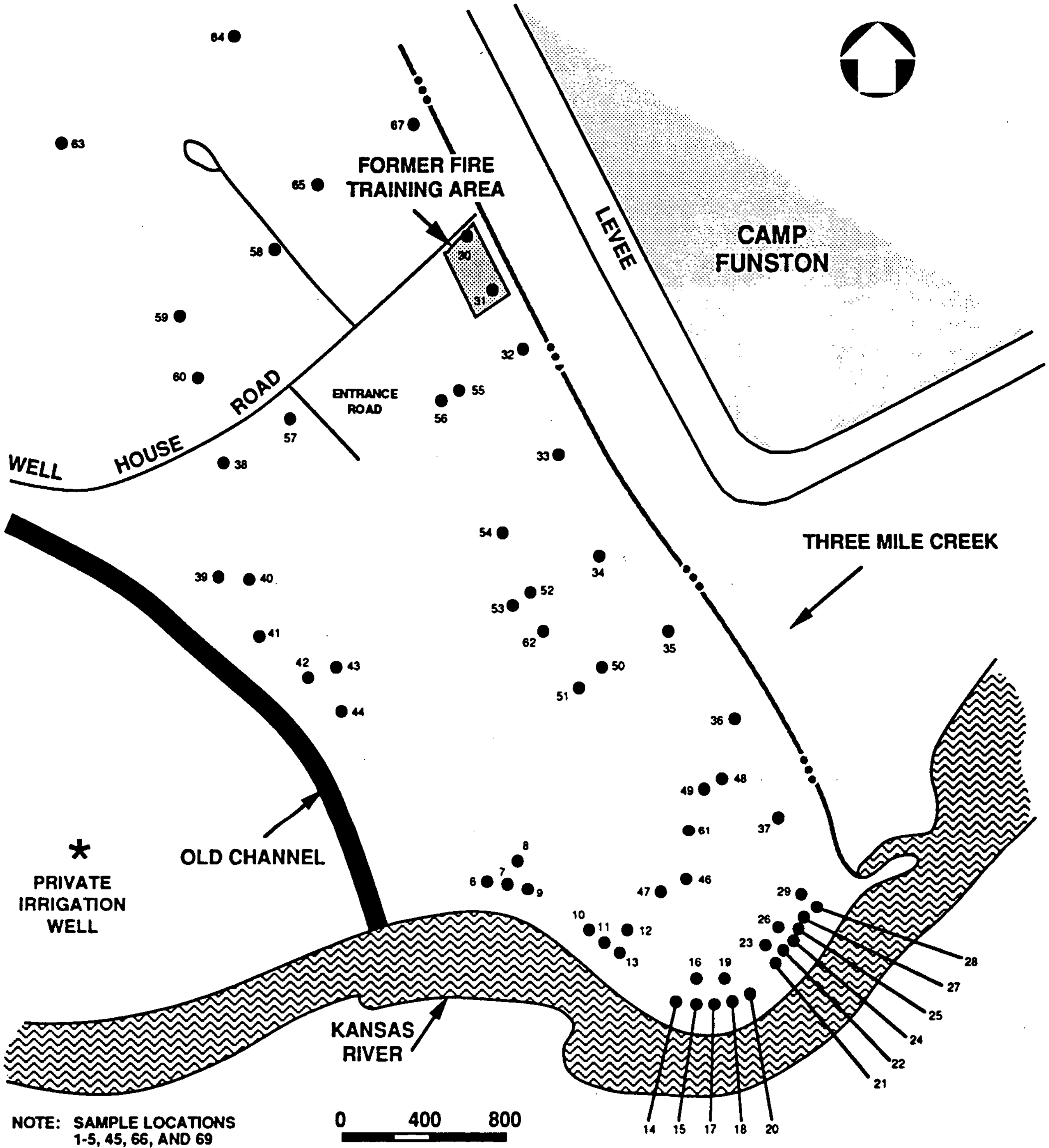
2.1.5.1 Soil Gas Study - In late October and early November 1991, a soil gas survey of unsaturated or vadose zone soils at the SFL was conducted. The areal extent of the soil gas survey was determined based on historical photographs, maps, surface features, and the results of the geophysical survey. The objective of this survey was to help evaluate the location of possible soil and groundwater contamination at the SFL and to aid in the placement of the monitoring wells. The results were used to select monitoring well locations. The soil gas survey, including the number and depth of sample collection points, was limited as a result of difficult access resulting from very poor weather and field conditions (snow and saturated surface soils).

Soil gas samples were collected at 61 locations at the SFL site, as shown on Figure 2-5. The procedures for soil gas sampling are described in Appendix J. The sample numbering sequence began with 1 and continued to 69. However, sample numbers 1, 2, 3, 4, 5, 45, 66, and 69, correspond to field quality control samples and, therefore, are not included in the maps and figures. Sample 68 was collected at the location of the upgradient well, north of Huebner Road. It also is not shown on the map.

FIGURE 2-5

SOIL GAS SAMPLING LOCATIONS

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS



NOTE: SAMPLE LOCATIONS 1-5, 45, 66, AND 69 OMITTED FROM SEQUENCE

SAMPLE LOCATION 68 IS NORTH OF HUEBNER ROAD (NOT SHOWN).

LEGEND
- ● SOIL GAS SAMPLING LOCATION
- –•••• CREEK

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The sampling locations were selected, following the EM survey, to aid in the location of the landfill boundaries. Although a sampling depth of 10 feet was planned based on depth to groundwater, trenching methods, and soil type, poor weather conditions (saturated soil) prevented access by the hydraulic probe van and forced a change in the sampling plan to manual collection at a 4-foot depth. To collect the samples, a 1/2-inch diameter hole was advanced to a depth of approximately 4 feet by using a drive rod. However, Sample 9 was collected at a depth of 2 feet and Sample 30 at 3 feet due to probe refusal. The entire sampling system was purged with ambient air drawn through an organic vapor filter cartridge, and a stainless steel probe was inserted to the full depth of the hole and sealed off from the atmosphere. A sample of in-situ soil gas was then withdrawn through the probe and used to purge atmospheric air from the sampling system. A second sample of soil gas was withdrawn through the probe and encapsulated in a pre-evacuated glass vial at two atmospheres of pressure, or 15 pounds per square inch, gauge (psig). The self-sealing vial was detached from the sampling system, packaged, labeled, and stored for laboratory analysis. All samples were analyzed on site in the subcontractor's climate-controlled mobile laboratory. Laboratory procedures are presented in Appendix J. A summary of results is presented in Section 3.5.1 and discussed in Section 4.2.1.

2.1.5.2 Geotechnical Analysis - During drilling of the deep monitoring wells at the SFL site, a geologist collected two soil samples from each borehole for geotechnical analysis. The samples were used to characterize the physical nature of the strata encountered in the study area. Geotechnical sample testing consisted of and followed the American Society for Testing Materials (ASTM) test methods listed below:

- Grain-size Distribution (ASTM-D421 & 422)
- Atterberg Limits (ASTM - D423 & 424)
- Moisture Content (ASTM - D 2216)

Sixteen soil samples were submitted for geotechnical analysis. Soil samples were collected continuously from each of the deepest borings at each location. Geotechnical soil samples were selected from the depths representing the screened interval and at significant stratigraphic intervals encountered during drilling. Sample selection was made by the field geologist after review of the field notes and boring logs. The results of this activity are summarized in Section 3.5.2. Geotechnical laboratory data are included in Appendix F. Using geotechnical results (sieve analysis), the selection for the filter pack and screen slot size was calculated for the wells at SFL. The filter pack size ranged from sieve sizes of 10 to 20 and 20 to 40, with a screen slot size of 0.010-inch (10 slot).

2.1.5.3 Soils from Monitoring Well Borings - A total of 23 soil samples were collected for chemical analysis. The soil samples were collected from the deepest boring at each monitoring well cluster. These borings included SFL92-103, SFL92-203, SFL92-303, SFL92-403, SFL92-503, SFL92-603, SFL92-703, and SFL92-803. Three soil samples were collected for chemical analysis from seven of the eight deep wells. Two samples were collected from well SFL92-403. The approximate depths at which the samples were collected are presented below:

Well No.	Sample Collection Depths (ft.)		
SFL92-103	35	49	57
SFL92-203	19	33	50
SFL92-303	23	41	56
SFL92-403*	22	29	---
SFL92-503	19	27	34
SFL92-603	19	34	48
SFL92-703	15	32	52
SFL92-803	22	45	59

*Only two sub-surface soil samples were collected and submitted for analysis because auger refusal was encountered sooner than expected at this boring/well location.

Samples were collected and screened in the field using a PID. Those samples containing the highest PID readings were submitted for laboratory analysis. If the PID screening did not detect contamination, samples were then collected at the screen intervals of the clustered wells above lower permeability strata. Soil samples were collected for chemical analysis using a 3-inch O.D. steel continuous sampler with stainless-steel inserts. The depths at which these soil samples were collected for laboratory analyses for each well are included in Table 4-17 in Section 4.2.3.3.2.

2.1.5.4 Landfill Cover Soils - PRC (Planning Research Corporation) Environmental Management, Inc. was contracted by the Army through an Interagency Agreement (IAG) with the USEPA to perform a landfill cover study at the SFL site which included soil sampling and screening analysis using X-ray fluorescence (XRF) field analyses for lead, copper, and zinc. Law was on site at the time of sampling and observed these field activities.

This investigation was focused on the cover material of the landfill because of the suspected contaminants from small arms bullets. A portion of the cover material was excavated from the backstop of a rifle range north of the SFL site. The soil investigation conducted by PRC did not thoroughly characterize the contaminants present in the SFL cover and does not account for the possibility that additional contaminants may be present as SFL materials are exposed at the surface due to discontinuities in the cover material. The PRC report, provided in Appendix G, discusses the details of the field activities associated with this sampling effort.

A total of 114 surface soil samples were collected within the SFL boundary on a random sampling grid using stainless-steel spoons (Figure 2-6). The samples were placed in 1-gallon ziplock plastic bags and delivered to the XRF field station for analysis. Each soil sample was obtained from 0 to 6-inch depths and consisted of five aliquots, as shown on the inset of Figure 2-6. Some soil samples, next to the landfill boundary, consisted of only four aliquots. An additional 20 soil samples were collected from the SFL boundary (Figures 1 and 2 of the PRC report), three of which were used for determining background conditions. Descriptions for the soil sampling locations off the SFL proper are provided on Table 2-3. A characterization of the surface soils is summarized in Section 3.5.3. A summary of the chemical data and extent of contamination is presented in Section 4.2.3.

2.1.6 Groundwater Investigation

The primary objectives of the groundwater investigation were to evaluate groundwater flow characteristics and to identify the presence of selected chemical constituents through sampling and analysis. The quality of the groundwater within the study area was evaluated from samples from monitoring wells and a privately owned irrigation well adjacent to the SFL site. A total of 20 monitoring wells were drilled and installed at the SFL site as shown in Figure 2-3. Results from the drilling and sampling within the study area provided data to characterize the hydrogeology of the SFL site. Water levels measured at each well were used for the development of potentiometric surface maps. The results of the groundwater hydrogeological investigation are included in Section 3.6.2 of this report. The analytical results for groundwater samples are discussed in Section 4.2.2.

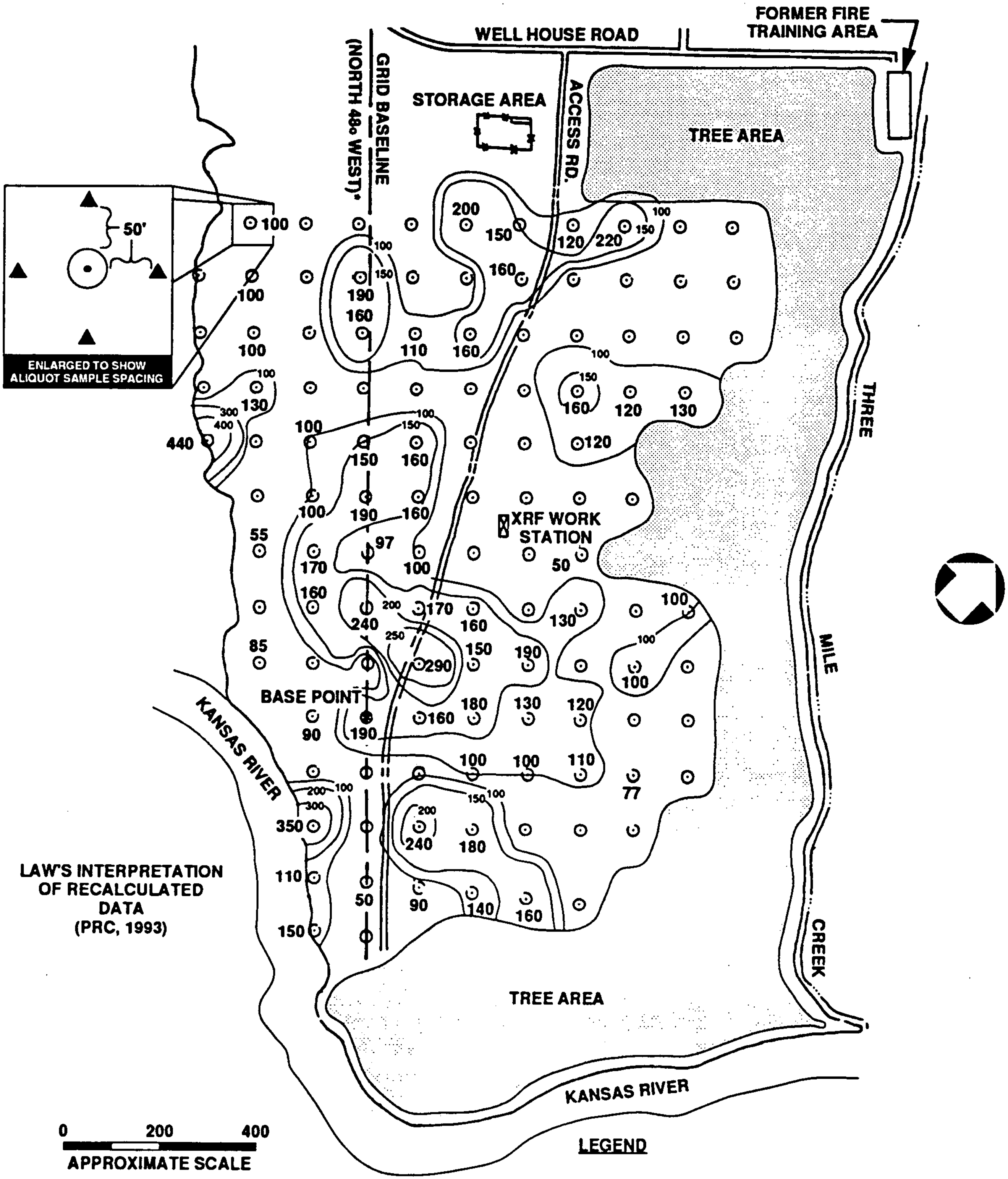
2.1.6.1 Monitoring Well Locations - The monitoring well locations were described in Section 2.1.4.2 and are shown in Figure 2-3.

2.1.6.2 Monitoring Well Development - The initial well development was performed at the SFL site following the procedures described in the Work Plans. However, turbid samples were observed during post-development purging for the baseline sampling event using the prescribed sampling procedure. Modifications to well development procedures and well sampling procedures were approved and implemented. The modified development procedures were:

FIGURE 2-6

LANDFILL CAP SAMPLE LOCATIONS

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS



LEGEND

⊙ SAMPLE LOCATION
120 LEAD CONCENTRATION IN mg/kg
MAGNETIC BEARING OF BASELINE ESTABLISHED WITH BRUNTON COMPASS, DECLINATION SET TO 0o

DRAFT FINAL RI, OCT. 1993 1530.75

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TABLE 2-3

OFF-LANDFILL (OLF) SURFACE SOIL SAMPLE LOCATIONS AND DESCRIPTIONS SOUTHWEST FUNSTON LANDFILL

SAMPLE	LOCATION/DESCRIPTION
OLF-01 and 02	Berms and trenches northeast of drill rig decontamination area, off of Well House Road. Five aliquots on linear grid across features.
OLF-03	Randomly located sample northwest of drill rig decontamination area off of Well House Road.
OLD-04 and 05	Collected from linear feature observed on old aerial photographs north of Well House Road.
OLF-06 to 08	Three samples collected from the former fire training area.
OLF-09	Sample collected from former borrow pit north of Well House Road near fire training area.
OLF-10	Sample collected from area adjacent to active borrow pit east of gate entrance on Well House Road.
OLF-11 to 13	Background samples collected off of trails at the old Territorial Capitol.
OLF-14 to 16	Three samples collected from the north side of Huebner Road.
OLF-17 to 19	Three samples collected from the former rifle range berms north of Huebner Road at the base of the river bluff.
OLF-20	Background sample collected from the top of the river bluff north of Huebner Road.

Source: PRC - Original Report, January 1993
PRC - Corrected and Revised Report, February 1993.

Notes:

All samples collected on a square five aliquot grid as used during landfill sampling unless otherwise noted. The OLF sample locations are shown on Figures 1 and 2 of the PRC Report in Appendix G. Samples OLF 11, 12, 13, and 20 were all background samples.

- Measure static water level.

- Measure total well depth.

- Surge as follows: 1) lower the surge ring/QED-brand system pump to the bottom of the monitoring well and surge the well screen with a short and gentle push/pull action (plunger-type motion) for 5 to 10 minutes; 2) pump the sediments and water from the well; 3) repeat step 1, increasing the plunger motion of the surge block to a more vigorous and longer stroking motion for 5 to 10 minutes; 4) repeat step 2 to remove sediments from the wellbore; and 5) continue alternating the surging action with pumping for a minimum of 4 hours or until the water was cleared and free of sediment.

- Remove five well volumes of groundwater plus three times the water loss during drilling/installation. Record temperature, pH, conductivity, and turbidity [in Nephelometric Turbidity Units (NTUs)] after removal of each well volume. Continue to remove water until a reading of 30 or less NTUs is achieved. If 30 NTUs cannot be achieved, notify the CEMRK Project Manager.

- Collect approximately 1 liter of water from the well in a clear glass jar, label and photograph it and submit a 35mm color slide to the CEMRK-Project Manager as part of the well log. The photograph should be a closeup and suitably backlit to show the clarity of the water.

- Record the total quantity of water removed.

- Measure static water level after 24 hours.

- Measure total well depth.

Depth of water was approximately 0.5 to 7.0 feet less during well development in late June 1992 compared to levels during the baseline sampling event in late July 1992. Rainfall amounts during July and prior to the sampling event exceeded the monthly average by more than two times. River stage conditions were also at higher levels during the sampling period in July. Both of these conditions contributed to the higher water levels observed in the monitoring wells.

The initial well development logs are presented in Appendix H; the additional well development logs are presented in Appendix I.

2.1.6.3 Monitoring Well Sampling - The baseline groundwater sampling was conducted from July 20, 1992, to July 24, 1992. Initially, dedicated bailers were to be used for groundwater sampling. However, it was observed during the pre-sample purging for the baseline sampling event that the bailing method subjected each well to a surge-type action which increased the turbidity of the groundwater samples. The sampling method was changed, prior to the baseline sampling event, to one using dedicated bladder pump systems, which were installed before groundwater sampling. Section 2.2 discusses the Technical Memorandum (TM) associated with the specific sampling procedures used. The sampling protocols at the SFL site were as follows:

- A water level indicator was used to establish the level of water in each monitoring well (which enabled the calculation of fluid volume in the casing). The water level indicator was decontaminated between each measurement.
- A dedicated bladder pump system was used to purge and collect groundwater samples (Figures 2-7 and 2-8). The bladder pump was designed to deliver a flow stream of 100 milliliters/minute to help provide volatile organic compound integrity, as well as maintain a constant flow rate throughout the sampling process. Bladder pumps in the shallow monitoring wells were placed 2 feet above the bottom of the screened interval, while bladder pumps for the intermediate and deep wells were placed 5 feet from the bottom of the screen interval. After purging a minimum of five fluid casing volumes and turbidity was determined to be below 30 NTUs, samples were collected and analyzed for the in-field indicator parameters.
- Water from purging and developing the wells was placed into 55-gallon drums, labeled, and stored at the SOC.

Subsequent quarterly sampling events were conducted in November 1992, February 1992, and May 1993. Groundwater analysis methods and results are presented in Section 4.2.2.

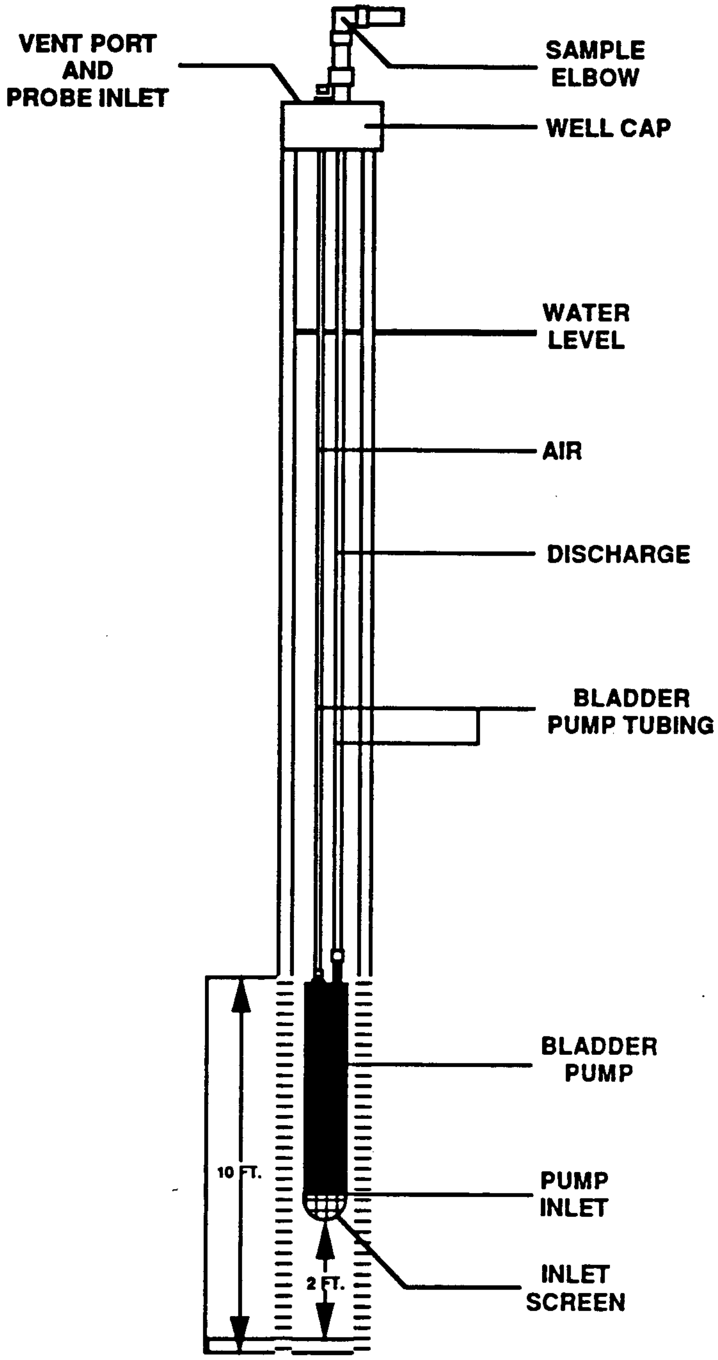
2.1.6.4 <u>Hydraulic Conductivity Field Tests</u> - Field tests to estimate the hydraulic conductivity of selected soil intervals beneath the water table were conducted at each of the SFL monitoring wells during the period of August 17, 1992, through August 21, 1992. The data were collected using pressure transducers and Hermit data loggers and analyzed using the equation and methods developed by Bouwer and Rice (1989). The Bouwer and Rice equation is as follows:

$$K = \frac{r_c^2 \ln (R_e/r_w)}{2L_e} \frac{1}{t} \ln \frac{Y_0}{Y_t}$$

FIGURE 2-7

DEDICATED WELL SYSTEM BLADDER PUMP–SHALLOW WELLS

SOUTHWEST FUNSTON LANDFILL
FT. RILEY, KANSAS



NOT TO SCALE

WELL SYSTEM BLADDER PUMP

INSTRUCTIONS

1. ATTACH INLET SCREEN TO BLADDER PUMP (IF APPLICABLE).
2. ATTACH BLADDER PUMP TUBING TO PUMP.
3. LOWER PUMP TO DESIRED DEPTH.
4. PASS DISCHARGE TUBE THROUGH CAP AND ATTACH AIR LINE UNDER CAP.

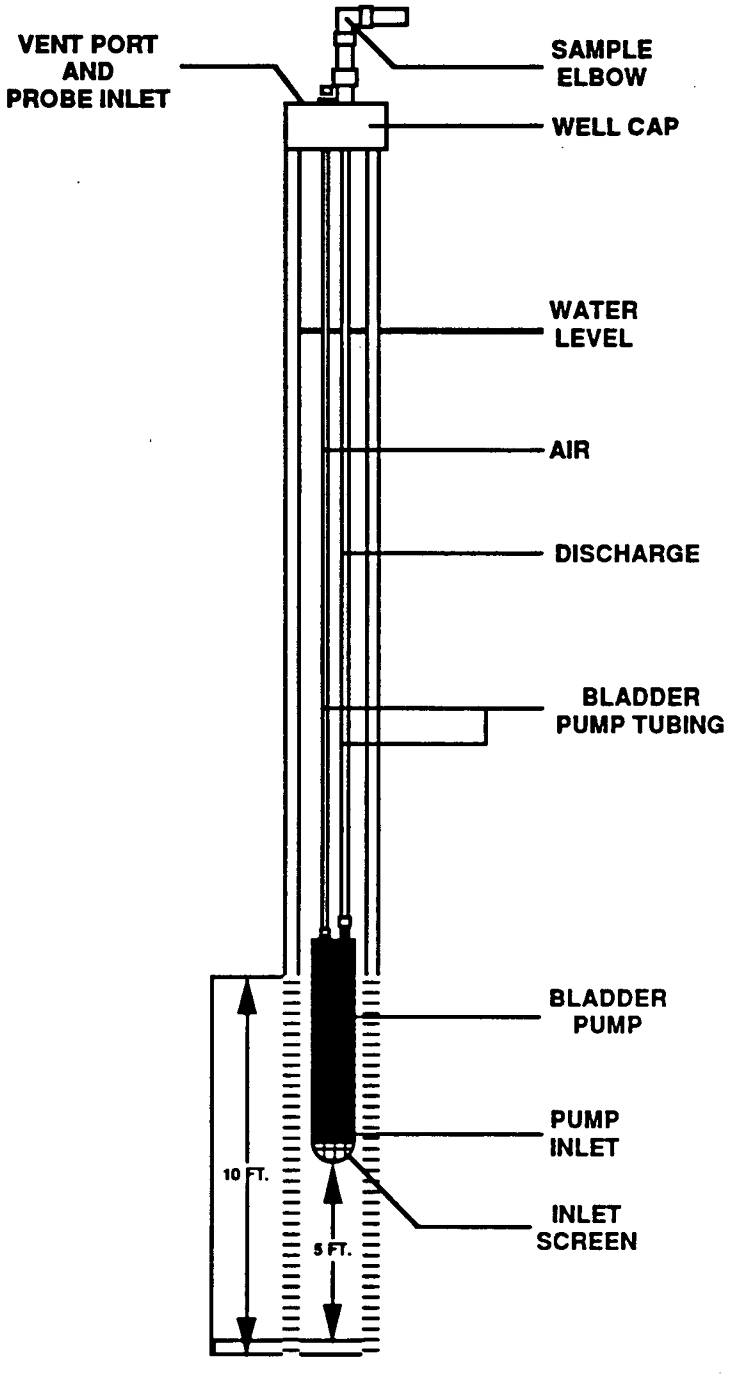
SOURCE: SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

NOTE: BOTTOM OF PUMP IS APPROXIMATELY 2 FEET ABOVE THE BOTTOM OF THE WELL

FIGURE 2-8

DEDICATED WELL SYSTEM
BLADDER PUMP–INTERMEDIATE AND DEEP WELLS

SOUTHWEST FUNSTON LANDFILL
FT. RILEY, KANSAS



NOT TO SCALE

WELL SYSTEM BLADDER PUMP

INSTRUCTIONS

1. ATTACH INLET SCREEN TO BLADDER PUMP (IF APPLICABLE).
2. ATTACH BLADDER PUMP TUBING TO PUMP.
3. LOWER PUMP TO DESIRED DEPTH.
4. PASS DISCHARGE TUBE THROUGH CAP AND ATTACH AIR LINE UNDER CAP.

SOURCE: SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

NOTE: BOTTOM OF PUMP IS APPROXIMATELY 5 FEET ABOVE THE BOTTOM OF THE WELL

Where:

K = Hydraulic conductivity (feet/sec)
L_e = Well screen length (feet)
Y = Vertical difference in water level inside well and static water table (feet) (general definition, see Y_o and Y_t below for analytical usage)
R_e = Effective radius distance over which Y is dissipated (feet)
r_w = Radius of screen plus filter pack (feet)
r_c = Casing (riser) radius (feet)
Y_0 = Displacement at time zero (minutes)
Y_t = Displacement at time "t" (minutes)
t = Time (minutes)

Initially, depth to groundwater was measured from the top of the casing. This static water level, along with the total depth of the well, was used to determine the depth of the water column and placement of the pressure transducer. The existing groundwater sampling bladder pump was then removed and placed on clean plastic sheeting. The transducer cable was connected to a Hermit Data Logger (Hermit-SE 1000C) and was lowered into the well to a depth of less than 23 feet below the top of the water table. The transducer would be damaged if subjected to water pressure at depths greater than 23 feet. The transducer depth was displayed on the Hermit unit, and the water level was allowed to stabilize. Once stabilization was achieved, the transducer was then referenced to zero feet. The "slug in" or "slug out" water levels were then monitored and recorded. During the permeability test field activity, the groundwater levels in seven of the eight shallow monitoring wells were above the screen intervals, thus allowing "slug-in" tests to be performed. A "slug-in" test was not performed for well SFL92-501 because the groundwater level in this well was below the top of the screen interval.

While performing the slug-in tests, the slug (a 5-foot long by 1.75-inch solid PVC rod) was lowered using poly-rope until it was one to two feet above the water level. The slug was then quickly lowered into the water and, at the same time, the data logger was switched on. As the groundwater level fell toward static water conditions, the data logger recorded the change in water levels or change in head. Several readings per second were taken near the start of the test, and the time between readings gradually increased as the test ran. The test was stopped when the water level returned essentially to static conditions.

While performing the slug-out tests, the slug remained in the well from the prior slug-in test, and the transducer was again referenced to zero. The data logger was switched on at the same time the slug was pulled out above the water level in the well. As the water level rose in the well, the data logger recorded the levels in a logarithmic mode until the water returned to essentially static conditions. The transducer was then removed from the well, and the bladder pump was placed back into the well. Downhole equipment was cleaned between each well. Data were transferred from the data logger to a computer disk for later analysis. The results are presented in Section 3.6.2.

2.1.6.5 Private Irrigation Well - A privately owned irrigation well is located adjacent to the SFL site, west of the old channel as shown in Figure 2-1. Because of its proximity to the SFL site, the groundwater at this well was also sampled during the baseline sampling of the new monitoring wells at the SFL. Groundwater samples collected from this well were analyzed for the same parameters as those collected from the new SFL monitoring wells. Data collected from the irrigation well have been used to aid in the assessment of the potential impacts to human health and the environment within a mile radius of the SFL site. However, the data from the private irrigation well were not used in the baseline risk assessment calculations. These data are used for qualitative comparisons with groundwater samples collected from the SFL monitoring wells. Section 4.2.2 discusses the contaminants which were detected in this well.

The private irrigation well was installed and completed on August 8, 1991, and replaced an older well which had been plugged. The old well was plugged due to screen collapse and sand heaving into the pump. The current irrigation well was installed to 59 feet below ground surface and consists of 16-inch diameter PVC casing and screen with glued joints (Appendix C). The screen inlet slots were cut with a saw and are capable of yielding up to 1500 gallons per minute. The screen interval for this well is between 39 and 59 feet below ground surface. According to the access agreement, as negotiated and secured by CEMRK, the owner of the well is contacted before each sampling event so samples can be collected. Because the first and second quarters for groundwater sampling (November and February, respectively) occurred during the winter months and at a time when the well had been winterized and temporarily taken out of service, samples were not collected. Samples were not collected during the third quarterly sampling event either because the spring of 1993 experienced typical precipitation and the well had not yet been returned to service. Groundwater sampling procedures were performed as outlined in the Technical Memorandum dated July 7, 1992 (Appendix Q).

2.1.7 Area Population

Available demographic data were reviewed to determine the current population of nearby cities and towns to assist in evaluating potential risk(s) associated with the SFL activities. Telephone interviews were conducted with appropriate local officials, and available literature/documentation was reviewed. The results are presented in Section 1.2.1.

2.1.8 Ecological Investigation

An ecological investigation was performed at the SFL site because of the potential impacts from the migration of contaminants from the landfill. The depth and methods by which materials were placed in the landfill and the periodic surface flooding by the adjacent Kansas River supported the need for this investigation. The objective of the ecological investigation was to identify and describe the population status of aquatic macroinvertebrates and to ascertain the status of threatened or endangered species and their habitats in the vicinity of the SFL site. The following sections describe the field investigative activities of the macroinvertebrate study and the threatened and endangered species study. Results of these activities are presented in Section 3.8.

2.1.8.1 Macroinvertebrate Study - An attempt was made to perform a macroinvertebrate assessment. Artificial substrate samplers (Hester-Dendy) were placed at seven sampling stations on July 15 and 16, 1992 (Figure 2-9). The sampling objectives are described in Table 2-1; the sampling locations are described in Table 2-2. The study was to be conducted when the Kansas River stage was in the low end of its range. Based on data between July 1992 and May 1993 (Table 3-5), the river stage ranged from approximately 4.5 to 18.5 feet.

During the placement of the samplers, the Kansas River stage was approximately 7.5 feet (the Kansas River stage height data used in this report were recorded at the Fort Riley (MAAF) gage station located next to the Henry Street Bridge at Kansas River mile 168.9). After placement of the substrate samplers, the river reached a crest height of 16.4 feet on July 24, 1992. Therefore, the samplers were exposed to a higher flow regime than anticipated. On September 1 and 3, 1992, the artificial substrate samplers were retrieved. At that time, sediment grab and sweep net samples were collected. The stage of the Kansas River during this event was 6 feet. The status of the sampling collections were as follows:

- Artificial substrate samplers were missing from the comparison station.
- Artificial substrate samplers (three or more) were retrieved from the remaining six site stations.
- Grab samples were collected from all sampling stations.
- Sweep net samples were collected from all sampling stations.

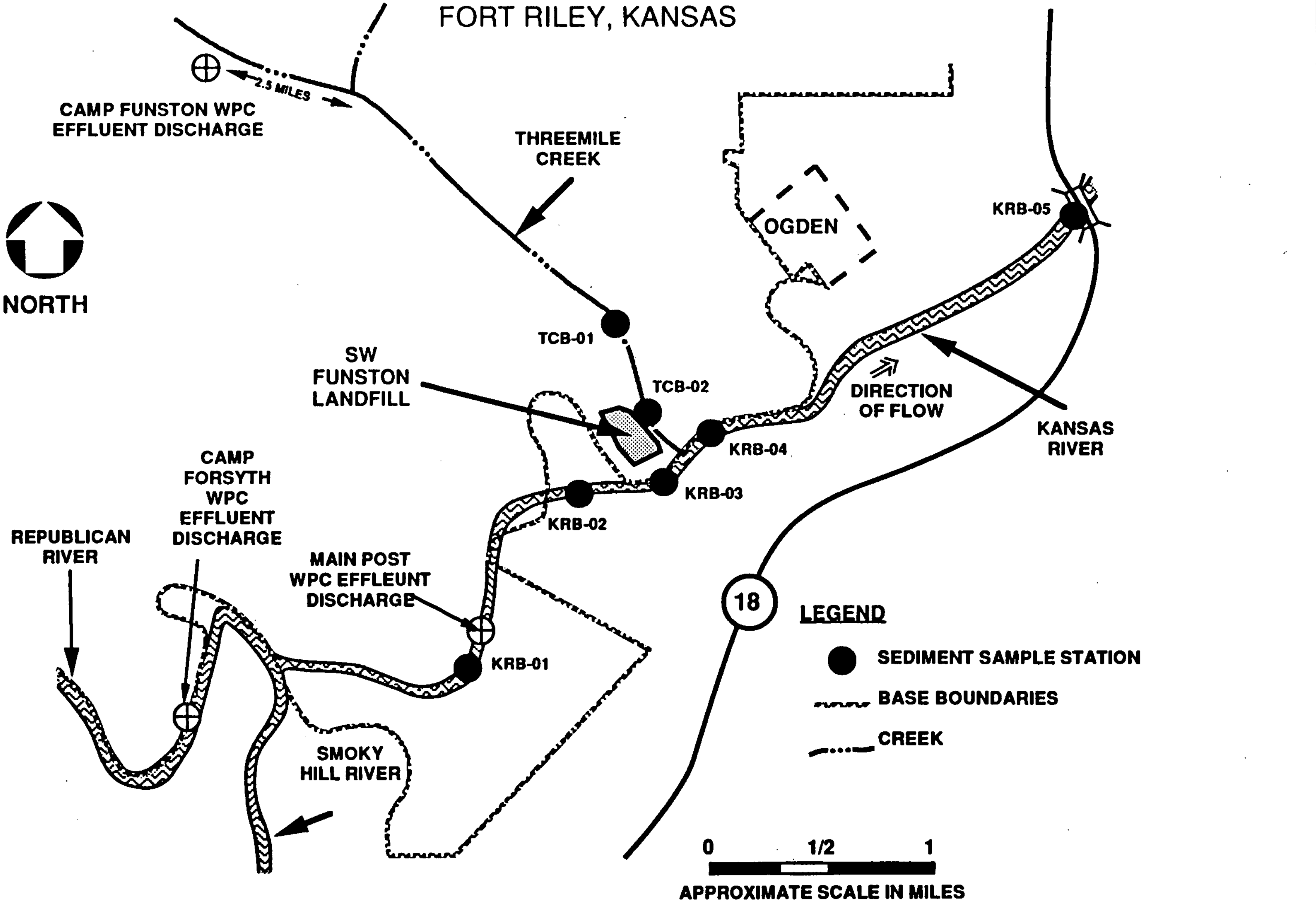
Several conversations between the CEMRK, DEH, and Law concerning the technical reliability of the data resulted in the termination of analysis of the substrate samplers, grab samples, and sweep samples at SFL. High river conditions dislocated several of the benthic sediment samplers so that the expected sampling population was reduced to levels that were considered non-representative. Also, based on the unanticipated high flow conditions, non-representative sediment dwellers were expected to be present at the intact sample locations. Therefore, the macroinvertebrate samples collected were not evaluated for this investigation.

2.1.8.2 Threatened and Endangered Species - A literature search and review were performed to aid in determining the status of any existing threatened and/or endangered species and their habitats. A threatened and endangered survey was performed by U.S. Fish and Wildlife Service

FIGURE 2-9

MACROINVERTEBRATE SAMPLING LOCATIONS

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS



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at the SFL to evaluate the status and impact upon the habitats located within or directly adjacent to the site (USFWS, 1992; Appendix R). In addition, during collection of the macroinvertebrate samples, a site reconnaissance was conducted to verify the presence or absence of habitats which could potentially support threatened or endangered species. The site reconnaissance consisted of a day long walkover of the SFL site and adjacent areas within a 5 mile radius of the SFL by two natural resource personnel from Law. The results of the U.S. Fish and Wildlife Service survey and the site reconnaissance are presented in Section 3.8.2.

2.2 TECHNICAL MEMORANDA

This section summarizes the changes or deviations from the planned field activities presented in the Work Plans. These changes resulted from either unanticipated conditions encountered while in the field and/or from specific changes in scoping or tasks. Due to the significant changes in field activities, these changes were documented in the form of Technical Memoranda and reviewed and approved by the Army, EPA and KDHE (Appendix Q). Following is a list by subject of the SFL Technical Memoranda:

- Change of Drilling and Installation Methods for the SFL Monitoring Wells, March 30, 1992 (Assumed to be Technical Memorandum No. SFL-001).

- Sampling Procedure for Private Irrigation Well at Southwest Funston Landfill, July 7, 1992, Technical Memorandum No. SFL-003.

- Sampling Procedures for Monitoring Wells at the Southwest Funston Landfill, July 10, 1992, Technical Memorandum No. SFL-004.

An additional Technical Memorandum (SFL-002) was drafted on July 7, 1992 which addressed abandonment of the six existing closure wells at the SFL site. There have been numerous discussions between the Army and CEMRK concerning these wells. It was concluded that these wells may serve as "piezometers" and thus provide useful hydrogeologic data. Therefore, as of the writing of this report, these wells have not been abandoned. However, the final disposition of these wells has not been determined.

3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section addresses the physical characteristics of the study area at the SFL, including descriptions of:

- Land surface and physiographic features
- Meteorology
- Surface water hydrology
- Surficial soils
- Geology
- Hydrogeology
- Demographics and land use
- Ecology

The investigative tasks performed to support this study provided data for evaluating selected physical characteristics of the SFL study area. The evaluation of these data are presented in this section.

3.1 LAND SURFACE AND PHYSIOGRAPHIC FEATURES

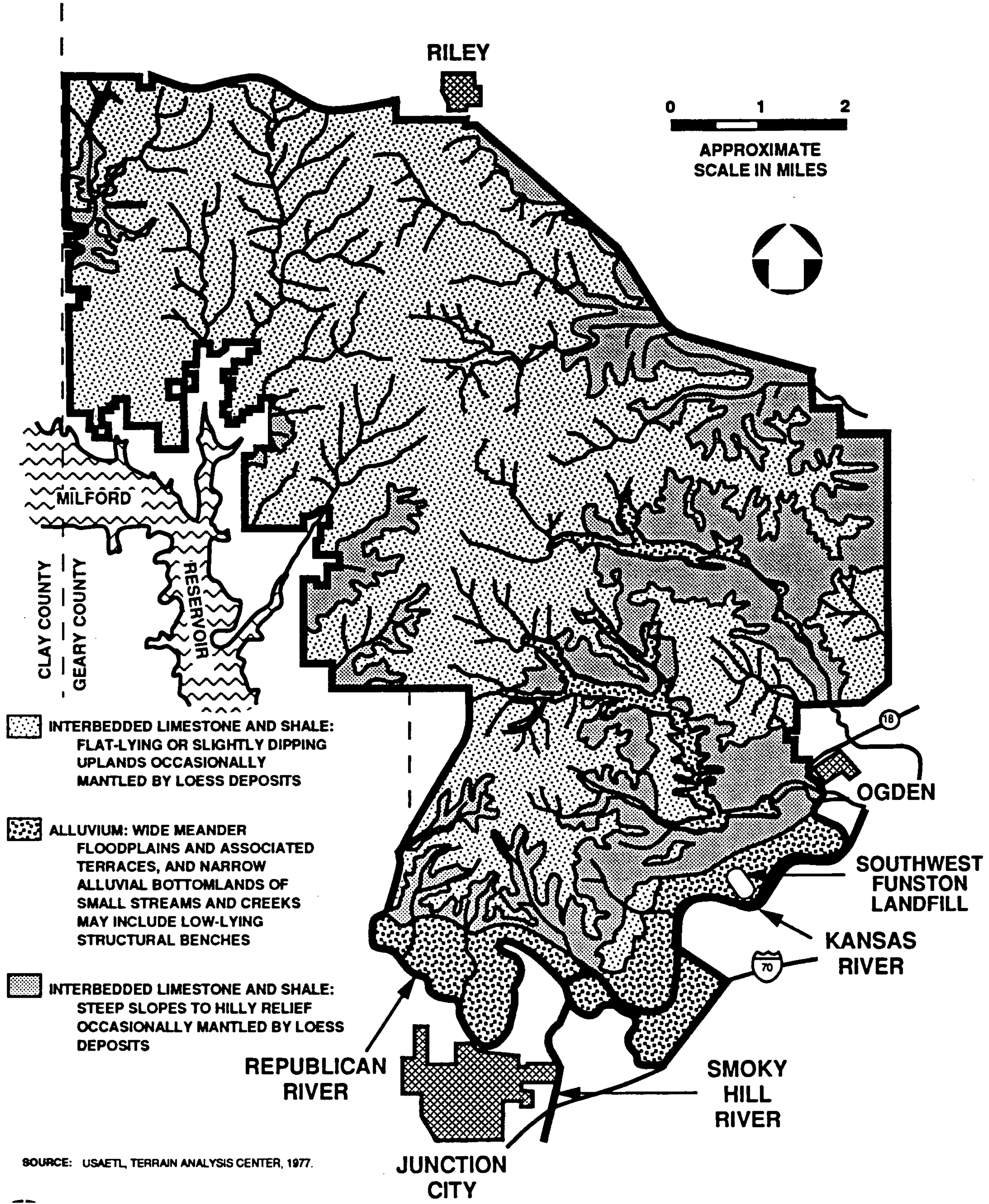
Fort Riley lies within the Osage Plains section of the Central Lowlands physiographic province. The general topography around Fort Riley consists of plains incised by steep drainage features. The elevation within Fort Riley ranges from 1,025 to 1,356 feet above mean sea level (msl). Terrain on the installation varies among (1) narrow alluvial bottomlands and wide meander flood plains and associated terraces along the Republican and Kansas Rivers, (2) steep slopes and hilly relief, and (3) flat-lying or slightly dipping uplands. Figure 3-1 illustrates these different terrain features.

The SFL is located in the alluvial bottomlands adjacent to the Kansas River and is relatively flat topographically with very little relief. The SFL site slopes very gently toward the east-southeast. Steep slopes exist along the banks of the Kansas River to the south and at the boundary of Threemile Creek to the east. The elevation of the capped landfill surface varies from about 1045 to 1052 feet msl. Plate 1 is a topographic contour map at two foot intervals of the general landfill area. It was prepared in November 1991 from land surveying on 100-foot centers. Survey data from surface water, sediment, soil, and groundwater sample locations are provided on Table 3-1.

FIGURE 3-1

GEOLOGIC MAP OF FORT RILEY

FORT RILEY, KANSAS



SOURCE: USAETL, TERRAIN ANALYSIS CENTER, 1977.

TABLE 3-1

SURVEY DATA SUMMARY FOR CLOSURE WELLS, MONITORING WELLS, SEDIMENT AND SURFACE WATER LOCATIONS

Southwest Funston Landfill
Fort Riley, Kansas

POINT NO.	NORTHING	EASTING	GROUND ELEVATION	TOP OF CASING ELEVATION
MW-1	276,893.46	2,356,481.70	1050.6	1053.50
MW-2	276,470.49	2,357,621.55	1047.6	1050.14
MW-3	276,142.81	2,358,889.20	1046.4	1049.24
MW-4	275,394.36	2,358,732.51	1051.1	1053.83
MW-5	275,500.67	2,357,531.98	1047.8	1050.34
MW-6	276,818.42	2,358,051.30	1046.5	1049.08
SFL92-101	278,771.07	2,354,102.87	1068.3	1069.98
SFL92-102	278,788.91	2,354,131.17	1067.6	1069.51
SFL92-103	278,784.81	2,354,116.29	1067.9	1069.81
SFL92-201	275,969.27	2,356,778.55	1046.0	1047.46
SFL92-203	275,987.22	2,356,767.38	1047.3	1049.35
SFL92-301	275,397.67	2,357,706.99	1048.4	1050.30
SFL92-302	275,397.95	2,357,723.64	1048.5	1050.19
SFL92-303	275,406.63	2,357,711.67	1048.6	1058.48
SFL92-401	275,465.94	2,359,073.02	1048.2	1050.07
SFL92-403	257,483.76	2,359,080.34	1048.0	1049.86
SFL92-501	276,774.73	2,359,609.62	1047.4	1049.22
SFL92-502	276,806.60	2,359,604.37	1046.4	1048.21
SFL92-503	276,789.17	2,359,606.63	1045.0	1048.46
SFL92-601	277,208.53	2,357,919.89	1052.2	1054.08
SFL92-602	277,212.76	2,357,944.58	1051.9	1053.93
SFL92-603	277,176.13	2,357,925.98	1051.7	1053.77
SFL92-701	278,415.93	2,357,971.96	1046.6	1048.21
SFL92-703	278,427.50	2,357,986.04	1045.9	1047.74
SFL92-801	278,512.92	2,356,599.47	1051.7	1053.50
SFL92-803	278,503.38	2,356,590.63	1051.9	1053.66
TCSD-01	281,585.63	2,356,045.02	1043.9	NA
TCSW-01	281,578.24	2,356,043.23	1043.6	NA
*TCSD-02	276,070.29	2,359,929.43	1033.8	NA
*TCSW-02	276,074.76	2,359,928.72	1032.3	NA
KRSD-01	267,225.65	2,341,228.28	1044.7	NA
KRSW-01	267,221.69	2,341,198.00	1044.2	NA
KRSD-02	264,669.38	2,347,605.45	1042.2	NA
KRSW-02	264,687.40	2,347,659.39	1041.9	NA
*KRSD-03	275,314.85	2,357,782.83	1042.4	NA
*KRSW-03	275,306.33	2,357,779.73	1032.7	NA
*KRSD-04	276,460.66	2,360,253.61	1032.4	NA
*KRSW-04	276,457.39	2,360,285.95	1032.2	NA
KRSD-05	278,084.31	2,364,736.05	1030.6	NA
KRSW-05	278,082.86	2,364,736.04	1030.1	NA

Notes:

MW = Closure Well
SFL92 = Southwest Funston Landfill Monitoring Well
TCSD/SW = Threemile Creek Sediment/Surface Water Sample
KRSD/SW = Kansas River Sediment/Surface Water Sample
NA = Not Applicable
Northings and eastings are based on the Lambert Coordinate Systems.
* Survey location was estimated.

3.2 METEOROLOGY

Based upon average monthly climatological data collected at the Marshall Airfield weather station near Fort Riley, the area experiences a temperate climate with a mean temperature of 80 degrees Fahrenheit (°F) in July and a mean temperature of 27°F in January.

Prevailing wind direction varies from south to southwest during the period of April to January and from a northerly direction during the months of February and March. Mean wind speed is fairly constant at 8 miles per hour with a normal maximum of 12 miles per hour.

Average annual precipitation near Fort Riley is approximately 35 inches. Approximately 70 percent of annual precipitation occurs from April through September. Twenty-four-hour event totals can exceed 3.5 inches from April through October during thunderstorm periods. June and July experience the highest incidence of thunderstorms per month. Lake evaporation is approximately 50 inches per year. Fort Riley is in a subhumid climatic region which would produce evapotranspiration rates approximately equal to the rainfall amount (USGS, 1993).

Average monthly precipitation and air temperature data for 1962 through 1992 consist of:

		Extreme Maximum Temperature	Mean Temperature	Extreme Minimum Temperature	Rain fall	Snow Fall
	DEC	77°F	32°F	-14°F	1.20"	4.00"
Winter	JAN	75°F	27°F	-26°F	0.90"	5.00"
	FEB	86°F	32°F	-21°F	1.00"	4.00"
	MAR	90°F	42°F	-10°F	2.20"	4.00"
Spring	APR	94°F	55°F	7°F	3.00"	1.00"
	MAY	100°F	65°F	27°F	4.60"	0.00"
	JUN	110°F	74°F	40°F	5.70"	0.00"
Summer	JUL	112°F	80°F	43°F	3.80"	0.00"
	AUG	109°F	78°F	45°F	3.40"	0.00"
	SEP	112°F	69°F	30°F	3.50"	0.00"
Fall	OCT	100°F	56°F	20°F	2.90"	0.00"
	NOV	84°F	43°F	-9°F	1.40"	1.00"

Source: First Weather Group, Detachment 8, Fort Riley Marshall Airfield

Daily precipitation amounts for the period July 1992 through May 1993 are provided on Table 3-2 and illustrated on Figure 3-2. All data were measured at Marshall Army Air Field approximately 4 miles southwest of the SFL. These data are assumed to be representative of rainfall at SFL. The July and November 1992 rainfall and the May 1993 rainfall exceeded the 30-year average by more than twice. Rainfall during all other months between August 1992 to April 1993 are within about one inch of the 30-year average. The relationship of precipitation patterns to river stage and infiltration is discussed in Sections 3.3.1.2 and 3.6.2.4, respectively.

TABLE 3-2

DAILY PRECIPITATION FOR JULY 1992 THROUGH MAY 1993
Marshall Army Air Field
Fort Riley, Kansas

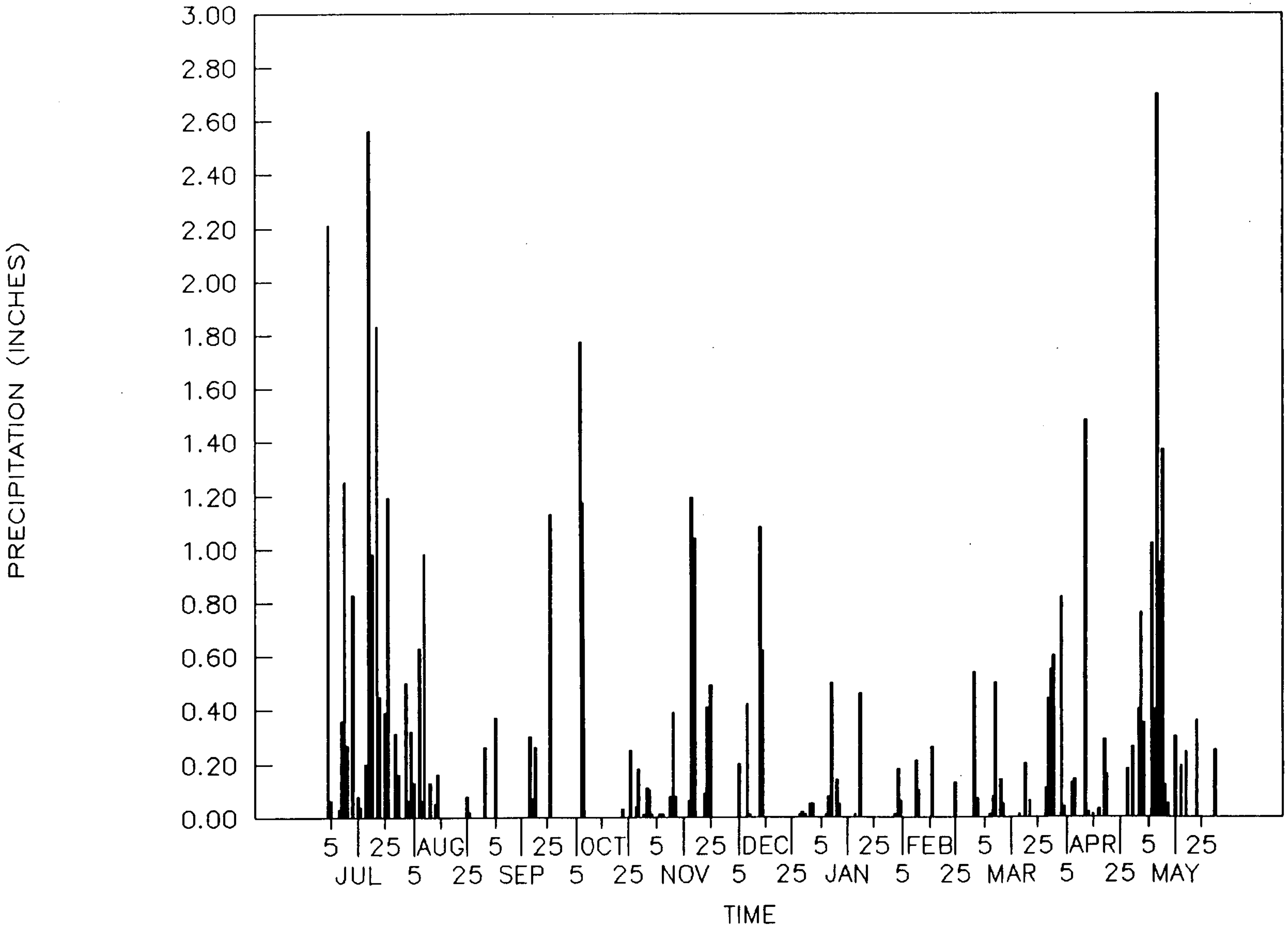
	1992						1993				
DATE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY
01	0	0	0.26	0	0.11	0	0.05	0	0.54	0	0.4
02	0	0.5	T	0	0.1	0	0.05	0.01	0.07	0	0.76
03	0	0.06	0	0	0.01	0	0	0.18	0	0.82	0.35
04	2.21	0.32	0	0	T	0	0	0.06	0	0.04	0
05	0.06	0.13	0.37	0	0	0.2	0	0	0	0	0
06	0	0	0	0	0.01	0	0	0	0	0	1.02
07	0	0.63	T	1.77	0.01	0	0.01	0	0.01	0.13	0.4
08	0.03	0.06	T	1.17	0	0.42	0.08	0	0.08	0.14	2.7
09	0.36	0.98	0	0	T	0.01	0.5	0	0.5	0	0.95
10	1.25	0	0	0	0.08	0	0	0.21	0	0	1.37
11	0.27	0.13	0	0	0.39	0	0.14	0.1	0.14	0	0.12
12	T	T	0	0	0.08	0	0.05	T	0.05	1.48	0.05
13	0.83	0.05	0	0	0	1.08	0	0	0	0.02	0
14	0	0.16	0	0	0	0.62	0	0	0	0	0
15	0.08	0	0	0	0	0	0	0	0	0.01	0.3
16	0.04	0	0	0	0	0	0	0.26	0	0	0
17	T	0	T	0	0.06	0	0	T	0	0.03	0.19
18	0.2	0	0.3	0	1.19	0	0.01	0	0.01	0	0
19	2.56	0	0.07	T	1.04	0	0	0	0	0.29	0.24
20	0.98	0	0.26	0	T	0	0.46	T	0.2	0.16	0
21	0	0	T	0	T	0	0	T	0	0	0
22	1.83	0	0	0	0	0	0	0	0.06	0	0
23	0.45	0	0	0.03	0.09	0	0	T	0	0	0.36
24	0	0	0	0	0.41	0	0	T	0	0	0
25	0.39	0.08	0	0	0.49	0	0	0.13	0	0	0
26	1.19	0.02	1.13	0.25	0	0	0	T	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0.04	0	0.01	0	0	0.11	0.18	0
29	0.31	0	0	0.18	0	0.02	0	---	0.44	0	0
30	0.16	0	0	T	0	0.01	0	---	0.55	0.26	0.25
31	0	0	---	0.01	---	0	0	---	0.6	---	0
TOTAL	13.2	3.12	2.39	3.45	4.07	2.37	1.35	0.95	3.36	3.56	9.46
1962-92 TOTALS	3.8	3.4	3.5	2.9	1.5	1.6	1.4	1.4	2.6	3.1	4.6

Data measurements in inches
T = Trace of precipitation (less than 0.005 inches)
Rain gage data collected at Marshall Army Air Field, Fort Riley, Kansas
Data provided by Detachment 8, 1st Weather Group and is representative of rainfall at the Southwest Funston Landfill, located approximately 4 miles northeast of MAAF. Localized, heavy rainfall events normally occur between April to June which may not cover both the MAAF and SFL area during these months.
Total values include conversion of snowfall to fluid by dividing snowfall by 10 for 1962-1992 average data and reported inches of melted snow for the July 1992 to May 1993 data.

FIGURE 3-2

Daily Precipitation July 1992—May 1993

Marshall Army Air Field, Fort Riley, KS



3.3 SURFACE WATER HYDROLOGY

Rainfall-runoff patterns on the Fort Riley installation are influenced primarily by overland flow to ditches, concrete-lined channels, impoundments, and area streams and rivers. Figure 3-3 illustrates the surface water drainage features in the vicinity of the installation. The following sections describe the surface drainage features that are relevant to the SFL.

3.3.1 Rivers

The major rivers in the vicinity of the site are the Republican, Smoky Hill, and Kansas rivers. The Smoky Hill River joins the Republican River to form the headwaters of the Kansas River approximately 5 miles upstream of the SFL (Figure 3-3). The Kansas River flows easterly, just south of the SFL site, and eventually drains into the Missouri River at Kansas City. Before the construction of Milford Dam (1965), major flooding of three- to five-day durations occurred approximately every 8 to 10 years. Historical records indicate that the SFL site and adjacent Camp Funston experienced repeated surface flooding in 1951. The levee between the SFL and Camp Funston (Figure 3-4) was raised in response to the 1951 floods. According to the Federal Emergency Management Agency (FEMA) flood insurance rate map dated January 1982, the entire SFL area is within the 100-year flood elevation of 1061.3 feet msl. The reported 50-year flood elevation is 1052.6 feet msl, which is above the SFL ground surface (FEMA, 1982).

3.3.1.1 Flow Characteristics of the Smoky Hill, Republican, and Kansas Rivers - River discharge rates have been reviewed to provide estimates of the contribution of the Smoky Hill and Republican Rivers to flow in the Kansas River at the gage station near Fort Riley. The mean annual river discharge rates from USGS gage stations on the Smoky Hill River (at Enterprise, KS, Station No. 06877600), Republican River (below Milford Dam, Station No. 06857100) and the Kansas River (at Fort Riley, Station No. 06879100) during the period 1978-1987 are listed on Table 3-3. The Smoky Hill gage station is approximately 43 miles upstream of its confluence with the Republican River and the Republican gage station is approximately 6 miles upstream of its confluence with the Smoky Hill River. The confluence of these two rivers forms the headwaters of the Kansas River. The Kansas River gage station at Fort Riley is approximately 1.5 miles downstream of its headwaters.

The Smoky Hill River mean annual discharge varied from 718 cubic feet per second (cfs) in 1978 to 3,204 cfs in 1987. The Republican River mean annual discharge varied from 445 cfs in 1981 to 1,962 cfs in 1987. The Kansas River mean annual discharge varied from 1,434 cfs in 1981 to 5,595 cfs in 1987.

FIGURE 3-3

SURFACE WATER DRAINAGE FEATURES

FORT RILEY, KANSAS

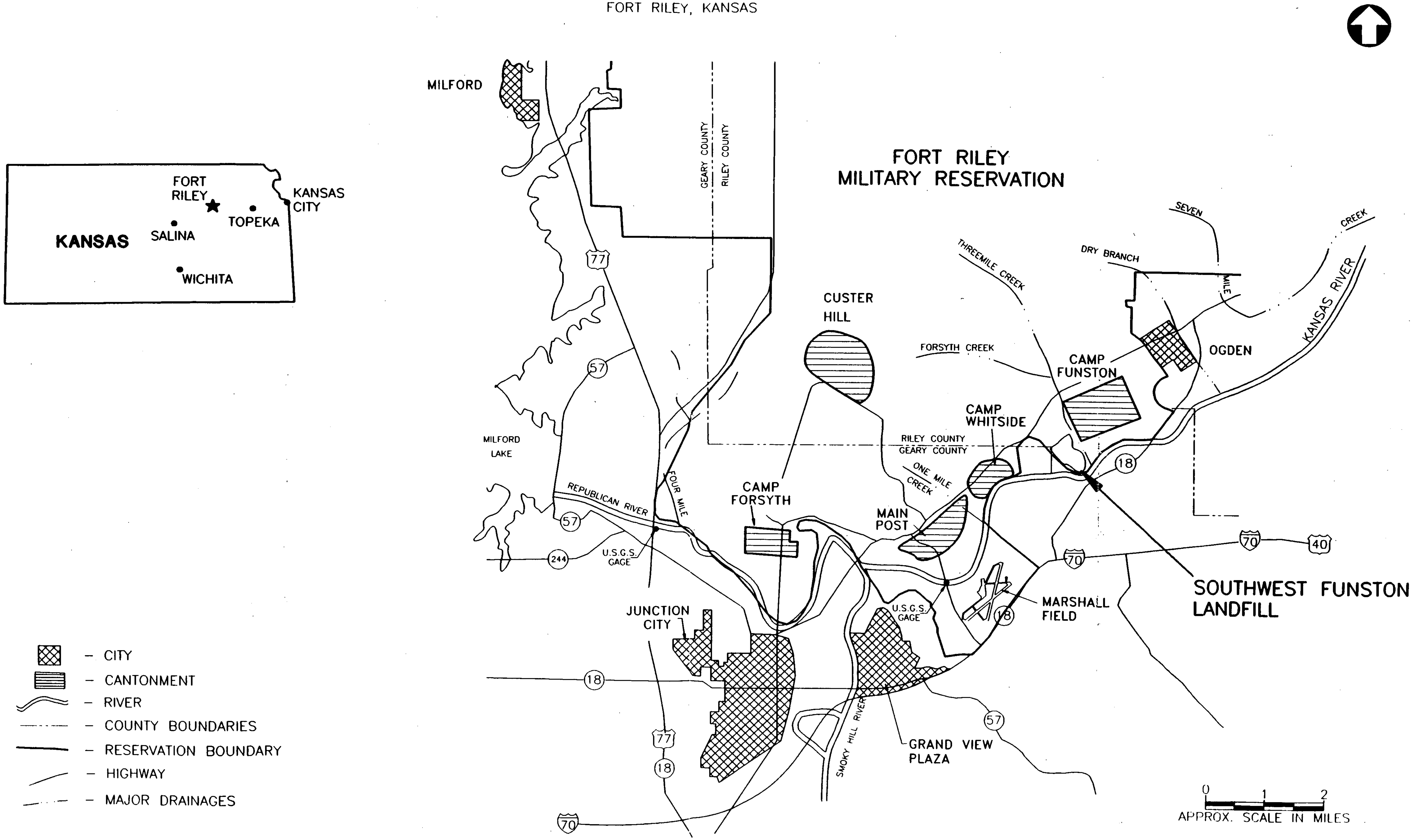


FIGURE 3–4

FLOOD MAP
SOUTHWEST FUNSTON LANDFILL

FORT RILEY, KANSAS

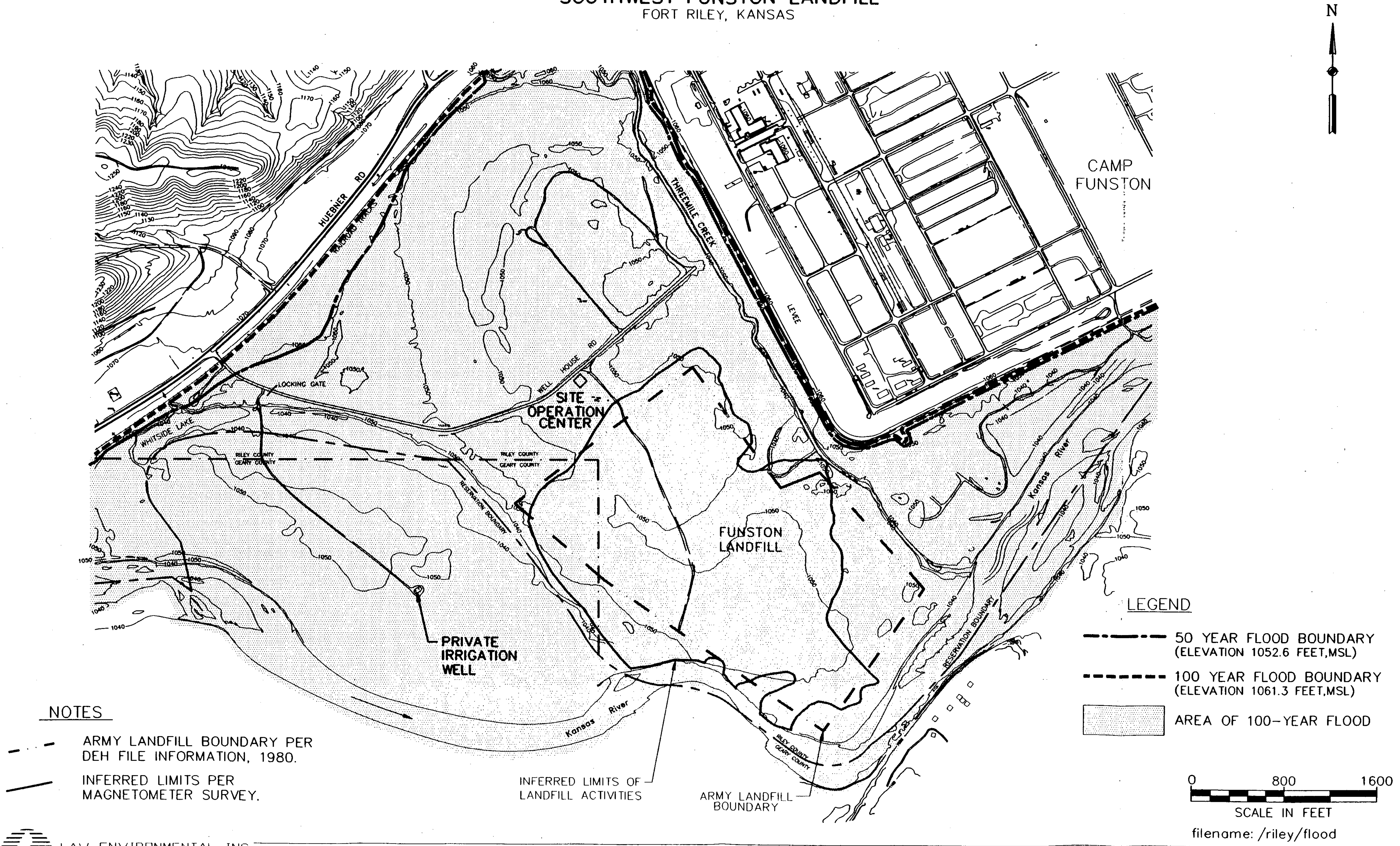


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TABLE 3-3

MEAN ANNUAL DISCHARGE, 1978-1987
SMOKY HILL, REPUBLICAN, AND KANSAS RIVERS
(values in cubic feet per second)

YEAR	SMOKY HILL	REPUBLICAN	KANSAS
1978	718	651	1,766
1979	1,873	1,141	3,542
1980	1,032	642	2,142
1981	796	445	1,434
1982	1,668	1,138	3,253
1983	720	981	2,004
1984	1,146	1,186	2,882
1985	1,239	886	2,741
1986	726	1,484	2,690
1987	3,204	1,962	5,595

Smoky Hill – discharge at Smoky Hill River gage station located at Enterprise, Kansas, approximately 43 miles upstream from Kansas River headwaters. USGS Station No. 06877600.

Republican – discharge at Republican River gage station located below Milford Dam, approximately 6 miles upstream from Kansas River headwaters. USGS Station No. 06857100.

Kansas – discharge at Kansas River gage station located at Fort Riley, approximately 1.5 miles downstream from Kansas River headwaters. USGS Station No. 06879100

Mean daily discharges for the Smoky Hill River (Enterprise, Kansas), two tributaries to the Smoky Hill downstream of Enterprise, Kansas, (Chapman Creek and Lyon Creek) and the Republican River below Milford Dam were obtained from the USGS Water Resources Data Report for Kansas as listed below (USGS, 1992).

GAGE STATION	MEAN DISCHARGE	PERIOD OF RECORD
Smoky Hill River at Enterprise, Kansas	1469 cfs	1935-1992
Chapman Creek	82 cfs	1954-1992
Lyon Creek	104 cfs	1953-1974
Republican River below Milford Dam	858 cfs	1968-1992

The periods of record are variable based on data collection periods. Chapman Creek and Lyon Creek join the Smoky Hill River about 25 miles and 3 miles upstream, respectively, from the Kansas River headwaters. Both these creeks contribute to the total flow in the Smoky Hill River.

The annual discharge data and mean daily values for the Smoky Hill and the Republican rivers indicate the Smoky Hill contributes about 65 percent of the flow in the Kansas River near Fort Riley. Milford Dam releases, which represent the largest fraction of total flow at the Republican River gage, contribute about 30 percent of the flow in the Kansas River. The remaining five percent is attributed to the watershed area of the Kansas River between the confluence of the Smoky Hill and Republican River and the Kansas River gage station at Fort Riley.

3.3.1.2 Flow Characteristics of the Kansas River near SFL - Based on annual peak gage height and discharge values at the Kansas River gage between 1964 and 1992 (Table 3-4), the Kansas River exhibits highest water stages between March through October. The lowest river stages usually occur between November and February.

Table 3-5 provides the daily peak gage heights for the Kansas River for the period July 1992 through May 1993. The data record is considered provisional by the USGS for the period October 1992 to May 1993. Final reporting of these data will occur near the end of 1993; however, the data are considered reliable for purposes of this report. These data, which are illustrated on Figure 3-5, indicate that the highest water stages (which appear as peaks on the figure) occurred principally between February and May 1993, with three additional high water stages recorded during the intervals of July 21 to August 20, October 10 to 13, and December 14 to 18, 1992.

TABLE 3–4

KANSAS RIVER AT FORT RILEY, KANSAS
PEAK GAGE HEIGHTS FROM 1964 TO 1992
Fort Riley, Kansas

YEAR	DATE MEASURED	DISCHARGE RATE (CFS)	PEAK GAGE HEIGHT (FT)
1964	23–Jun	17700.00	14.88
1965	29–Jun	27500.00	17.40
1966	23–Aug	8950.00	11.50
1967	21–Sep	26800.00	17.55
1968	07–Oct	29900.00	18.31
1969	12–Jun	21500.00	15.94
1970	04–Jun	15160.00	14.02
1971	23–May	34300.00	18.46
1972	04–Sep	18000.00	– –
1973	11–Mar	25700.00	17.44
1974	14–Oct	59400.00	23.74
1975	26–Jun	17000.00	14.36
1976	29–Apr	14400.00	13.05
1977	18–Jun	22900.00	16.03
1978	15–Mar	9910.00	11.24
1979	25–May	22900.00	16.03
1980	31–Mar	26500.00	16.99
1981	30–Jul	9640.00	11.12
1982	10–Jul	25700.00	16.80
1983	07–Apr	9890.00	11.53
1984	01–Mar	19600.00	14.93
1985	05–Jun	16180.00	13.71
1986	11–Oct	24500.00	16.51
1987	16–Apr	25900.00	17.02
1988	03–Oct	3420.00	7.31
1989	10–Sep	11700.00	12.37
1990	17–Aug	15800.00	13.90
1991	06–Jun	7400.00	10.39
1992	26–Jul		16.37

NOTES:

Gage Datum Elevation = 1034.69 feet
– – Not Obtained
CFS – Cubic Feet per Second
FT – Feet
* – Station No. 06879100 is a USGS water stage recorder site located on the right bank at the downstream side of Military Highway Bridge, 1.5 miles below the confluence of the Republican River and the Smoky Hill River at Kansas River mile 168.9.

Source: USGS – Water Resources Division, Kansas River at Fort Riley, February 1993

TABLE 3–5

KANSAS RIVER AT FORT RILEY, KANSAS
AVERAGE DAILY PEAK GAGE HEIGHTS (FT)
FROM JULY 1992 TO MAY 1993
Fort Riley, Kansas

	1992						1993				
DAY	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
1	4.78	10.03	6.00	4.56	5.17	7.37	5.78	6.68	8.75	12.83	8.66
2	4.75	10.08	6.23	4.49	5.13	7.34	5.69	6.55	10.20	13.08	9.04
3	4.71	10.33	6.18	4.44	5.08	7.42	5.89	7.33	13.38	13.15	12.04
4	4.62	11.51	6.11	4.40	5.06	7.44	6.03	9.13	12.82	--	13.83
5	4.89	12.24	6.09	4.36	5.12	7.45	5.78	10.02	13.68	14.24	13.54
6	4.48	12.34	6.06	4.33	5.25	7.41	5.85	10.45	14.23	14.17	13.37
7	4.41	11.96	6.01	4.33	5.33	7.34	5.82	10.88	14.07	14.47	12.93
8	4.34	11.43	6.00	4.64	5.40	7.27	5.72	10.78	14.12	13.98	13.75
9	4.31	11.93	6.66	6.22	5.26	7.27	5.60	11.12	14.27	13.14	17.70
10	4.34	13.00	7.23	11.07	5.23	7.49	5.32	11.31	14.01	13.17	17.90
11	5.14	12.59	7.23	11.68	5.22	8.30	5.31	11.35	12.57	13.49	18.15
12	5.17	13.78	7.09	11.48	5.22	8.38	5.39	12.23	11.86	12.97	18.57
13	5.36	13.89	6.41	9.84	5.38	8.69	5.59	13.39	12.52	12.90	18.41
14	6.28	13.86	6.18	8.37	5.33	9.99	5.48	13.72	12.34	12.49	17.58
15	7.30	13.18	5.79	7.48	5.27	11.78	5.63	13.68	12.28	11.86	16.92
16	7.35	12.35	5.42	6.62	5.24	11.96	5.77	13.60	12.22	11.20	16.21
17	6.91	11.86	5.26	6.33	5.22	11.04	5.76	12.85	12.14	10.94	14.12
18	6.49	10.90	5.25	6.13	5.24	10.17	5.71	11.74	12.08	10.78	12.74
19	6.34	9.42	5.23	5.99	5.58	--	5.71	10.93	12.02	10.67	11.98
20	8.37	8.42	5.22	5.89	7.30	--	5.80	10.35	11.94	10.60	12.51
21	9.84	7.95	5.20	5.81	7.65	8.92	5.89	10.30	11.89	10.61	12.82
22	12.34	7.61	5.15	5.60	7.55	8.83	5.86	10.29	11.92	10.56	12.51
23	14.48	7.47	5.08	5.29	7.32	8.83	5.86	10.15	11.48	10.41	12.36
24	15.82	7.26	5.08	5.24	6.99	8.66	5.84	10.04	10.94	10.32	12.24
25	15.98	7.02	5.06	5.18	6.81	8.49	5.83	9.96	10.38	10.15	12.32
26	15.96	6.82	5.15	5.16	6.71	8.39	5.90	9.46	9.54	9.68	12.30
27	15.90	6.72	5.03	5.16	6.92	8.36	5.94	9.00	8.85	9.10	12
28	15.65	6.71	4.92	5.35	7.15	7.84	6.00	8.97	8.20	8.81	12.
29	14.76	6.60	4.79	5.45	7.01	6.65	6.19	--	7.85	8.72	11.96
30	12.25	6.32	4.66	5.32	7.01	6.62	6.22	--	7.95	8.66	11.98
31	10.02	6.02	--	5.22	--	6.34	6.59	--	10.69	--	11.68

NOTES:

-- Not obtained

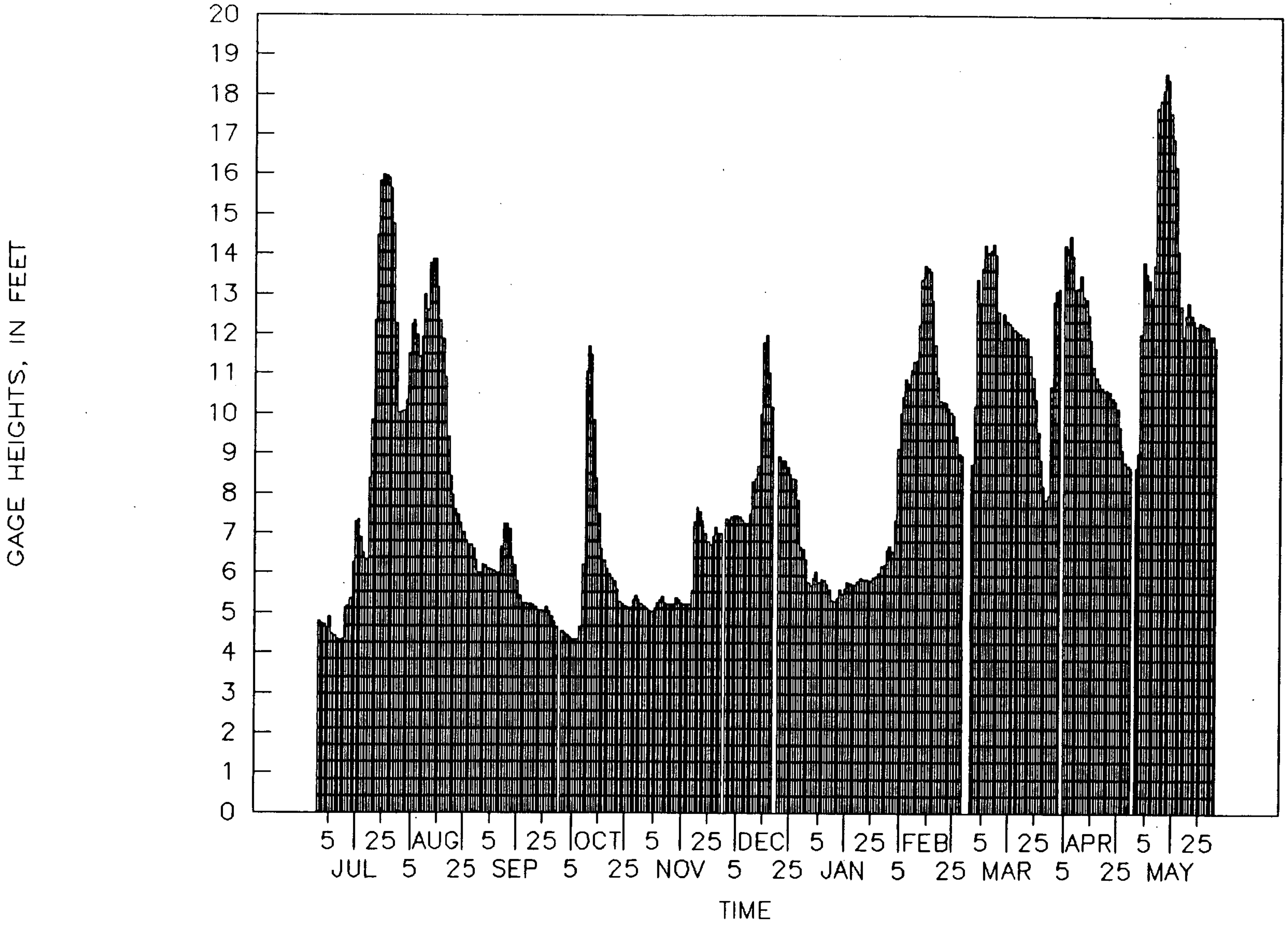
• – Station No. 06879100 is a USGS water stage recorder site located on the right bank at the downstream side of Military Highway Bridge, 1.5 miles below the confluence of the Republican River and the Smoky Hill River at Kansas River Mile 168.9. Gage datum elevation is 1034.89 feet msl.

Source: USGS – Water Resources Division, Kansas River at Fort Riley, Provisional Data (Oct 92 – May 93)
Final Data (Jul 92 – Sep 92)

FIGURE 3-5

Daily Peak Gage Heights (Ft)

at Fort Riley (July 1992 to May 1993)



Comparison of daily precipitation records (Figure 3-2) with daily peak gage heights (Figure 3-5) reveal that the two highest river stages (July 23 to 29, 1992, and May 4 to 17, 1993) occurred within two to three days after rainfall events between July 19 to 26, 1992 and May 6 to 10, 1993, which provided cumulative rainfall totals of 7.4 inches and 7.95 inches respectively. Similarly, a moderately high river stage recorded between October 10 to 12 followed within two to three days after a two-day rainfall event totalling 2.94 inches on October 7 to 8, 1992.

However, exceptions to the relationship described above can be noted. For example, relatively high river stages in mid-February, early March, and early April, 1993 occurred during a period of relatively low local rainfall. Conversely, significant local rainfall events on September 26 (1.13 inches) and November 18 to 19 (2.23 inches) are not associated with high river stages.

The relationship between Kansas River flow rates measured at Fort Riley and releases from Milford Dam was previously discussed in Section 3.3.1.1. Milford Dam releases water to the Republican River for purposes of flood control and water level maintenance in the reservoir. For example, during high flow rates in the Kansas River and high local precipitation events (July 1992, October 1992, and May 1993), releases from the dam were deliberately controlled at lowered rates (USACE, 1993). Releases are also made for downstream surface water users and to satisfy minimum streamflow requirements set by the State (USGS, personal communication).

Additional discussion of the relationship between the river stage in the Kansas River and measured groundwater elevations at the SFL is presented in Section 3.6.2.3.

3.3.2 Drainage Features

Most of the drainage features (streams, creeks, ravines, ditches) at Fort Riley serve primarily to transport water from precipitation events to the Kansas River. Larger drainage features entering the Kansas River include One Mile Creek, upstream of the SFL, and Threemile Creek, Dry Branch and Seven Mile creeks east of and downstream of the SFL (Figure 3-3). The water quality and discharge characteristics in these drainage features would be expected to be variable depending on the frequency and intensity of precipitation events.

Threemile Creek is adjacent to the east side of the SFL. Without augmentation, this stream would likely have only seasonal flow but the addition of approximately 1,485,000 gallons per day of sewage treatment plant effluent about three miles upstream into a tributary (Forsyth Creek) of Threemile Creek puts this creek in the perennial class (USATHAMA, 1984). The treatment plant effluent enters Threemile Creek just north of Huebner Road. It is unknown how much discharge enters Threemile Creek or how much of the initial effluent discharge is lost through seepage and evapotranspiration along Forsyth Creek.

The soil type and thickness of the streambed as well as discharge characteristics of Threemile Creek along its reach near the SFL are unknown. These factors would aid in evaluating the degree of potential hydraulic connection between Threemile Creek and the groundwater system. This report presents Threemile Creek as a hydraulic boundary condition for groundwater flow in the alluvial aquifer system, functioning either as a line source of recharge or discharge depending on the location and on the stage of the Kansas River and Threemile Creek relative to the local groundwater system. The basis for this presentation is an analysis of streambed elevations, groundwater elevations measured in monitoring wells, water surface elevations, and the assumption that streambed materials and the porous media of the alluvial aquifer are directly connected hydraulically.

Because groundwater flows in the direction of decreasing head, water will flow from the creek and into the aquifer when the water level (or head) is higher in Threemile Creek than in the surrounding alluvial aquifer system. In this case, flow from Threemile Creek would establish a line of locally higher head in the alluvial aquifer system, preventing flow towards and under the creek and thereby resulting in a "hydraulic boundary condition." Conversely, when the water level (or head) in the surrounding aquifer system is higher than that in Threemile Creek, a line of lower hydraulic head is established in the creek. As a result, groundwater will flow from the alluvial aquifer system and into the creek, and will subsequently be discharged into the Kansas River. Also, since groundwater flows in the direction of lower head, in this case the groundwater in the alluvial aquifer system directly beneath the creek will flow upwards to the creek. This establishes a "hydraulic boundary condition," causing groundwater in the vicinity of Threemile Creek to flow into the creek (discharged to the Kansas River) and preventing groundwater flow under the creek. Additional evaluation of the relationship between Threemile Creek and groundwater flow in the alluvial aquifer system is presented in Section 3.6.2.

3.3.3 Surface Impoundments

Surface water impoundments at or near Fort Riley include two man-made reservoirs, several oxbow lakes, and many ponds. Tuttle Creek Reservoir, northeast of Fort Riley, is fed by the Blue River. The Blue River drains into the Kansas River downstream of the SFL. Milford Reservoir, west of Fort Riley and upstream of the SFL site, is fed by the Republican River.

The nearest impoundment to the SFL is Whitside Lake, an oxbow lake located about a half mile northwest of the site. This lake was formed as a result of the 1951 flood. The lake gradually dried up but it was recently refilled during excessive precipitation of the summer of 1992 (Fort Riley, 1992d). No direct drainage from the SFL site into Whitside Lake was observed during the field investigation.

During periods of heavy precipitation, localized ponding of the SFL site occurs as observed during the field investigation. No significant, predominant drainage features or patterns exist at the site due to the flat-lying topography. Based on field observations, surface water runoff during excessive precipitation drains generally to the east-southeast toward Threemile Creek and the Kansas River through minor depressions.

3.3.4 Flooding and River Movement

According to the FEMA flood insurance rate map dated January 1982, the elevation of the 100-year flood is 1061.3 feet msl at Camp Funston (Kansas River Mile 164.8), which is adjacent to the SFL. Based on a review of several years of river gage readings at Fort Riley (Kansas River Mile 168.9), extrapolated to the site of the SFL, the water level during flooding periods has consistently risen to within a few feet of the top of bank. The river elevation at the SFL was estimated from flood profiles of the Kansas River, prepared by the Corps of Engineers, which indicates an approximate drop of 10 feet in river elevation between the Fort Riley gage and the Camp Funston Levee (east of the SFL). Available topographic information shows the elevation of the top of the river bank to be typically less than 1048 msl. The elevation of the SFL surface is generally less than 1052 msl. The 50-year flood elevation (1052.6 feet) and greater floods will cover the SFL, as shown on Figure 3-4.

Historical movement or meandering of the Kansas River and its effects on the erosion of the river banks has been studied by the Corps of Engineers (USACE, 1988). Documented channel configurations since the late 1800s show that the channel in the area of Camp Funston has periodically migrated. The amount of migration after 1951 (period of record flood event) has been significantly less than prior to 1951, based on Corps of Engineers' review of reliable maps and aerial photographs. During the 1951 flood, a bend of the river along the west border of the present SFL was cut off from the main flow of the river. This former bend is illustrated on Figure 3-6. The Corps of Engineers' report also documents migration toward the northwest vicinity of the SFL. Available aerial photographs dated prior to 1951 and dated 1976 and 1984 were reviewed to estimate migration of the river channel in the vicinity of the SFL during the time period between 1951 and 1984, as shown in Figure 3-6.

3.4 GEOLOGY

The geological characterization of the study area was accomplished by using the information collected from the geophysical survey and information obtained from the deep borings of the monitoring wells (Appendix D). This section contains results of the geological investigations and a discussion of the regional and site geology.

3.4.1 Geophysical Survey

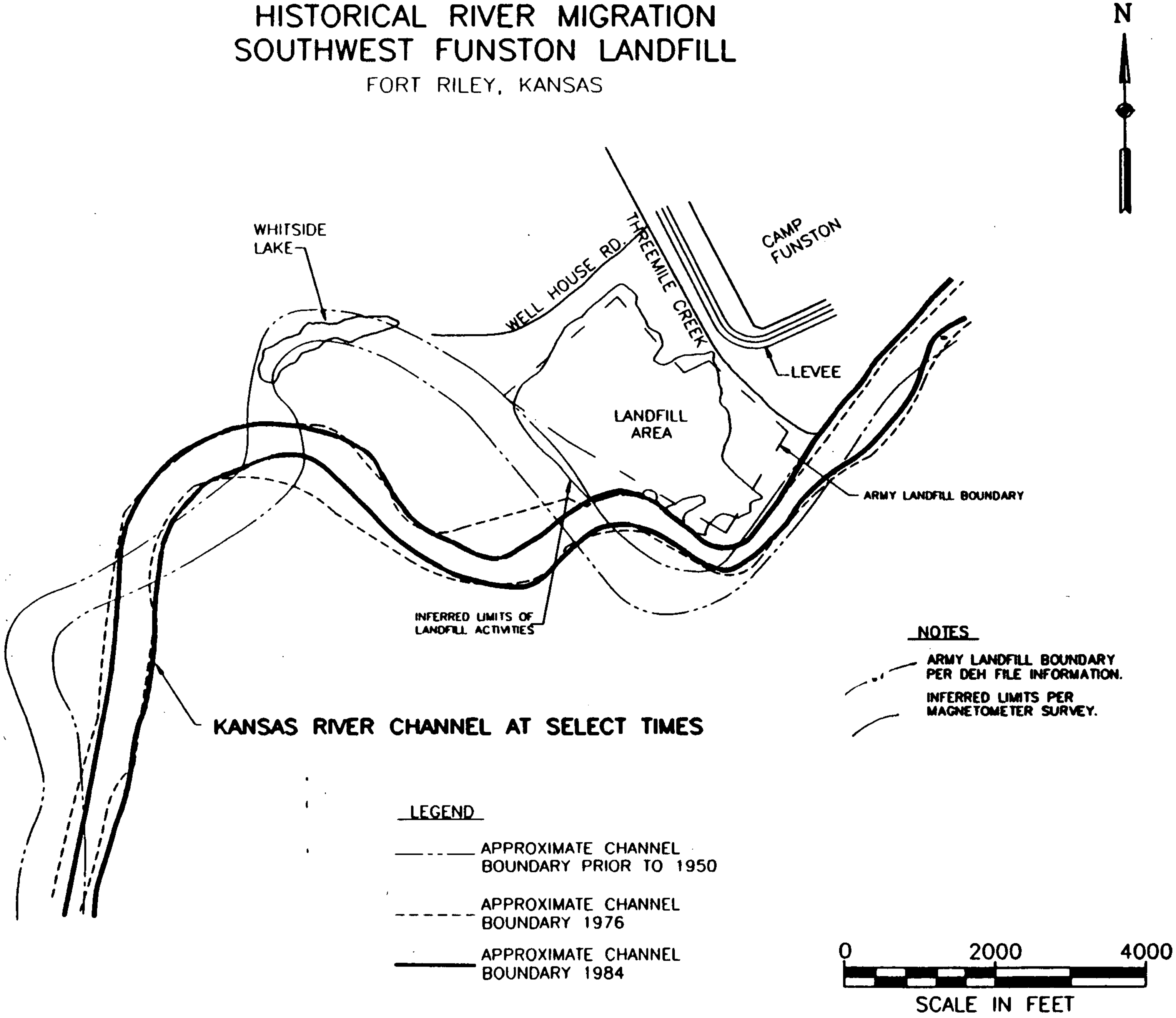
Geophysical surveys using EM and magnetometer instrumentation were conducted as described in Section 2.1.4.1. The magnetometer surveys consisted of a perimeter profile and several radial profiles south of Well House Road to locate subsurface metallic features within the area. The EM survey consisted of perimeter profiles around the area south of Well House Road. The magnetometer and EM data are provided in Appendix J. Locations of the geophysical profiles are shown on Figure 3-7.

The interpretation of the extent of subsurface metallic debris, based upon the geophysical survey data, is presented in Figure 3-8. The area of inferred metallic debris may be the result of grading activities which reportedly occurred following cessation of landfilling and which may have resulted in near-surface metallic debris in areas not previously used for landfilling. The inferred limits of landfill activity shown on various figures in this report represent the general

FIGURE 3-6

HISTORICAL RIVER MIGRATION SOUTHWEST FUNSTON LANDFILL

FORT RILEY, KANSAS



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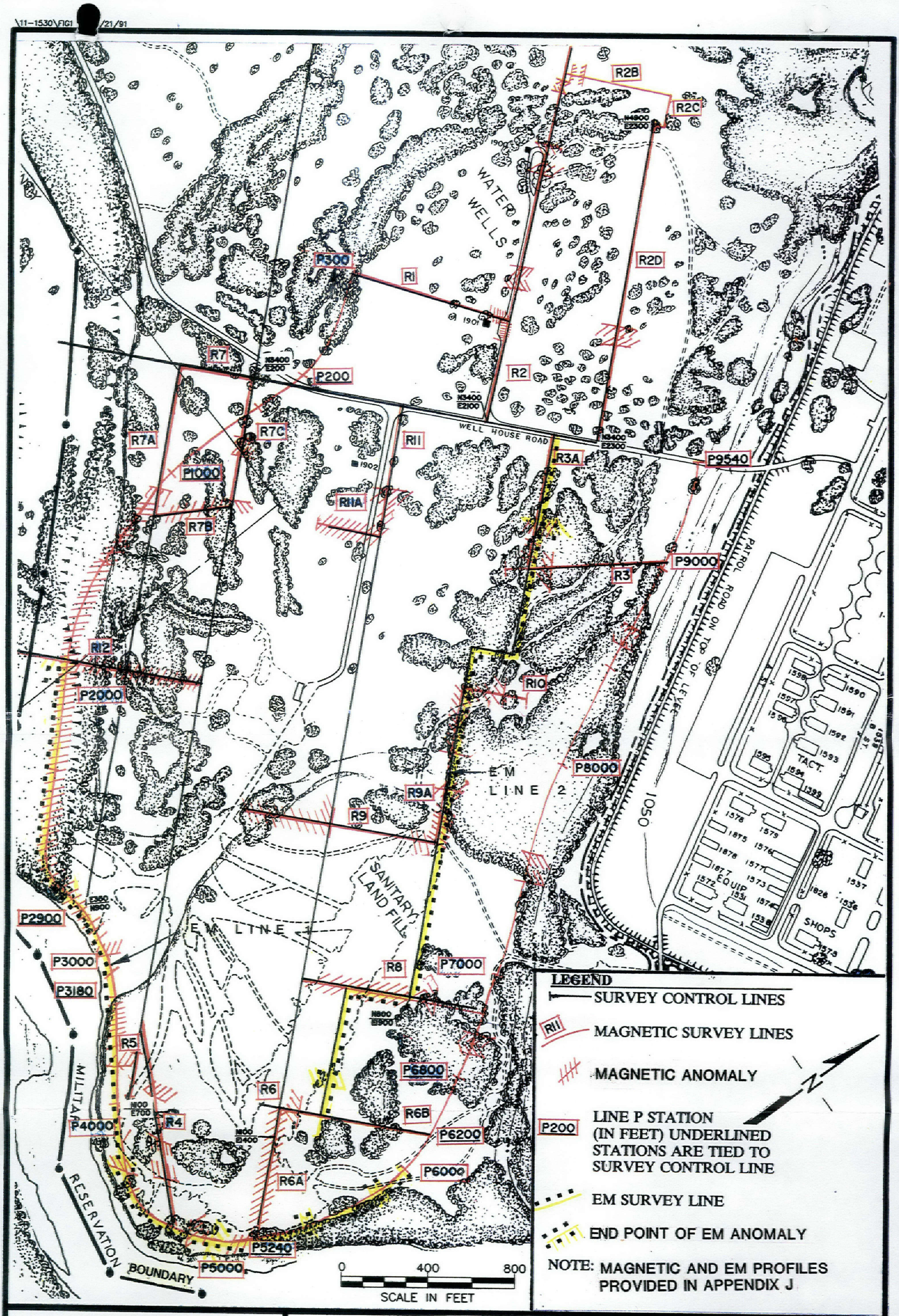


SOUTHWEST
FUNSTON LANDFILL
FORT RILEY, KANSAS

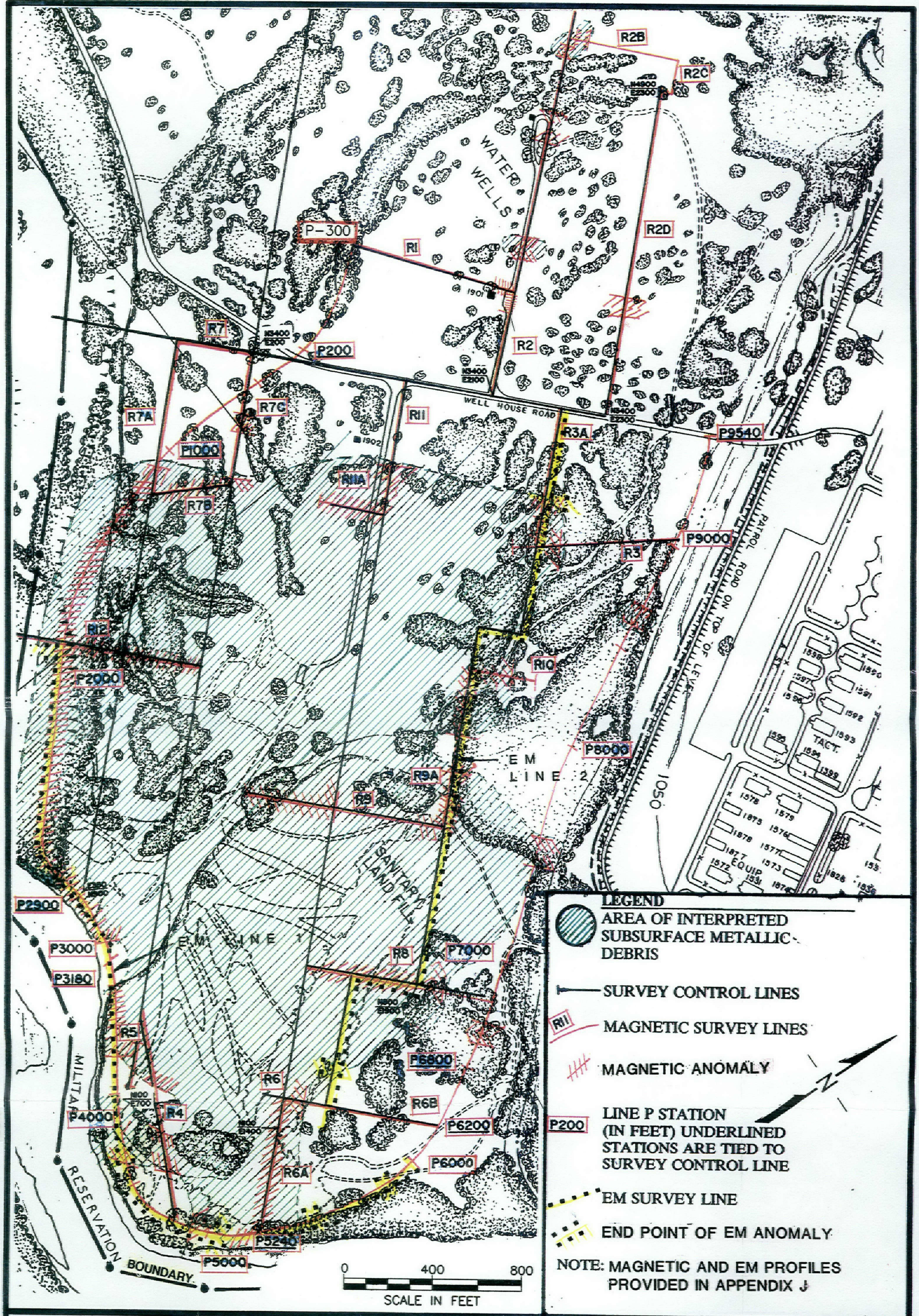
LAW ENVIRONMENTAL, INC.
GOVERNMENT SERVICES DIVISION
114 TOWN PARK DRIVE
KENNESAW, GEORGIA

SUMMARY
of
GEOPHYSICAL ANOMALIES

PROJECT NO. 11-1530

FIGURE 3-7

\11-1530\FIG2 11/21/91



SOUTHWEST
FUNSTON LANDFILL
FORT RILEY, KANSAS

LAW ENVIRONMENTAL, INC.
GOVERNMENT SERVICES DIVISION
114 TOWN PARK DRIVE
KENNESAW, GEORGIA

INTERPRETATION
of
GEOPHYSICAL RESULTS

PROJECT NO. 11-1530 FIGURE 3-8

area of metallic debris identified by the geophysical survey. A continuous perimeter of metallic anomalies was not detected during the geophysical survey and therefore the boundary of inferred metallic debris on Figure 3-8 is somewhat interpretive.

The inferred debris area extends westward to the Old Channel and southward to the Kansas River, except at a few areas as indicated on Figure 3-8. The eastward extent of the inferred debris area is irregular in shape and roughly coincides with the edge of the area which has been cleared of trees. The northern limit of the inferred debris area is approximately 400 feet south of Well House Road.

Anomalous areas detected by the EM survey generally coincide with the anomalous areas detected by the magnetometer survey. These areas were characterized by widely fluctuating values in both the quadrature and in-phase modes (Appendix J). An exception was noted at approximately Station 5400 of Line P. At this location, a broad quadrature mode anomaly was detected with no corresponding in-phase mode anomaly or magnetic anomaly. These data indicate the presence of electrically conductive materials other than metallic debris (e.g., a clayey zone or possible leachate plume).

North of Well House Road, five anomalous areas were detected by the magnetometer survey. The anomalous areas at the intersection of lines R1 and R2, and at the end of the north-trending road ending in a cul-de-sac (Figure 3-8), may be related to the nearby former water supply wells 1900 (FUN-1) and 1901 (FUN-2) and associated piping. The anomaly on Line R2D has a low amplitude (Appendix J) and may be related to a buried pipe leading eastward from former water supply well 1901 to Camp Funston. DEH file drawing F9-0001-0J titled "Decommission Camp Funston Wells" (25 October 1989) shows the location of water supply lines which indicate they were abandoned in place. The two other anomalies detected north of Well House Road are of relatively small amplitude and may also be the result of buried pipes. However, no former water supply wells are mapped near these anomalies; therefore, these areas are interpreted as having subsurface metallic debris.

An area containing several trenches, observable on historical aerial photographs and located north of the cul-de-sac, was also surveyed with the magnetometer (the trenches and intervening elongate mounds are still present although covered with vegetation). No anomalous magnetometer readings were recorded in this area; this indicates that the trenches were not burial sites for metallic debris.

3.4.2 Regional Geology

Fort Riley is situated in three distinct geological-topographical areas (USAETL, 1977) as illustrated on Figure 3-1. The first is the uplands area, consisting of flat-lying to gently northwesterly dipping limestones and shales. The uplands area generally is covered by various shale units which overlie the escarpment-forming limestones. Small streams have dissected these thick shale units and eroded much of the area into a rolling plateau. Local topographic relief (the change in land-surface elevation within a specified area) ranges from 164 to 240 feet in the uplands area. The second geological-topographical area is the steep to hilly country. It is composed of alternating limestones and shales, which extend from the uplands down to the third area known as the alluvial bottomlands. The alluvial bottomlands consist of deposits from the Republican and Kansas Rivers. Relief in this area ranges from 25 to 60 feet.

Stratigraphic rock units present at Fort Riley are Lower Permian in age and consist of alternating limestones and shales (KGS, 1968). The Chase Group and the Council Grove Group are among the geologic units of interest near the site, with the Chase Group being the uppermost (Figure 3-9). The bedding planes generally dip gently to the northwest at approximately 15 feet per mile.

Upper geologic formations from oldest to youngest within the Council Grove Group include:

- Stearns Shale
- Bader Limestone
- Easly Creek Shale
- Crouse Limestone
- Blue Rapids Shale
- Funston Limestone
- Speiser Shale

The Stearns Shale is mostly gray to olive-gray, but red shale occurs in the middle and lower parts. It contains a minor amount of argillaceous limestone. The thickness ranges from about 5 to 20 feet. The Bader Limestone formation consists of, in ascending order, the Eiss Limestone member, the Hooser Shale member and the Middleburg Limestone member. The Bader Limestone ranges in thickness between 15 and 33 feet (KGS, 1968).

The Eiss member contains two limestone beds separated by shale and is remarkably persistent across Kansas (KGS, 1968). The lower limestone, which is between 1.5 feet and 6 feet thick, is shaley, thin bedded and fossiliferous, containing many small, high spired gastropods (KGS, 1968). The middle part is 2 to 11 feet thick and consists of gray fossiliferous shale. The uppermost limestone bed is 2 to 3 feet thick and can contain locally abundant chert.

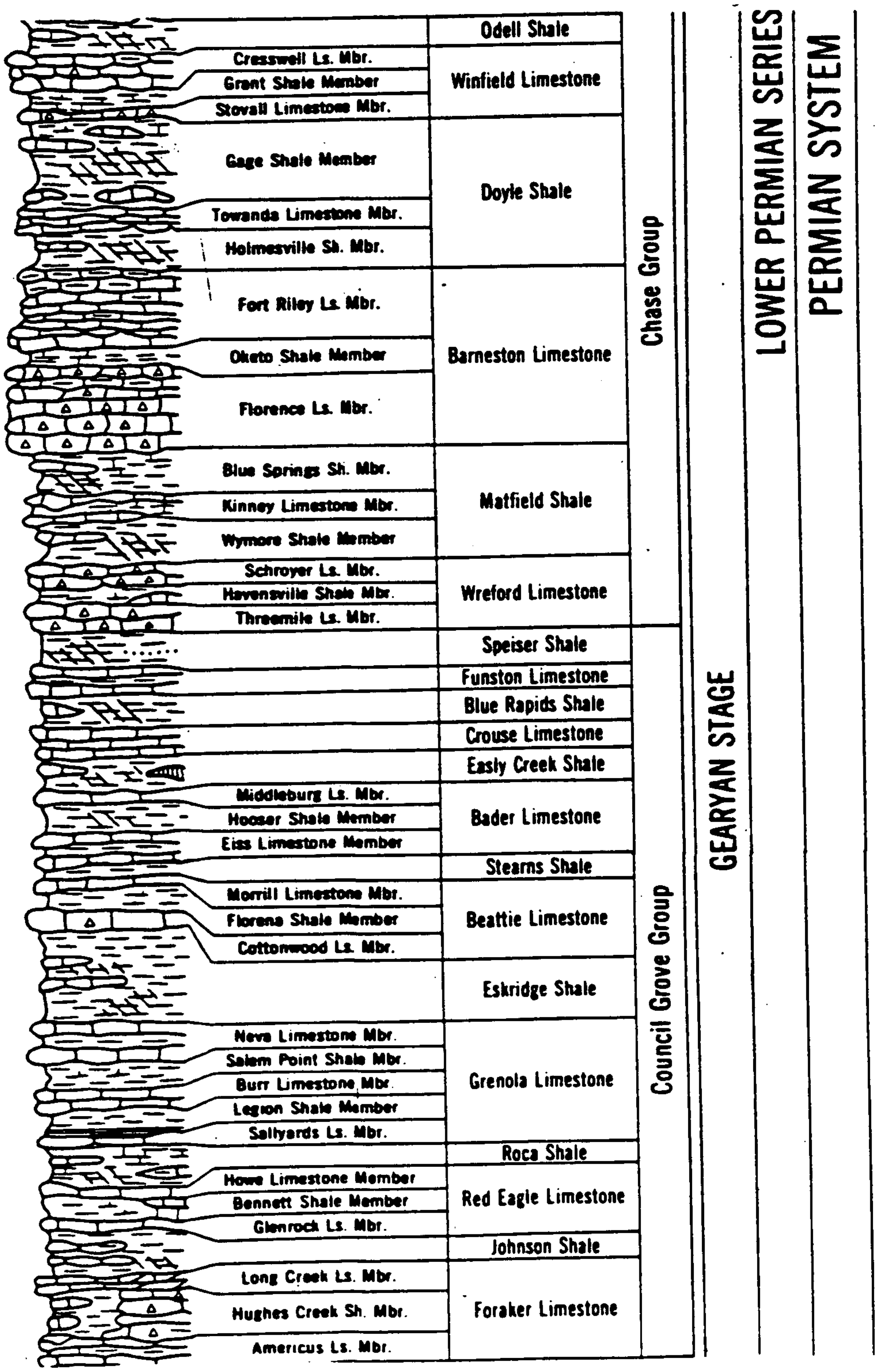
The Hooser Shale member of the Bader Limestone Formation is a gray to grayish-green and red shale. It ranges in thickness from approximately 7 to 11 feet.

The Middleburg Limestone member consists of a massive, slabby limestone and a light olive to gray shale. The lower part of this member is fossiliferous (no species are noted in the reference). Thicknesses range between 1.5 feet and 8 feet.

FIGURE 3-9

UPPERMOST ROCK UNITS

FORT RILEY, KANSAS



SOURCE: ZELLER, 1968

The Easly Creek Shale formation consists of a single member approximately 10 feet to 20 feet thick. This shale is red, green, and gray and can contain locally thin limestone beds.

The Crouse Limestone is comprised of upper and lower beds of localized cherty limestone separated by a few feet of fossiliferous shale (KGS, 1968). The upper portion displays platy structure and weathers tan to brown, and the lower portion is massive. The thickness ranges from about 6 to 18 feet. The Blue Rapids Shale consists of a gray, green, and red shale, containing some limestone. Its thickness ranges from about 15 to 30 feet. The Funston Limestone is a light-gray to bluish-gray limestone separated by gray to yellowish-gray shale that is abundantly fossiliferous. The thickness of this formation ranges from about 5 to 28 feet. The upper part of the Speiser Shale consists of gray fossiliferous shale underlain by a fairly persistent limestone bed, which is commonly less than a foot thick and occurs about 3 feet below the Wreford Limestone. The remainder of this formation consists of beds of varicolored shale, red shale being predominant. The Speiser Shale is about 18 feet thick.

Geologic formations within the Chase Group, in ascending order, include:

- Wreford Limestone
- Matfield Shale
- Barneston Limestone
- Doyle Shale

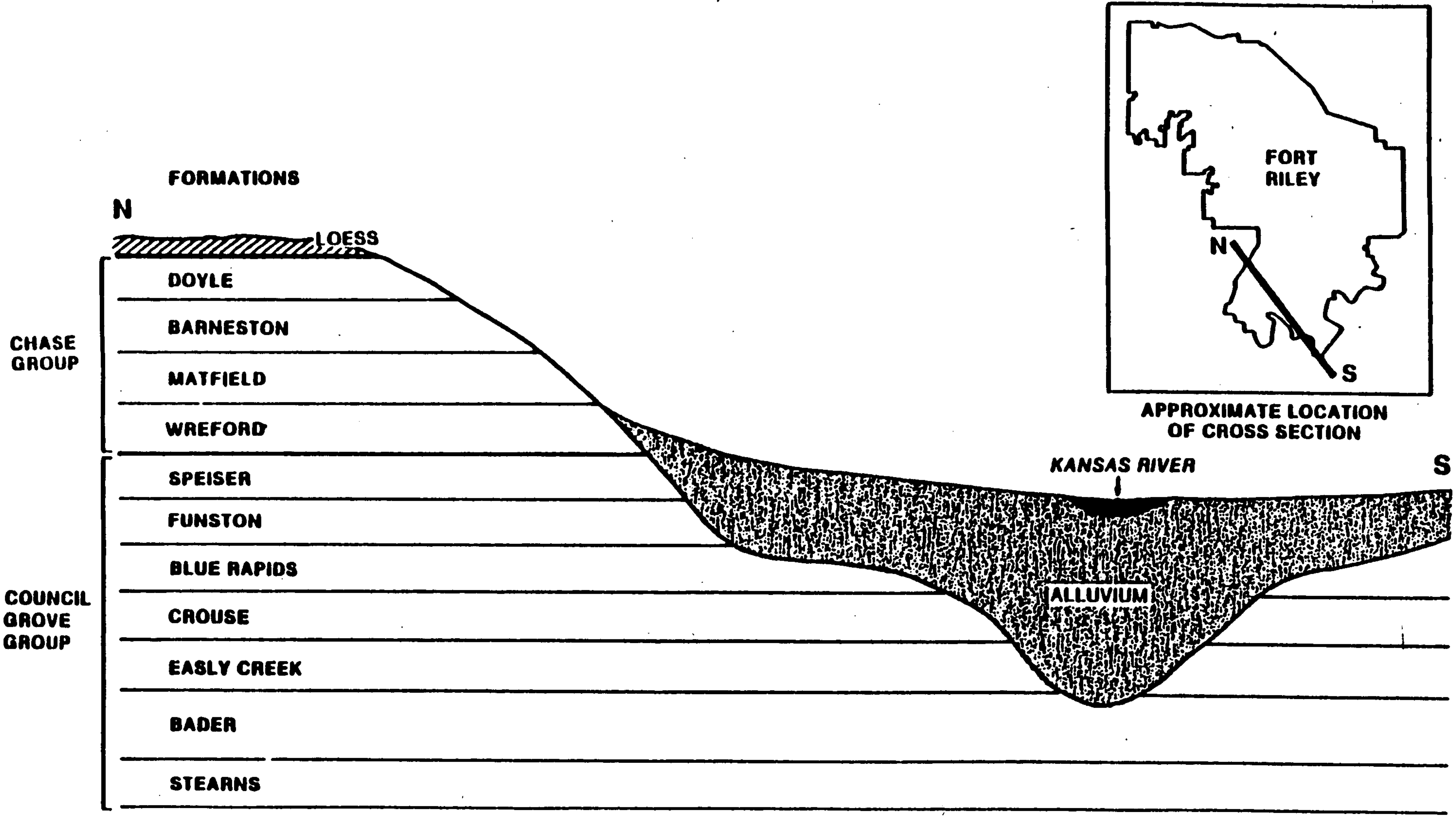
This group is made up of about 335 feet of escarpment-making limestones alternating with shales. The formations are characterized by shales of red and green. The thick chert-bearing limestones, a prominent topographic feature, are generally more massive and thick than the beds in the underlying Council Grove Group. The Wreford Limestone consists of two limestone members and a shale member. The limestones are characterized by an abundance of chert. The formation thickness ranges from about 30 to 40 feet. The Matfield Shale contains two varicolored shale members separated by a limestone member. Its thickness ranges from about 50 to 80 feet. The Barneston Limestone is comprised of two thick limestone members separated by a thin shale member. The upper limestone crops out as a steep escarpment that extends from north to south across eastern Kansas. The Barneston Limestone caps much of the western part of the Flint Hills. The thickness of this formation ranges from about 80 to 90 feet. The Doyle Shale is about 70 feet thick and is comprised of two shale members and a separating limestone member.

Overlying the bedrock units are alluvial deposits, residual soil developed from the bedrock, and windblown loess of Pleistocene and Recent age (Figure 3-10). The loess deposits at Fort Riley range from 0 to 2 feet in thickness (USAETL, 1977). Where the Republican and Kansas Rivers have cut into the Permian limestones and shales, alluvial deposits of silt, clay, and very fine sand may be found near the surface grading to coarser sand and gravel with depth. The maximum identified thickness of the alluvium on Fort Riley, as determined from well logs, is 91 feet.

FIGURE 3-10

GENERALIZED GEOLOGICAL CROSS SECTION THROUGH FORT RILEY

FT. RILEY, KANSAS



NOTE: WINFIELD FORMATION DOES NOT OUTCROP ON FORT RILEY.

SOURCES: USAETL, TERRAIN ANALYSIS CENTER, 1977.

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3.4.3 Local Geology

This section uses data obtained during the field investigation supplemented with historical geologic and hydrologic information. The variable nature of the soils and alluvium across the site requires application of professional judgment to interpret subsurface conditions between boring locations. The geologic characterizations discussed are consistent with those reported in historical literature. The boring records in Appendix D provide detailed descriptions of subsurface findings at each boring location.

3.4.3.1 Monitoring Well Borings - Deep monitoring well borings at the eight clustered locations were used to characterize the unconsolidated material within the study area (Figure 3-11). Each of the deep borings was sampled continuously to the top of bedrock. Depth to the shale/limestone bedrock ranged from 34 to 67 feet below ground surface. The alluvial materials grade upward from tan to gray limestone gravel and tan to green coarse sand to fine sand, silt, and silty clay. Little clay was encountered in the borings.

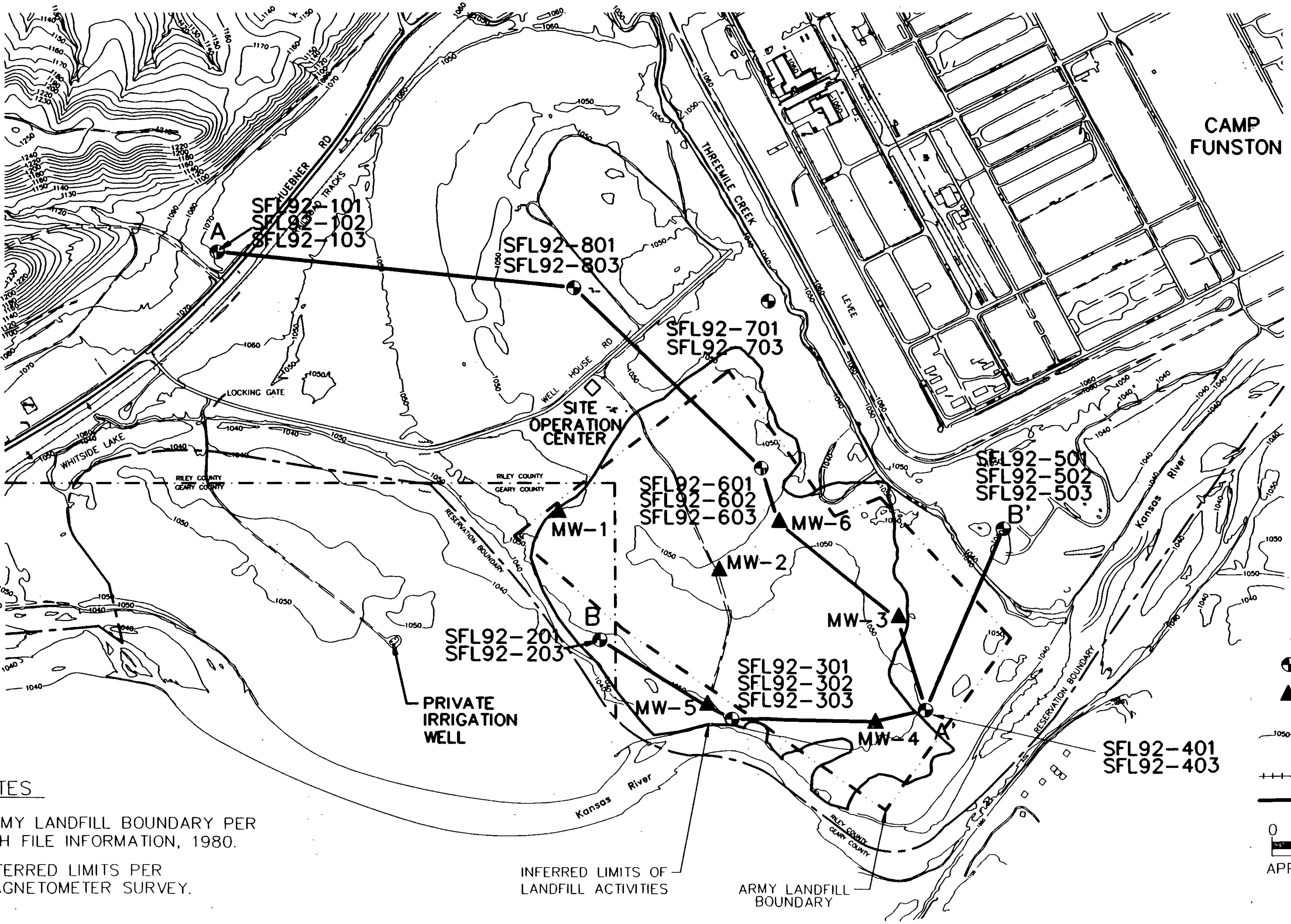
3.4.3.2 Cross Sections - Two cross sections have been developed for the SFL site to illustrate the relationships of the geologic units encountered throughout the study area. The cross section locations are shown in Figure 3-11. Cross section A to A' is a northwest to southeast cross section which shows the interpreted stratigraphic relationships between wells SFL92-103, SFL92-803, SFL92-603, MW-6, MW-3 and SFL92-403 (Figure 3-12). Cross section B to B' is a west to east cross section which shows the interpreted stratigraphic relationships between wells SFL92-203, MW-5, SFL92-303, MW-4, SFL92-403 and SFL92-503 (Figure 3-13). Both cross sections show a general coarsening downward sequence of alluvial material. Silt to silty sand occurs in the upper 10 to 20 feet underlain by approximately 10 to 20 feet of a fine to medium grain sand which overlies about 15 to 40 feet of coarse grain sand, gravel and cobbles. This unconsolidated (alluvial) material is underlain with variably weathered shaley limestone. Discontinuous clay lenses, ranging up to 10 feet thick, occur in about one-half of the borings. An exception to this general pattern is about a 25-foot thick clay deposit that occurs at closure well MW-4. This may represent a depositional feature common near the terminus of former meander bends where natural levee deposits are often re-established subsequent to rechannelization.

The bedrock surface shows evidence of past erosional processes that allow deposition of thicker unconsolidated deposits near well clusters 2, 6 and 8. The bedrock surface near cluster 2 probably reflects erosion from the Kansas River channel immediately prior to 1951, when it was rechannelized due to high river stages. The similar depth to bedrock near clusters 6 and 8 may reflect the location of the Kansas River prior to any recorded observations.

FIGURE 3-11

CROSS SECTION LINES A-A' AND B-B'
SOUTHWEST FUNSTON LANDFILL

FORT RILEY, KANSAS



NOTES

—·— ARMY LANDFILL BOUNDARY PER DEH FILE INFORMATION, 1980.

—— INFERRED LIMITS PER MAGNETOMETER SURVEY.

LEGEND

⊕ CLUSTERED WELL LOCATION

▲ EXISTING CLOSURE WELLS

~1050~ LAND SURFACE ELEVATIONS CONTOUR INTERVAL 10 FEET

+++++ RAILROAD TRACKS

—— CROSS SECTION LINE

0 800 1600

APPROXIMATE SCALE IN FEET

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FIGURE 3-12

CROSS SECTION A-A'

SOUTHWEST FUNSTON LANDFILL
FT. RILEY, KANSAS

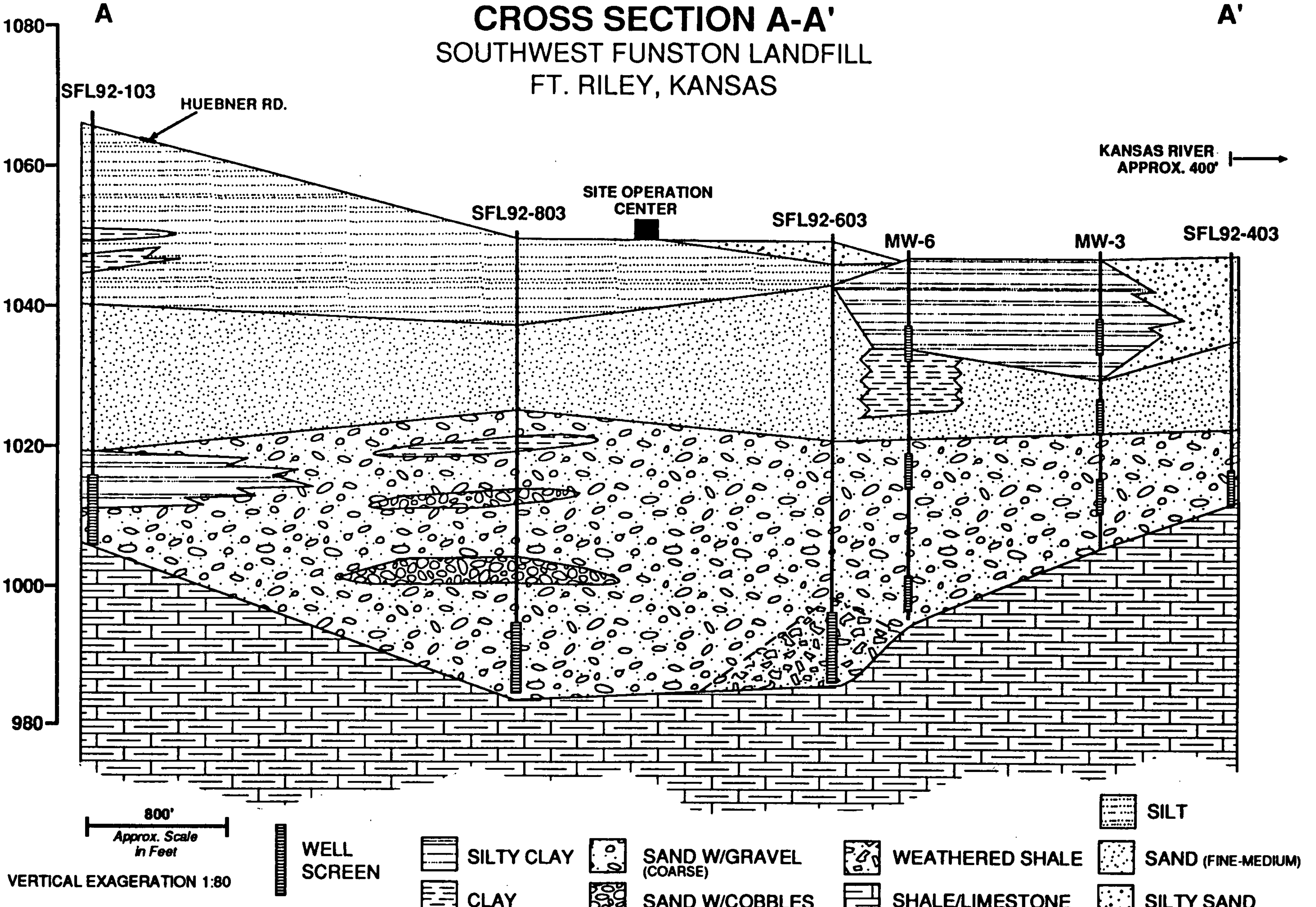

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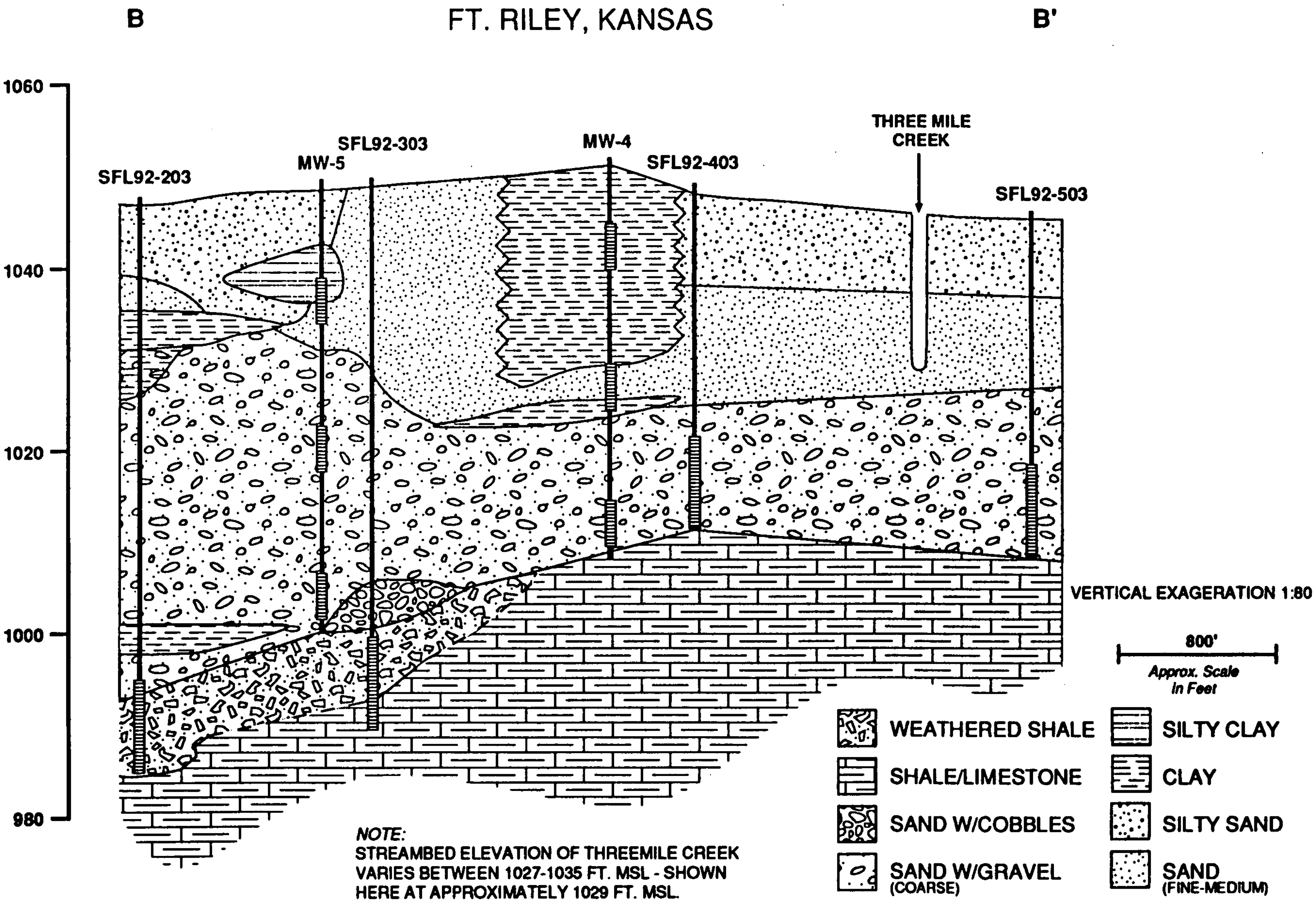
FIGURE 3-13

CROSS SECTION B-B'

SOUTHWEST FUNSTON LANDFILL
FT. RILEY, KANSAS



NOTE:
STREAMBED ELEVATION OF THREEMILE CREEK VARIES BETWEEN 1027-1035 FT. MSL - SHOWN HERE AT APPROXIMATELY 1029 FT. MSL.

As illustrated in these cross sections, the uppermost geologic unit identified throughout the SFL study area is the alluvial bottomlands consisting of those materials described above. Based on the regional literature, the bedrock beneath the alluvium consists of alternating beds of shale and limestone that are of the Council Grove Group, which is Lower Permian in age and part of the Gearyan Stage.

3.5 SOILS

Information obtained from the soil gas survey, visual soil descriptions from the deep borings, and the geotechnical laboratory results for soils from the well borings were used to aid in identifying and evaluating the stratigraphy of the alluvial bottomland deposits at SFL. In addition, shallow subsurface soils were investigated to aid in determining the present condition of the landfill cover at SFL.

3.5.1 Soil Gas Survey

This section includes the general results of the soil gas survey performed in October and November of 1991. A more specific discussion of the soil gas analytical results using field instrumentation is presented in Section 4.2.1. The raw soil gas data, with contour maps, are included in Appendix J. The Flame Ionization Detector (FID) Total Volatiles results revealed detectable concentrations at the western survey boundary to the north and in other isolated samples on site. Detections occurred primarily near the western survey boundary, but volatile organics were also present in isolated areas on the southern survey boundary and in the north central survey area.

Discussions with personnel performing the soil gas survey indicated that the soil gas analysis by gas chromatograph equipped with an electron capture detector did not quantitatively detect vinyl chloride. Therefore, confirmation of vinyl chloride by gas chromatograph with mass spectrometry detection was not performed.

3.5.2 Soil Descriptions

The following description of soils at SFL is based primarily on the Soil Survey for Riley County performed by the U.S. Department of Agriculture, Soil Conservation Service (USDA-SCS, 1988) and the results of the geotechnical testing for soils from the well borings (Table 3-6).

TABLE 3-6

SUMMARY OF GEOTECHNICAL TESTING
Southwest Funston Landfill
Fort Riley, Kansas

BORING	SAMPLE COLLECTION DEPTH (ft)	USCS (1)	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	Cc	Cu
SFL92-103	36-38	SM	NP	NP	NP	NA	NA
SFL92-103	53-54	SP-SM	NP	NP	NP	0.13	48.8
SFL92-203	14-16	CL	33	20	13	NA	NA
SFL92-203	58-60	SW-SM	NP	NP	NP	2.56	23.10
SFL92-303	20-22	SM	17	14	3	NA	NA
SFL92-303	50-54	SM	23	19	4	NA	NA
SFL92-403	10-12	SM	NP	NP	NP	NA	NA
SFL92-403	32-34	SM	NP	NP	NP	NA	NA
SFL92-503	22-24	SW	NP	NP	NP	1.82	9.57
SFL92-503	30-32	SW	NP	NP	NP	1.10	6.40
SFL92-603	16-18	SM	18	17	1	NA	NA
SFL92-603	58-60	SW-SM	NP	NP	NP	2.27	9.09
SFL92-703	14-22	SP	NP	NP	NP	1.02	4.50
SFL92-703	50-52	SW-SM	16	15	1	2.69	8.24
SFL92-803	58-60	SP-SM	NP	NP	NP	2.39	0.51
SFL92-803	58-60	SP-SM	NP	NP	NP	0.90	5.53

NOTES:

(1) USCS: Unified Soil Classification System (ASTM D 2487-66T)
CL - Low plasticity clays, sandy or silty clays
SM - Silty sands, silty gravelly sands
SP - Gap graded or uniform sands, gravelly sands
SW - Well graded sands, gravelly sands
NP - Non Plastic
Cu - Coefficient of Uniformity
Cc - Coefficient of Curvature
NA - Not Applicable

The central portion of the landfill contains soil characterized as Haynie Series calcareous soils (USDA-SCS, 1988). These soils usually occur on the floodplains along rivers and are formed in calcareous alluvium. The soil varies from very fine sandy loam to silty clay loam, 50 to 60 inches deep. It has moderate permeability (infiltration rate of 0.6 to 2.0 inches per hour) (USDA-SCS, 1988). Well boring SFL92-603 revealed the uppermost horizon as silty sand of very low plasticity, sand, clayey silt, or silt (Table 3-6). The upper horizon is underlain with a mixture of sand, silt, gravel, and minor clay down to the bedrock. The landfill operation, particularly surface grading and placement of fill soil, has reworked and removed some of the surficial soils.

Soils on the southern edge of the landfill area are characterized as Sarpy Series formed in alluvial sediments (USDA-SCS, 1988). This soil varies from a loamy fine sand to a very fine sandy loam and can occur to depths of 60 inches. It has high permeability (infiltration rate of greater than 20 inches per hour) and is readily drained (USDA-SCS, 1988). Well boring SFL92-403 revealed the uppermost horizon as nonplastic clayey, fine-grained sand underlain with a mixture of sand and gravel down to the top of bedrock.

Soils to the east and northeast of the landfill are characterized as Ivan and Kennebec Series silt loams (USDA-SCS, 1988). Soils in these series occur on bottomlands along most creeks and are formed in noncalcareous alluvium. This soil varies from a silt loam to a silty clay loam to 60 inches deep. These soils are well drained to moderately well drained and have moderate permeability (infiltration rate of 0.6 to 2.0 inches per hour) (USDA-SCS, 1988). Well borings SFL92-203 and SFL92-303 revealed the uppermost horizon as fine-grained sand. The upper horizon is underlain by silt with low to moderate plasticity, silty sand, sand, and gravel down to the bedrock.

Generally, soils north and west of the landfill are deep, stratified alluvial deposits. The upgradient well (SFL92-103), north of the landfill, is located in the Reading Series silt loam. This soil is formed in alluvial sediments, is well drained, and has moderate to moderately slow permeability (0.2 to 2.0 inches per hour). The surface layer is a silty loam with a silty clay loam to 60 inches (USDA-SCS, 1988). The well borings in the area (SFL92-103 and SFL92-803) revealed clayey silt, silt, silty clay, and medium to coarse sand to bedrock.

3.5.3 Surficial Soils

This section presents a summary of the landfill cover study which included field screening of surficial soils using X-ray fluorescence (XRF) (PRC, 1993). The PRC report suggested that the source of the lead contamination may be borrow soils from former rifle range berms which were used to cover portions of the SFL. Specific chemical analysis results from the XRF sampling and analysis activities are presented in Section 4.2.3.

Soil samples from the landfill surface did not contain observable (with the naked eye) lead and/or bullet fragments as was noted during inspection of the presumed source material originating from the small arms range north of Heubner Road. However, numerous lead and bullet fragments were observed during collection of the soil samples from the former rifle range berms, which are not on the SFL. The soil at the existing rifle range berms was also observed to contain many rocks. This material appeared to be derived from the edge or base of an adjacent river bluff outcrop. Conversely, the soil cover at the landfill surface (0 to 6-inch depths) was generally a clay to silty loam with very few rock fragments (PRC, 1993).

Lead contamination was detected in laboratory analysis of surface soil at the SFL. The PRC report states at least two hypotheses concerning the nature and origin of the surface soils at the SFL (PRC, 1993). First, if the rifle range berm material was used to cover the landfill, it in turn may have been covered with several inches of topsoil from another source. Spreading the top soil over material from the rifle range berms and grading of the soil may have produced the lead contamination currently detected at the landfill surface. Secondly, material from berms previously existing at the firing range may have been used at the landfill as a cover in some locations. The metals content of these former berms may be similar to that observed on the landfill surface (PRC, 1993).

3.6 HYDROGEOLOGY

This section includes discussions on the regional and site hydrogeology. The regional hydrogeology information presented in this section is based on the literature search and personal interviews. Results and conclusions from the field investigation study, including hydraulic conductivity tests, are presented in the discussion of the site hydrogeology.

3.6.1 Regional Hydrogeology

The Fort Riley Military Reserve area covers a portion of the watershed for the Republican River, Milford Lake Reservoir, and the Kansas River. The area is characterized by poorly developed karst topography in interbedded limestones and shales (KGS, 1968). The term "karst" refers to topographic and lithologic characteristics associated with carbonate dissolution by groundwater. The bedrock is overlain by residual soil, alluvium, and loess.

The alluvium adjacent to the Kansas River and the Newman and Buck Creek terrace deposits of Pleistocene Age are major geologic units in the river valley region. The water-bearing materials that are most significant with regard to groundwater movement are the sand and gravel in the alluvium and terrace deposits. In general, the relative positions of the alluvium and terraces are as follows:

- Alluvium occurs from the river to a northern limit (approximated by Heubner Road) which is the first distinguishable escarpment toward the valley wall on either side of the river.

- Newman terrace occurs from the first escarpment (approximately Heubner Road) to the next escarpment or change in soil texture toward the valley wall.

- Buck Creek terrace, where present, is adjacent to the valley wall.

The alluvial deposits are capable of yielding more than 1,000 gallons per minute (gpm) from a single well. This aquifer is recharged through direct infiltration of rain and by seepage from limestone and shales and the adjacent rivers. Water levels in the Fort Riley water supply wells screening the alluvial deposits generally range from 15 to 25 feet below land surface.

The primary source of drinking water for Fort Riley, Junction City, the Riley County Rural Water district, and Ogden, is the valley fill alluvium (alluvial aquifer) of the Republican and Kansas rivers. Junction City and Fort Riley's water supply wells are within the Republican River floodplain and are five miles upstream of the SFL sites. Ogden's water supply wells are located within the Kansas River floodplain, approximately 2.6 miles downstream of the site (USGS, 1982). Groundwater yields from this aquifer system are greater than 1,000 gpm.

The principal source of water for municipal, industrial, and irrigation supplies in the northeast quarter of the post is the combined river and valley-fill deposits (alluvium and terrace deposits) of the Kansas River valley. Groundwater is also produced, to a limited extent, from solution channels and joints in the limestone and shale of the Permian bedrock, which underlie the valley-fill deposits.

The Fort Riley and Florence limestones, members of the Barneston Limestone Formation, are the chief bedrock aquifers. The bedrock aquifer is an adequate resource for local drinking water supplies and moderate agricultural activities. Depth and presence of groundwater varies depending on local physiographic, geologic, and hydrologic conditions. Wells completed in limestone at Fort Riley are producing from zones approximately 70 feet below the ground surface.

3.6.2 Site Hydrogeology

The SFL site is located entirely within the Kansas River alluvium. During seasonal periods of high river stage, the alluvial aquifer receives recharge from the Kansas River. Site-specific hydrogeologic conditions were investigated by obtaining data from six existing closure wells, installing 20 new monitoring wells, and performing in-situ hydraulic conductivity tests. The following discussion summarizes the hydrogeological information gathered from this investigation.

3.6.2.1 Existing Closure Wells - Six closure wells were installed at the SFL site in May 1983 as part of the approved closure plan dated July 1982 (Figure 3-11). As shown on Table 3-7, several groundwater level measurements were obtained from the six wells from August 1991 through October 1992. Additional information is presented in Section 1.2.3.

3.6.2.2 Groundwater Levels - Groundwater levels were measured in the 20 newly-installed monitoring wells on July 23, 1992; October 1, 1992; February 1, 1993; April 12, 1993; May 3, 1993; and September 7, 1993. During the last three of these measurement events, groundwater levels were also measured in monitoring wells installed at Camp Funston (as part of an unrelated investigation) east of Threemile Creek. The groundwater level data are provided in Table 3-8. Kansas River stage levels were obtained for each of the sampling events to allow comparison of river stage to groundwater levels. The river stage levels near the SFL were estimated using procedures described in Section 3.3.1.2; these estimated stage levels are shown on Table 3-8.

The measured water levels in the monitoring wells have varied substantially during the sampling period, as shown in the table below:

Well No.	Min. Water Level (ft, MSL)	Date	Max. Water Level (ft, MSL)	Date	Difference (ft)
SFL92-101	1032.4	July 23, 1992	1039.2	May 3, 1993	6.8
SFL92-201	1032.8	Oct. 1, 1992	1039.7	April 12, 1993	6.9
SFL92-301	1031.6	Oct. 1, 1992	1039.8	April 12, 1993	8.2
SFL92-401	1031.8	Oct. 1, 1992	1038.7	April 12, 1993	6.9
SFL92-501	1031.9	Oct. 1, 1992	1037.5	April 12, 1993	5.6
SFL92-601	1032.6	July 23, 1992	1038.0	April 12, 1993	5.4
SFL92-701	1032.3	July 23, 1992	1037.2	April 12, 1993	4.9
SFL92-801	1032.4	July 23, 1992	1039.2	May 3, 1993	6.8

Increases in groundwater levels at the SFL can be caused by infiltration from precipitation and/or influx from the Kansas River and Threemile Creek. Regarding precipitation, above-average rainfall was recorded for seven of the eleven months between July 1992 and May 1993. Referring to Table 3-2, rainfall during this period exceeded the average by about 17.5 inches. Rainfall during the months of July 1992, November 1992, and May 1993 exceeded the average amounts by a total of 16.8 inches.

The water levels measured during six measurement events (Table 3-8) in the shallow and deep monitoring wells in each cluster were examined in an effort to determine vertical gradients at individual well clusters and their significance in the interpretation of groundwater flow in the SFL area. The data were interpreted as follows: a shallow well with a higher water level than the deep well in the same cluster indicates a downward vertical gradient at that well cluster; a deep well with a higher water level than the shallow well in the same cluster indicates an upward vertical gradient at that well cluster.

The groundwater level data in the individual well clusters do not reveal marked differences in hydraulic head. Vertical gradients at individual well clusters varied between upward and downward with no apparent correlation. The minor head differences noted fluctuate over time and show no correlation with either river stage, season, or vertical gradients at other well clusters. Also, the lack of correlation is evidenced in that, of the six measurement events, the maximum downward gradient (1.18 feet at the 700 well cluster) and the maximum upward gradient (0.62 feet at the 200 well cluster) were both observed during the same measurement event (June 23, 1992). In general, observed head differences may be due to transient conditions in the aquifer system resulting from changing stage in the Kansas River or Threemile Creek. The lack of significant hydraulic head differences suggests common flow patterns among shallow and deeper sections of the alluvial aquifer system, and supports the interpretation that distinct aquitards or aquicludes are not present.

Due to variations in water-level elevations with time, Threemile Creek appears to act as a source of recharge to the groundwater system under certain conditions and an area of groundwater

continues on page 3-38

TABLE 3-7

GROUNDWATER WELL MEASUREMENTS FOR SFL CLOSURE WELLS
Southwest Funston Landfill
Fort Riley, Kansas

WELL NUMBER	DATE OBTAINED	TOP OF CASING ELEVATION (ft)	DEPTH TO WATER	CORRECTED WATER ELEVATION (ft)
MW-1	08-30-91	1053.36	21.76	1031.60
	09-27-91		22.13	1031.23
	10-29-91		22.03	1031.33
	11-29-91		22.17	1031.19
	12-31-91		22.29	1031.07
MW-2	08-30-91	1050.00	18.63	1031.37
	09-27-91		19.06	1030.94
	10-29-91		19.02	1030.98
	11-29-91		19.26	1030.74
	12-31-91		19.32	1030.68
MW-3	08-30-91	1049.20	18.26	1030.94
	09-27-91		18.61	1030.59
	10-29-91		18.71	1030.49
	11-29-91		18.72	1030.48
	12-31-91		18.96	1030.24
MW-4	08-30-91	1053.77	22.70	1031.07
	09-27-91		23.22	1030.55
	10-29-91		23.38	1030.39
	11-29-91		23.14	1030.63
	12-31-91		23.61	1030.16
MW-5	08-30-91	1050.18	18.72	1031.46
	09-27-91		19.11	1031.07
	10-29-91		19.40	1030.78
	11-29-91		19.16	1031.02
	12-31-91		19.61	1030.57
MW-6	08-30-91	1049.08	17.82	1031.26
	09-27-91		18.26	1030.82
	10-29-91		18.14	1030.94
	11-29-91		18.35	1030.73
	12-31-91		18.43	1030.65

NOTES:

1. Water depths were measured from the top of the protective casing.
2. Elevations are referenced to Mean Sea Level established by the United States Coastal and Geodetic Survey
3. Top of casing elevations are based on field measurements taken from top of brass monument to the top of casing, and differ slightly from subsequent surveyed elevations presented in Table 3-1.

TABLE 3-8

WATER LEVEL DATA
Southwest Funston Landfill
Fort Riley, Kansas

MONITORING WELL ID	GROUND SURFACE ELEVATION	TOP OF CASING ELEVATION	SWL	SWE	SWL	SWE	SWL	SWE	SWL	SWE	SWL	SWE	SWL	SWE
			(07/23/92)		(10/01/92)		(02/01/93)		(04/12/93)		(05/03/93)		(09/07/93)	
SFL92-101	1068.30	1069.98	37.59	1032.39	34.83	1035.15	35.98	1034.89	31.29	1038.69	30.81	1039.17	24.19	1045.79
SFL92-102	1067.60	1069.51	36.93	1032.58	34.49	1035.02	34.67	1034.84	30.68	1038.83	30.30	1039.21	23.87	1045.64
SFL92-103	1067.90	1069.81	37.25	1032.56	34.90	1034.91	34.98	1034.83	30.80	1039.01	30.53	1039.28	24.22	1045.59
SFL92-201	1046.00	1047.46	11.85	1035.61	14.67	1032.79	13.84	1033.62	7.77	1039.69	10.09	1037.37	5.82	1041.64
SFL92-203	1047.30	1049.35	13.12	1036.23	16.58	1032.77	15.78	1033.57	9.66	1039.69	11.87	1037.48	7.69	1041.66
SFL92-301	1048.40	1050.30	11.03	1039.27	18.66	1031.64	16.98	1033.32	10.54	1039.76	13.27	1037.03	9.45	1040.85
SFL92-302	1048.50	1050.19	10.92	1039.27	18.51	1031.68	16.87	1033.32	10.46	1039.73	12.95	1037.24	9.38	1040.81
SFL92-303	1048.60	1050.48	11.30	1039.18	18.76	1031.72	17.11	1033.37	10.66	1039.82	13.23	1037.25	9.60	1040.88
SFL92-401	1048.20	1050.07	15.80	1034.27	18.27	1031.80	17.56	1032.51	11.35	1038.72	14.25	1035.82	10.15	1039.92
SFL92-403	1048.00	1049.86	15.67	1034.19	18.04	1031.82	17.34	1032.52	11.15	1038.71	14.02	1035.84	9.91	1039.95
SFL92-501	1048.40	1049.22	16.75	1032.47	17.27	1031.95	16.73	1032.49	11.73	1037.49	13.36	1035.86	9.38	1039.84
SFL92-502	1046.40	1048.21	15.70	1032.51	16.24	1031.97	15.82	1032.39	10.74	1037.47	12.41	1035.80	8.34	1039.87
SFL92-503	1045.00	1048.46	15.93	1032.53	16.49	1031.97	16.05	1032.41	10.97	1037.49	12.63	1035.83	8.58	1039.88
SFL92-601	1052.20	1054.08	21.53	1032.55	21.31	1032.77	21.03	1033.05	16.09	1037.99	17.51	1036.57	13.08	1041.00
SFL92-602	1051.90	1053.93	21.32	1032.61	21.20	1032.73	20.87	1033.06	15.92	1038.01	17.37	1036.56	12.98	1040.95
SFL92-603	1051.70	1053.77	21.08	1032.69	21.02	1032.75	20.69	1033.08	15.71	1038.06	17.19	1036.58	12.77	1041.00
SFL92-701	1046.60	1048.21	15.89	1032.32	15.21	1033.00	15.02	1033.19	10.98	1037.23	11.86	1036.35	7.72	1040.49
SFL92-703	1045.90	1047.74	16.60	1031.14	14.72	1033.02	14.56	1033.18	10.62	1037.12	11.26	1036.48	6.89	1040.85
SFL92-801	1051.70	1053.50	21.65	1031.85	19.77	1033.73	19.76	1033.74	15.94	1037.56	16.08	1037.42	11.11	1042.39
SFL92-803	1051.90	1053.66	21.86	1031.80	19.91	1033.75	19.88	1033.78	16.05	1037.61	16.20	1037.46	11.27	1042.39
IT-1	1065.16	1066.98	NM	NM	NM	NM	NM	NM	30.99	1035.99	30.10	1036.88	NM	NM
IT-2	1066.57	1068.76	NM	NM	NM	NM	NM	NM	32.84	1035.92	31.97	1036.79	25.40	1043.36
IT-3	1065.68	1067.06	NM	NM	NM	NM	NM	NM	31.15	1035.91	30.29	1039.77	NM	NM
IT-4	1066.17	1068.00	NM	NM	NM	NM	NM	NM	32.03	1035.97	31.17	1036.83	NM	NM
DM-1090		1061.07	NM	NM	NM	NM	NM	NM	25.50	1035.57	24.79	1036.28	18.58	1042.54
DM-1044		1058.38	NM	NM	NM	NM	NM	NM	25.04	1033.34	23.99	1034.39	17.43	1040.95
DM-1539		1055.38	NM	NM	NM	NM	NM	NM	19.46	1035.92	19.21	1036.17	13.88	1041.50
DM-1890		1051.47	NM	NM	NM	NM	NM	NM	15.20	1036.27	15.31	1036.16	10.22	1041.25
DM-1190		1055.13	NM	NM	NM	NM	NM	NM	19.97	1035.16	19.47	1035.66	13.38	1041.75
DM-1637		1045.69	NM	NM	NM	NM	NM	NM	12.30	1033.39	11.81	1033.88	7.98	1037.71
DM-1245		1051.31	NM	NM	NM	NM	NM	NM	18.20	1033.11	17.84	1033.47	14.10	1037.21
AEHA-4		1055.87	NM	NM	NM	NM	NM	NM	NM	NM	19.89	1035.98	14.34	1041.53
AEHA-5		1043.36	NM	NM	NM	NM	NM	NM	NM	NM	8.03	1035.33	3.88	1039.48
AEHA-6		1051.52	NM	NM	NM	NM	NM	NM	NM	NM	18.40	1033.12	14.59	1036.93
AEHA-7		1043.36	NM	NM	NM	NM	NM	NM	NM	NM	9.86	1033.50	7.18	1036.18
Kansas River near SFL92-301				1041.20		1031.30		1033.40		1040.00		1038.70		

NM – not measured
1 – based on field measurements; cross referenced to river gauge data

SWL – Depth of water below top of casing
SWE – Elevation of water

discharge under certain conditions. In the absence of confirming hydraulic characterization data for the streambed of Threemile Creek and creek stage levels for the six water-level measurement events, the groundwater flow scenario represented for each of the six water-level measurement dates indicates that Threemile Creek acts as a hydraulic boundary condition for groundwater flow. That is, groundwater flow beneath Threemile Creek appears to be inhibited by the recharge/discharge conditions of the creek interaction with the groundwater system. Due to the effects of transient conditions in Threemile Creek and the Kansas River, groundwater flow under Threemile Creek could possibly occur under certain circumstances. However, it is highly likely that any such flow under Threemile Creek would subsequently be toward the Kansas River. Based on regional patterns of groundwater discharge to the Kansas River, it is unlikely that groundwater flow under Threemile Creek would continue for a substantial distance parallel to the Kansas River toward Ogden. Potentiometric surface maps for each of the six measurement events were developed and are presented and discussed in the following sections.

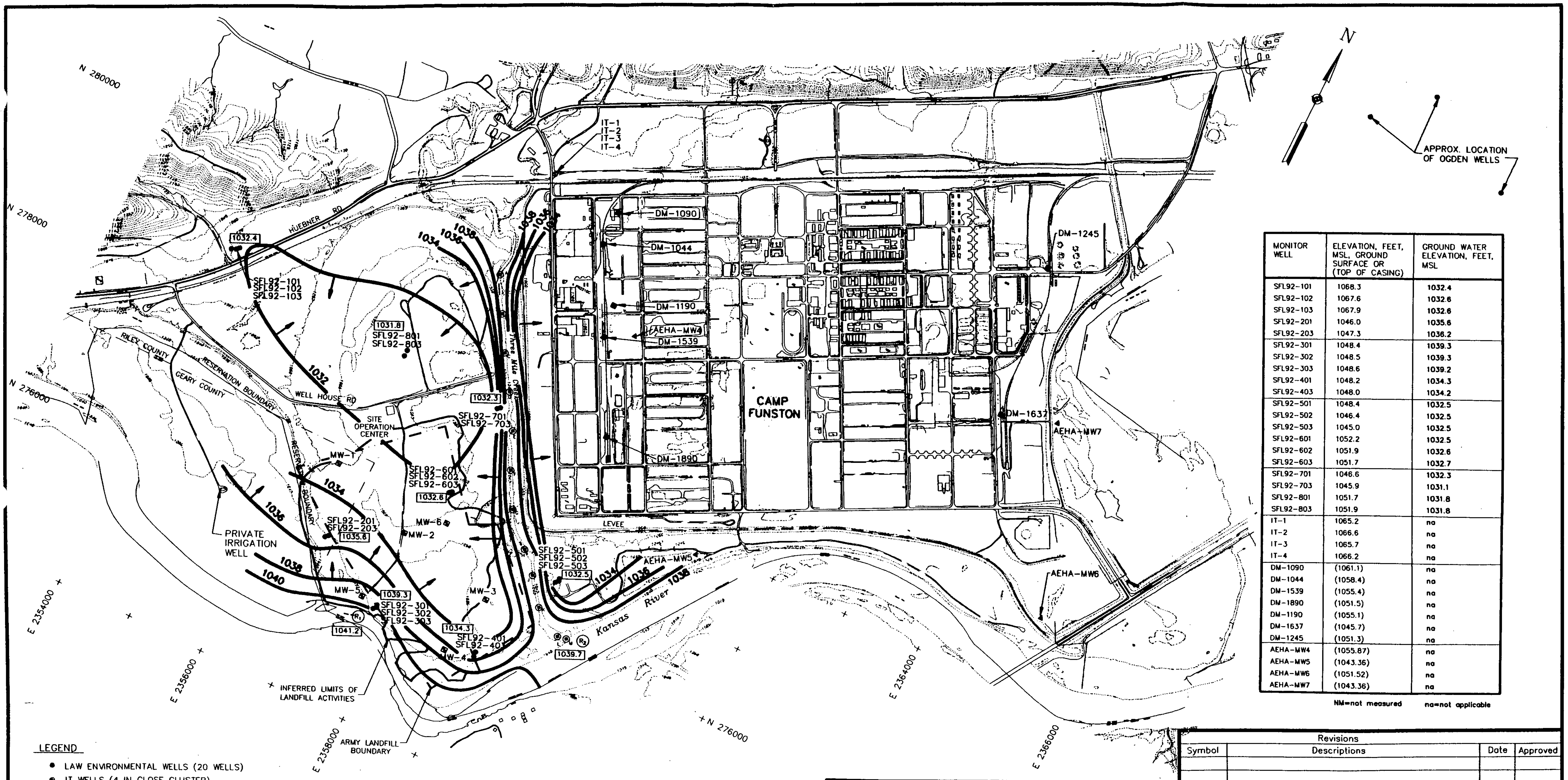
3.6.2.2.1 Groundwater Levels on July 23, 1992 - Water levels in monitoring wells were measured on July 23, 1992. Figure 3-14 presents the water table contour map for this date. During the 19-day period prior to July 23, 7.71 inches of rain was recorded. The Kansas River stage rose approximately eight feet in the three days preceding the July 23 measurement event. It appears that wells SFL92-101, SFL92-501, SFL92-601, SFL92-701, and SFL92-801 had not yet responded (as of July 23) to the high stage in the Kansas River and Threemile Creek. In contrast, wells SFL92-201, SFL92-301, and SFL92-401 are believed to have been affected by the Kansas River stage, which was estimated to be 1041.2 near well SFL92-301 on July 23. Total rainfall during July 1992 was 13.2 inches, while the average July rainfall is 3.8 inches.

The estimated river stage near well SFL92-301 during the July 23, 1992, event was approximately 1041 feet, which is the highest river stage of the six water-level measurement events. As shown in Figure 3-14, the groundwater gradient beneath SFL on this date was generally northeastward, away from the Kansas River. The groundwater gradient is relatively steep (0.008 feet/foot) near the river and decreases (to about 0.002 feet/foot) approximately 800 to 1000 feet north of the river. The gradient near Threemile Creek is steep (0.025 feet/foot). The average gradient in the SFL site area is about 0.002 feet/foot. Based on an assumed effective porosity of saturated alluvial soils of 0.30 and using hydraulic conductivities of 10 and 500 feet/day, the calculated flow velocity in the SFL site area ranged from 0.07 to 3.4 feet/day for the July 1992 water levels. The groundwater velocities for the SFL area were calculated using the following relation derived from Darcy's equation:

$$V = Ki/n$$

where V = the groundwater velocity
K = the hydraulic conductivity
i = the hydraulic gradient
n = the effective porosity of the aquifer

The hydraulic conductivity value of 10 feet/day is based on the analysis of slug-in and slug-out field test procedures performed on each of the 20 newly installed monitoring wells at the SFL. The hydraulic conductivity value of 500 feet/day is based on interpretation of specific capacity



MONITOR WELL	ELEVATION, FEET, MSL, GROUND SURFACE OR (TOP OF CASING)	GROUND WATER ELEVATION, FEET, MSL
SFL92-101	1068.3	1032.4
SFL92-102	1067.6	1032.6
SFL92-103	1067.9	1032.6
SFL92-201	1046.0	1035.6
SFL92-203	1047.3	1036.2
SFL92-301	1048.4	1039.3
SFL92-302	1048.5	1039.3
SFL92-303	1048.6	1039.2
SFL92-401	1048.2	1034.3
SFL92-403	1048.0	1034.2
SFL92-501	1048.4	1032.5
SFL92-502	1046.4	1032.5
SFL92-503	1045.0	1032.5
SFL92-601	1052.2	1032.5
SFL92-602	1051.9	1032.6
SFL92-603	1051.7	1032.7
SFL92-701	1046.6	1032.3
SFL92-703	1045.9	1031.1
SFL92-801	1051.7	1031.8
SFL92-803	1051.9	1031.8
IT-1	1065.2	na
IT-2	1066.6	na
IT-3	1065.7	na
IT-4	1066.2	na
DM-1090	(1061.1)	na
DM-1044	(1058.4)	na
DM-1539	(1055.4)	na
DM-1890	(1051.5)	na
DM-1190	(1055.1)	na
DM-1637	(1045.7)	na
DM-1245	(1051.3)	na
AEHA-MW4	(1055.87)	na
AEHA-MW5	(1043.36)	na
AEHA-MW6	(1051.52)	na
AEHA-MW7	(1043.36)	na

NM=not measured na=not applicable

LEGEND

- ● LAW ENVIRONMENTAL WELLS (20 WELLS)
- ◉ IT WELLS (4 IN CLOSE CLUSTER)
- ■ DM WELLS (7 WELLS)
- ▲ AEHA WELLS (4 WELLS)
- ▣ CLOSURE WELLS (6 WELLS)
- ◉ CHANNEL SURVEY STATION
- (R1) RIVER ELEVATION
- (R2) INFERRED RIVER ELEVATION
- 1050 — TOPOGRAPHIC CONTOUR INTERVAL=10 FEET, MSL
- 1040 ━ WATER TABLE CONTOUR INTERVAL=1 FOOT
- [1032.5] GROUND-WATER ELEVATION, FEET MSL
- ──► GROUND-WATER FLOW DIRECTION

NOTES:

1. CONTOURS CONSTRUCTED USING LAW WELLS (-01 SERIES WELLS/SHALLOW)
2. ALL LAW AMD DM WELLS SCREEN WATER TABLE EXCEPT:
   SFL92-02 SERIES - MIDPOINT OF AQUIFER
   SFL92-03 SERIES - BOTTOM OF AQUIFER
3. IT AND AEHA WELLS ARE PRESUMED TO SCREEN WATER TABLE - CONSTRUCTION DETAILS UNAVAILABLE.
4. TOP OF CASING ON DM AND AEHA WELLS APPROX. 2-3 FEET ABOVE GROUND SURFACE.

GRAPHIC SCALE

600 0 300 600 1200 2400

(IN FEET)

MAP LETTER	STATION	THREE MILE CREEK BOTTOM OF CHANNEL ELEVATION, FEET, MSL
A	0+00	1034.6
B	5+00	1034.4
C	10+00	1034.9
D	15+00	1033.9
E	20+00	1030.7
F	25+00	1031.5
G	30+00	1030.4
H	35+00	1027.4
J	39+75	1028.8
K	44+75	1028.5
L	48+30 CREEK	1031.4
M	48+30 MOUTH	1032.1

Revisions

Symbol	Descriptions	Date	Approved

LAW ENVIRONMENTAL INC.
GOVERNMENT SERVICES BRANCH
KENNESAW, GEORGIA

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

US ARMY CORPS OF ENGINEERS

FIGURE 3-14

WATER TABLE CONTOUR MAP

JULY 23, 1992

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS

Designed by: A.J.W.
Drawn by: P.P.R.
Checked by: J.K.C./A.J.W.
Submitted by: J.K.C./A.J.W.
Scale: AS NOTED
Date: JULY 28, 1993
Dwg. No.
Sheet number:

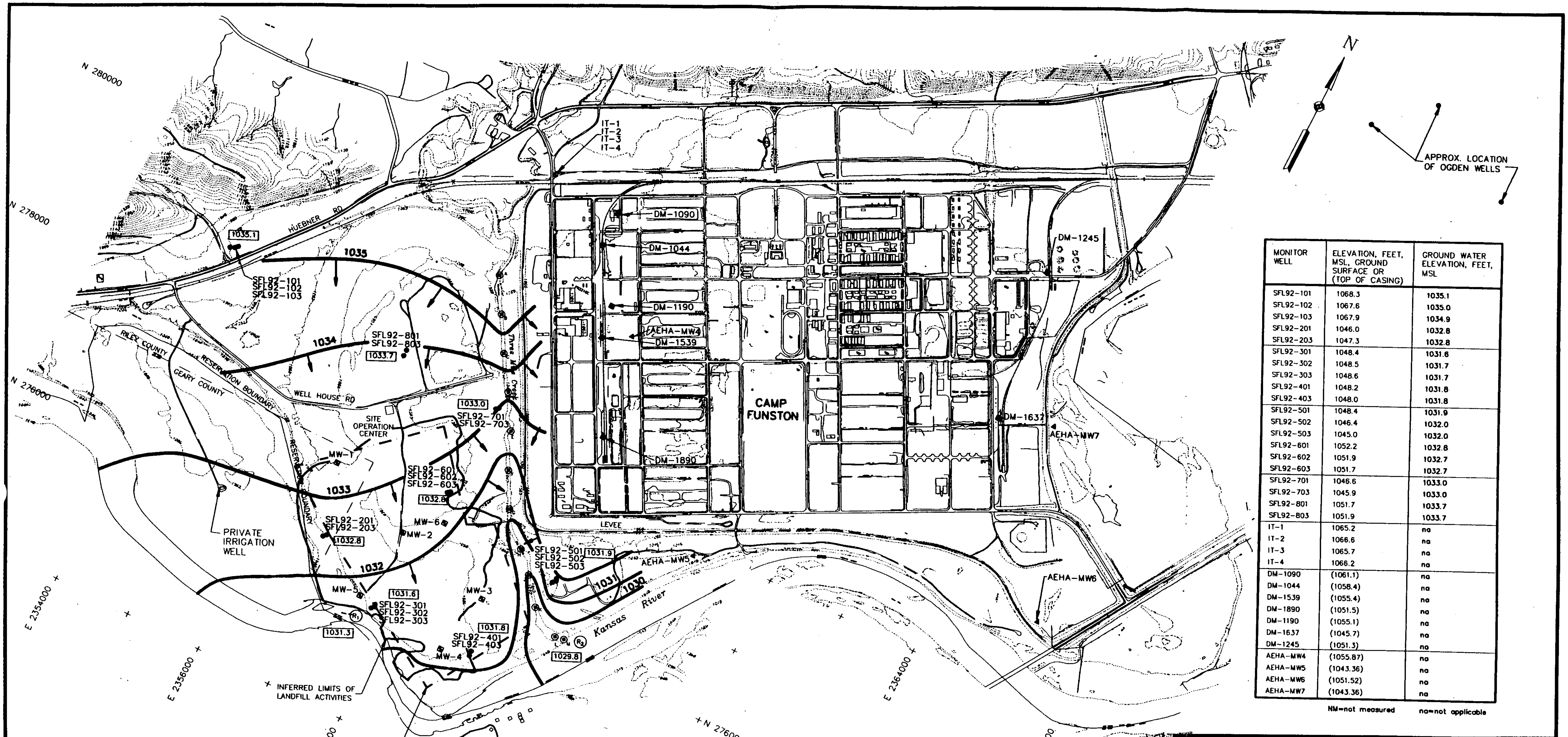
riley/base/1530bas1.dwg
layer: 7-23

data available for Funston supply wells FUN1, 2, 3 and 4 (Figure 1-6) (Latta, 1949). Based on these data, the range of 10 to 500 feet/day is assumed to represent the likely range of hydraulic conductivity at the SFL site.

Due to the high stage in the Kansas River, Threemile Creek is represented in a backwater condition in Figure 3-14 influenced by the Kansas River. Threemile Creek thus acts as a line source of recharge to the groundwater system and serves as an apparent hydraulic boundary condition to northeastward groundwater flow from the SFL site. The area northwestward of the SFL site is surrounded by areas of higher groundwater elevation and is configured as a local sink for groundwater flow. The observed water levels and the existence of an apparent local sink represent a transient condition resulting from the high stage in the Kansas River and backwater in Threemile Creek.

3.6.2.2.2 Groundwater Levels on October 1, 1992 - Rainfall amounts during August and September 1992 were slightly below average, and evapotranspiration rates are typically high during these months of the year. Rainfall occurred only a few days during each month, which is typical of summer thunderstorms in Kansas. Therefore, considering runoff and the high evapotranspiration rates, only minor contributions to infiltration are likely to have occurred during these two months. Water levels measured on October 1, 1992, show an increase in wells SFL92-101, SFL92-701, and SFL92-801, a decrease in wells SFL92-201, SFL92-301, SFL92-401, and essentially no change in well SFL92-601 from July 23, 1992 (Figure 3-15). Well SFL92-701 was also believed to be affected locally by Threemile Creek. The bottom elevation of Threemile Creek near this well varies from about 1032 to 1033 msl. Some minimum flow is always expected in Threemile Creek due to a wastewater treatment plant discharge location upstream (Figure 2-2). Threemile Creek is believed to be a source of aquifer recharge during high creek water levels and an aquifer discharge feature during periods of lower creek levels and higher groundwater levels.

The increased water levels observed in October 1992 in wells SFL92-101 and SFL92-801 are believed to be due to the percolation of excess rainfall into the aquifer following the high rainfall level of July 1992. The decreased water levels in wells SFL92-201, SFL92-301, SFL92-401 and SFL92-501 (since July 23, 1992) coincide with a drop in Kansas River stage height. Well SFL92-701 is believed to be influenced by the seasonal aquifer water levels (similar to SFL92-801) and also by Threemile Creek, which rises and falls with the Kansas River adjacent to the SFL due to backwater effects. The rise in water level at SFL92-701 between July 1992 and October 1992 was 0.7 feet, while SFL92-801 increased 1.9 feet. The Kansas River level decreased 9.9 feet between the July 1992 and October 1992 measurements. These measurements support the assertion that Threemile Creek is a groundwater discharge feature during periods of low river stage, having apparently influenced the water level in SFL92-701 during October 1992.



MONITOR WELL	ELEVATION, FEET, MSL, GROUND SURFACE OR (TOP OF CASING)	GROUND WATER ELEVATION, FEET, MSL
SFL92-101	1068.3	1035.1
SFL92-102	1067.6	1035.0
SFL92-103	1067.9	1034.9
SFL92-201	1046.0	1032.8
SFL92-203	1047.3	1032.8
SFL92-301	1048.4	1031.6
SFL92-302	1048.5	1031.7
SFL92-303	1048.6	1031.7
SFL92-401	1048.2	1031.8
SFL92-403	1048.0	1031.8
SFL92-501	1048.4	1031.9
SFL92-502	1046.4	1032.0
SFL92-503	1045.0	1032.0
SFL92-601	1052.2	1032.8
SFL92-602	1051.9	1032.7
SFL92-603	1051.7	1032.7
SFL92-701	1046.6	1033.0
SFL92-703	1045.9	1033.0
SFL92-801	1051.7	1033.7
SFL92-803	1051.9	1033.7
IT-1	1065.2	na
IT-2	1066.6	na
IT-3	1065.7	na
IT-4	1066.2	na
DM-1090	(1061.1)	na
DM-1044	(1058.4)	na
DM-1539	(1055.4)	na
DM-1890	(1051.5)	na
DM-1190	(1055.1)	na
DM-1637	(1045.7)	na
DM-1245	(1051.3)	na
AEHA-MW4	(1055.87)	na
AEHA-MW5	(1043.36)	na
AEHA-MW6	(1051.52)	na
AEHA-MW7	(1043.36)	na

NM=not measured na=not applicable

LEGEND

- ● LAW ENVIRONMENTAL WELLS (20 WELLS)
- ⊙ IT WELLS (4 IN CLOSE CLUSTER)
- ■ DM WELLS (7 WELLS)
- ▲ AEHA WELLS (4 WELLS)
- ▣ CLOSURE WELLS (6 WELLS)
- ◉ CHANNEL SURVEY STATION
- (R1) RIVER ELEVATION
- (R2) INFERRED RIVER ELEVATION
- 1050 — TOPOGRAPHIC CONTOUR INTERVAL=10 FEET, MSL
- 1040 ━ WATER TABLE CONTOUR INTERVAL=1 FOOT
- [1032.5] GROUND-WATER ELEVATION, FEET MSL
- ──► GROUND-WATER FLOW DIRECTION

NOTES:

1. CONTOURS CONSTRUCTED USING LAW WELLS (-01 SERIES WELLS/SHALLOW)
2. ALL LAW AND DM WELLS SCREEN WATER TABLE EXCEPT:
   SFL92-02 SERIES – MIDPOINT OF AQUIFER
   SFL92-03 SERIES – BOTTOM OF AQUIFER
3. IT AND AEHA WELLS ARE PRESUMED TO SCREEN WATER TABLE – CONSTRUCTION DETAILS UNAVAILABLE.
4. TOP OF CASING ON DM AND AEHA WELLS APPROX. 2-3 FEET ABOVE GROUND SURFACE.

GRAPHIC SCALE

(IN FEET)

MAP LETTER	STATION	THREE MILE CREEK BOTTOM OF CHANNEL ELEVATION, FEET, MSL
A	0+00	1034.6
B	5+00	1034.4
C	10+00	1034.9
D	15+00	1033.9
E	20+00	1030.7
F	25+00	1031.5
G	30+00	1030.4
H	35+00	1027.4
J	39+75	1028.8
K	44+75	1028.5
L	48+30 CREEK	1031.4
M	48+30 MOUTH	1032.1

Revisions

Symbol	Descriptions	Date	Approved

LAW ENVIRONMENTAL INC.
GOVERNMENT SERVICES BRANCH
KENNESAW, GEORGIA

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

Designed by: A.J.W.
Drawn by: P.P.R.
Checked by: J.K.C./A.J.W.
Submitted by: J.K.C./A.J.W.

US ARMY CORPS OF ENGINEERS

FIGURE 3-15

WATER TABLE CONTOUR MAP

OCTOBER 1, 1992

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS

Scale: AS NOTED
Date: JULY 28, 1993
Dwg. No.:
Sheet number:

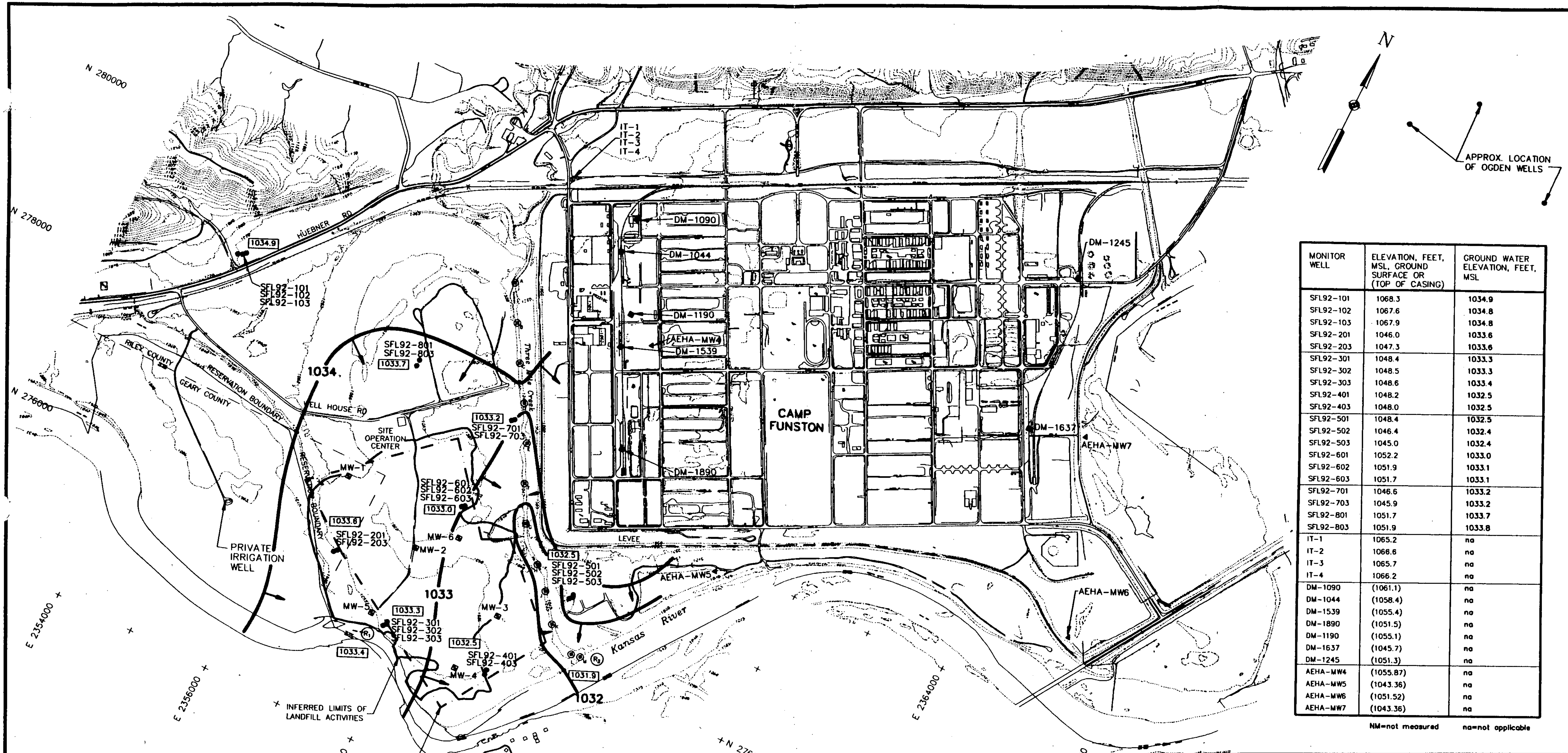
riley/base/1530bas1.dwg

The river stage near SFL92-301 on October 1, 1992, was approximately 1031 feet, which is the lowest river stage of the five measurement events. The groundwater gradient on this date (Figure 3-15) was southeastward, toward the Kansas River. The magnitude of the gradient averaged about 0.0008 feet/foot in the SFL area, indicating a flow velocity ranging from 0.03 to 1.3 feet/day based on a hydraulic conductivity range of 10 to 500 feet/day. Based on measured groundwater elevations and inferred surface-water elevations, Threemile Creek is an area of recharge to the groundwater system in the northern portion of the SFL site area, and is an area of groundwater discharge in the southern portion of the SFL site area.

3.6.2.2.3 Groundwater Levels on February 1, 1993 - Water levels measured in monitoring wells on February 1, 1993, were taken after a month of low river stage on the Kansas River and average rainfall during January 1993 (Figure 3-16). Above average rainfall did occur during November to December 1992, and river levels were above elevation 1034 during most of December. Water levels in wells SFL92-101, SFL92-601, SFL92-701, and SFL92-801 on February 1, 1993, were essentially unchanged from the October levels, all being within 0.2 feet of the October 1992 sampling event, while the Kansas River stage elevation was about 2.1 feet higher on February 1 than on October 1. In contrast, water levels in wells closer to the river (SFL92-201, SFL92-301, SFL92-401, and SFL92-501) were higher on February 1, 1993 than October 1, 1992, which reflects the higher river stage on February 1, 1993. Groundwater at SFL92-701 was probably moderately affected by the Threemile Creek level in February 1993.

The river stage near SFL92-301 on February 1, 1993, was approximately 1033 feet. The groundwater gradient on this date was approximately 0.0009 feet/foot in the SFL area and directed eastward parallel to or toward the Kansas River (Figure 3-16). The groundwater gradient resulted in an estimated flow velocity ranging from 0.03 to 1.5 feet/day based on a hydraulic conductivity range of 10 to 500 feet/day. Based on measured groundwater elevations and inferred surface-water elevations, Threemile Creek is an area of groundwater recharge in the northern portion of the SFL site area, and is an area of groundwater discharge in the southern portion of the SFL site area.

3.6.2.2.4 Groundwater Levels on April 12, 1993 - The groundwater levels measured on April 12 and May 3, 1993, are similar and can be described in relation to the February 1, 1993, observations. Water levels in monitoring wells 101, 601, 701, and 801 increased between 3.8 and 5.0 feet from the February sampling event. Precipitation during February 1993 was below average. Rainfall amounts during March and early April exceeded average levels. Water levels in SFL92-101 and SFL92-801 were greater than or similar to the July 1992 levels and are not believed to be controlled by the Kansas River stage which changed significantly during the study period. The increased groundwater elevations at SFL92-101 and SFL92-801 from February to May 1993 are believed to be due to seasonal fluctuations in the local water table influenced by the large amount of rainfall received during the previous nine months.



MONITOR WELL	ELEVATION, FEET, MSL, GROUND SURFACE OR (TOP OF CASING)	GROUND WATER ELEVATION, FEET, MSL
SFL92-101	1068.3	1034.9
SFL92-102	1067.6	1034.8
SFL92-103	1067.9	1034.8
SFL92-201	1046.0	1033.6
SFL92-203	1047.3	1033.6
SFL92-301	1048.4	1033.3
SFL92-302	1048.5	1033.3
SFL92-303	1048.6	1033.4
SFL92-401	1048.2	1032.5
SFL92-403	1048.0	1032.5
SFL92-501	1048.4	1032.5
SFL92-502	1046.4	1032.4
SFL92-503	1045.0	1032.4
SFL92-601	1052.2	1033.0
SFL92-602	1051.9	1033.1
SFL92-603	1051.7	1033.1
SFL92-701	1046.6	1033.2
SFL92-703	1045.9	1033.2
SFL92-801	1051.7	1033.7
SFL92-803	1051.9	1033.8
IT-1	1065.2	na
IT-2	1066.6	na
IT-3	1065.7	na
IT-4	1066.2	na
DM-1090	(1061.1)	na
DM-1044	(1058.4)	na
DM-1539	(1055.4)	na
DM-1890	(1051.5)	na
DM-1190	(1055.1)	na
DM-1637	(1045.7)	na
DM-1245	(1051.3)	na
AEHA-MW4	(1055.87)	na
AEHA-MW5	(1043.36)	na
AEHA-MW6	(1051.52)	na
AEHA-MW7	(1043.36)	na

NM=not measured na=not applicable

LEGEND

- ● LAW ENVIRONMENTAL WELLS (20 WELLS)
- ⊛ IT WELLS (4 IN CLOSE CLUSTER)
- ■ DM WELLS (7 WELLS)
- ▲ AEHA WELLS (4 WELLS)
- ▣ CLOSURE WELLS (6 WELLS)
- ◉ CHANNEL SURVEY STATION
- (R1) RIVER ELEVATION
- (R2) INFERRED RIVER ELEVATION
- 1050 — TOPOGRAPHIC CONTOUR INTERVAL=10 FEET, MSL
- 1040 ━ WATER TABLE CONTOUR INTERVAL=1 FOOT
- [1032.5] GROUND-WATER ELEVATION, FEET MSL
- ⟶ GROUND-WATER FLOW DIRECTION

NOTES:

1. CONTOURS CONSTRUCTED USING LAW WELLS (-01 SERIES WELLS/SHALLOW)
2. ALL LAW AND DM WELLS SCREEN WATER TABLE EXCEPT:
   SFL92-02 SERIES - MIDPOINT OF AQUIFER
   SFL92-03 SERIES - BOTTOM OF AQUIFER
3. IT AND AEHA WELLS ARE PRESUMED TO SCREEN WATER TABLE - CONSTRUCTION DETAILS UNAVAILABLE.
4. TOP OF CASING ON DM AND AEHA WELLS APPROX. 2-3 FEET ABOVE GROUND SURFACE.

GRAPHIC SCALE

600 0 300 600 1200 2400

(IN FEET)

MAP LETTER	STATION	THREE MILE CREEK BOTTOM OF CHANNEL ELEVATION, FEET, MSL
A	0+00	1034.6
B	5+00	1034.4
C	10+00	1034.9
D	15+00	1033.9
E	20+00	1030.7
F	25+00	1031.5
G	30+00	1030.4
H	35+00	1027.4
J	39+75	1028.8
K	44+75	1028.5
L	48+30 CREEK	1031.4
M	48+30 MOUTH	1032.1

Revisions

Symbol	Descriptions	Date	Approved

LAW ENVIRONMENTAL INC.
GOVERNMENT SERVICES BRANCH
KENNESAW, GEORGIA

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

US ARMY CORPS OF ENGINEERS

FIGURE 3-16

WATER TABLE CONTOUR MAP
FEBRUARY 1, 1993
SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS

Designed by: A.J.W.
Drawn by: P.P.R.
Checked by: J.K.C./A.J.W.
Submitted by: J.K.C./A.J.W.
Scale: AS NOTED
Date: JULY 28, 1993
Dwg. No.
Sheet number:

riley/base/1530bas1.dwg

Well SFL92-601 appears to be influenced by infiltration processes similar to SFL92-801 and also by the Kansas River stage. Compared to February levels, water levels in SFL92-601 in April and May 1993 reflected the river stage more closely than water levels at SFL92-801 or SFL92-101. This also suggests an influence from Threemile Creek, which is closer to SFL92-601 than is the Kansas River, since Threemile Creek stage is apparently influenced by the Kansas River stage except at low stages. For the April and May 1993 events, water levels at SFL92-201, SFL92-301, SFL92-401, and SFL92-501 were apparently influenced by the Kansas River stage.

The river stage near SFL92-301 on April 12, 1993, was approximately 1040 feet, which is the third highest of the six measurements taken from July 1992 through September 1993. The groundwater gradient in the SFL area on this date was northeastward, toward Threemile Creek (Figure 3-17). The magnitude of the gradient was approximately 0.001 feet/foot, resulting in an estimated flow velocity ranging from 0.03 to 1.7 feet/day based on a hydraulic conductivity range of 10 to 500 feet/day. Due to the relatively high river stage, Threemile Creek is represented in a backwater condition and inferred to be a source of recharge to the groundwater system. Thus, Threemile Creek apparently acts as a hydraulic boundary condition constraining northeastward groundwater flow from the SFL site.

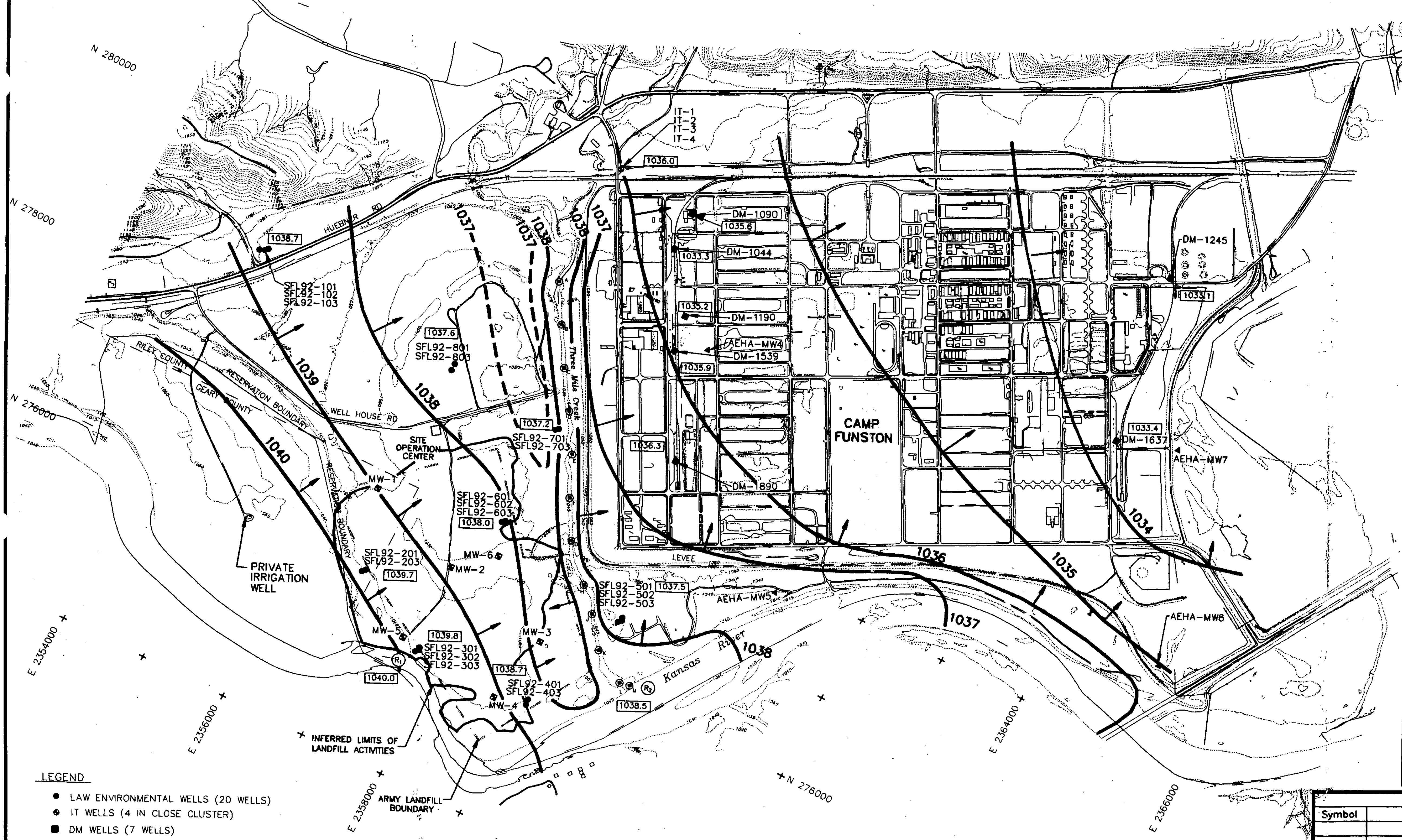
3.6.2.2.5 Groundwater Levels on May 3, 1993 - The river stage near SFL92-301 on May 3, 1993, was approximately 1039 feet, which is relatively high. The groundwater gradient in the SFL area on this date was approximately 0.0007 feet/foot to the east, toward Threemile Creek (Figure 3-18). The estimated flow velocity ranged from 0.02 to 1.2 feet/day based on a hydraulic conductivity range of 10 to 500 feet/day. Based on measured groundwater elevations and inferred surface-water elevations, Threemile Creek appears to act as a line source of recharge to the groundwater system and a hydraulic boundary condition constraining eastward groundwater flow from the SFL site. The area near MW-3 and SFL92-401 is surrounded by higher groundwater elevations and is configured as a local sink for groundwater flow. The observed water levels and the existence of an apparent local sink represent a transient condition resulting from the relatively high stage of the Kansas River.

3.6.2.2.6 Groundwater Levels on September 7, 1993 - The river stage near SFL92-301 on September 7, 1993, was approximately 1041 feet, which is the second highest of the six measurements taken from July 1992 to September 1993. The groundwater gradient in the SFL area on this date was approximately 0.0009 feet/foot to the east, toward Threemile Creek (Figure 3-22). The estimated flow velocity ranged from 0.03 to 1.5 feet/day based on a hydraulic conductivity range of 10 to 500 feet/day. Based on measured groundwater elevations and inferred surface-water elevations, Threemile Creek appears to act as a line source of discharge from the groundwater system and as a hydraulic boundary condition constraining eastward groundwater flow from the SFL site.

3.6.2.2.7 Discussion of Water Levels - Potentiometric maps derived from six water-level measurement events (Figures 3-14 through 3-18, and 3-18a) indicate considerable variation in groundwater gradient beneath the SFL. The direction of the gradient in the SFL area ranged from northeastward to southeastward. The magnitude of the gradient ranged from 0.0007 feet/foot across most of the SFL site on May 3, 1993, to 0.008 feet/foot adjacent to the Kansas River on July 23, 1992. Based upon these gradients and hydraulic conductivity values of 10 and 500 feet/day, the estimated flow velocity ranged from 0.02 to 3.4 feet/day.

Water level data show that water levels in all the SFL wells can vary significantly. The evaluations presented here are based on observations from six sampling events; the fluctuations of water levels in the monitoring wells and changes in gradients are not known for the time periods between the sampling events. Groundwater levels in the wells can be influenced both by precipitation and changes in the stages of Threemile Creek and the Kansas River. On an average, long-term basis, the direction of groundwater flow will be toward the southeast with discharge from the groundwater system to the surface water system. During various times, conditions will reverse and flow will be into the groundwater system in response to variations in stage.

Under conditions of long stable stages in the Kansas River and Threemile Creek, transitory flow under Threemile Creek may occur. However, precipitation events, regular releases to the Kansas River and its tributaries from upstream reservoirs and wastewater discharges to the Threemile Creek drainage basin result in persistently fluctuating stages. It is highly likely that any such flow under Threemile Creek would subsequently be toward the Kansas River and would not continue for a substantial distance parallel to the Kansas River toward Ogden.



APPROX. LOCATION OF OGDEN WELLS

MONITOR WELL	ELEVATION, FEET, MSL, GROUND SURFACE OR (TOP OF CASING)	GROUND WATER ELEVATION, FEET, MSL
SFL92-101	1068.3	1038.7
SFL92-102	1067.6	1038.8
SFL92-103	1067.9	1039.0
SFL92-201	1046.0	1039.7
SFL92-203	1047.3	1039.7
SFL92-301	1048.4	1039.8
SFL92-302	1048.5	1039.7
SFL92-303	1048.6	1039.8
SFL92-401	1048.2	1038.7
SFL92-403	1048.0	1038.7
SFL92-501	1048.4	1037.5
SFL92-502	1046.4	1037.5
SFL92-503	1045.0	1037.5
SFL92-601	1052.2	1038.0
SFL92-602	1051.9	1038.0
SFL92-603	1051.7	1038.1
SFL92-701	1046.6	1037.2
SFL92-703	1045.9	1037.1
SFL92-801	1051.7	1037.6
SFL92-803	1051.9	1037.6
IT-1	1065.2	1036.0
IT-2	1066.6	1035.9
IT-3	1065.7	1035.9
IT-4	1066.2	1036.0
DM-1090	(1061.1)	1035.6
DM-1044	(1058.4)	1033.3
DM-1539	(1055.4)	1035.9
DM-1890	(1051.5)	1036.3
DM-1190	(1055.1)	1035.2
DM-1637	(1045.7)	1033.4
DM-1245	(1051.3)	1033.1
AEHA-MW4	(1055.87)	na
AEHA-MW5	(1043.36)	na
AEHA-MW6	(1051.52)	na
AEHA-MW7	(1043.36)	na
	nm=not measured	na=not applicable

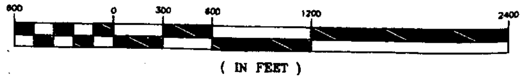
LEGEND

●	LAW ENVIRONMENTAL WELLS (20 WELLS)
⊕	IT WELLS (4 IN CLOSE CLUSTER)
■	DM WELLS (7 WELLS)
▲	AEHA WELLS (4 WELLS)
▣	CLOSURE WELLS (6 WELLS)
◉	CHANNEL SURVEY STATION
(R1)	RIVER ELEVATION
(R2)	INFERRED RIVER ELEVATION
1050 —	TOPOGRAPHIC CONTOUR INTERVAL=10 FEET, MSL
1040 ━	WATER TABLE CONTOUR INTERVAL=1 FOOT DASHED WHERE INFERRED
1032.5	GROUND-WATER ELEVATION, FEET MSL
⟶	GROUND-WATER FLOW DIRECTION

NOTES:

1. CONTOURS CONSTRUCTED USING LAW (01-SERIES), DM, IT WELLS.
2. ALL LAW AND DM WELLS SCREEN WATER TABLE EXCEPT:
   SFL92-02 SERIES - MIDPOINT OF AQUIFER
   SFL92-03 SERIES - BOTTOM OF AQUIFER
3. IT AND AEHA WELLS ARE PRESUMED TO SCREEN WATER TABLE - CONSTRUCTION DETAILS UNAVAILABLE.
4. TOP OF CASING ON DM AND AEHA WELLS APPROX. 2-3 FEET ABOVE GROUND SURFACE.
5. DM WELL 1044 CONTAINED APPROX. 3.2 FEET OF HYDROCARBON-WATER ELEVATION LOCALLY DEPRESSED. NOT CONTOURED.

GRAPHIC SCALE



MAP LETTER	STATION	THREE MILE CREEK BOTTOM OF CHANNEL ELEVATION, FEET, MSL
A	0+00	1034.6
B	5+00	1034.4
C	10+00	1034.9
D	15+00	1033.9
E	20+00	1030.7
F	25+00	1031.5
G	30+00	1030.4
H	35+00	1027.4
J	39+75	1028.8
K	44+75	1028.5
L	48+30 CREEK	1031.4
M	48+30 MOUTH	1032.1

Revisions

Symbol	Descriptions	Date	Approved

LAW ENVIRONMENTAL INC.
GOVERNMENT SERVICES BRANCH
KENNESAW, GEORGIA

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

Designed by: A.J.W.
Drawn by: P.P.R.
Checked by: J.K.C./A.J.W.
Submitted by: J.K.C./A.J.W.

US ARMY CORPS OF ENGINEERS

FIGURE 3-17

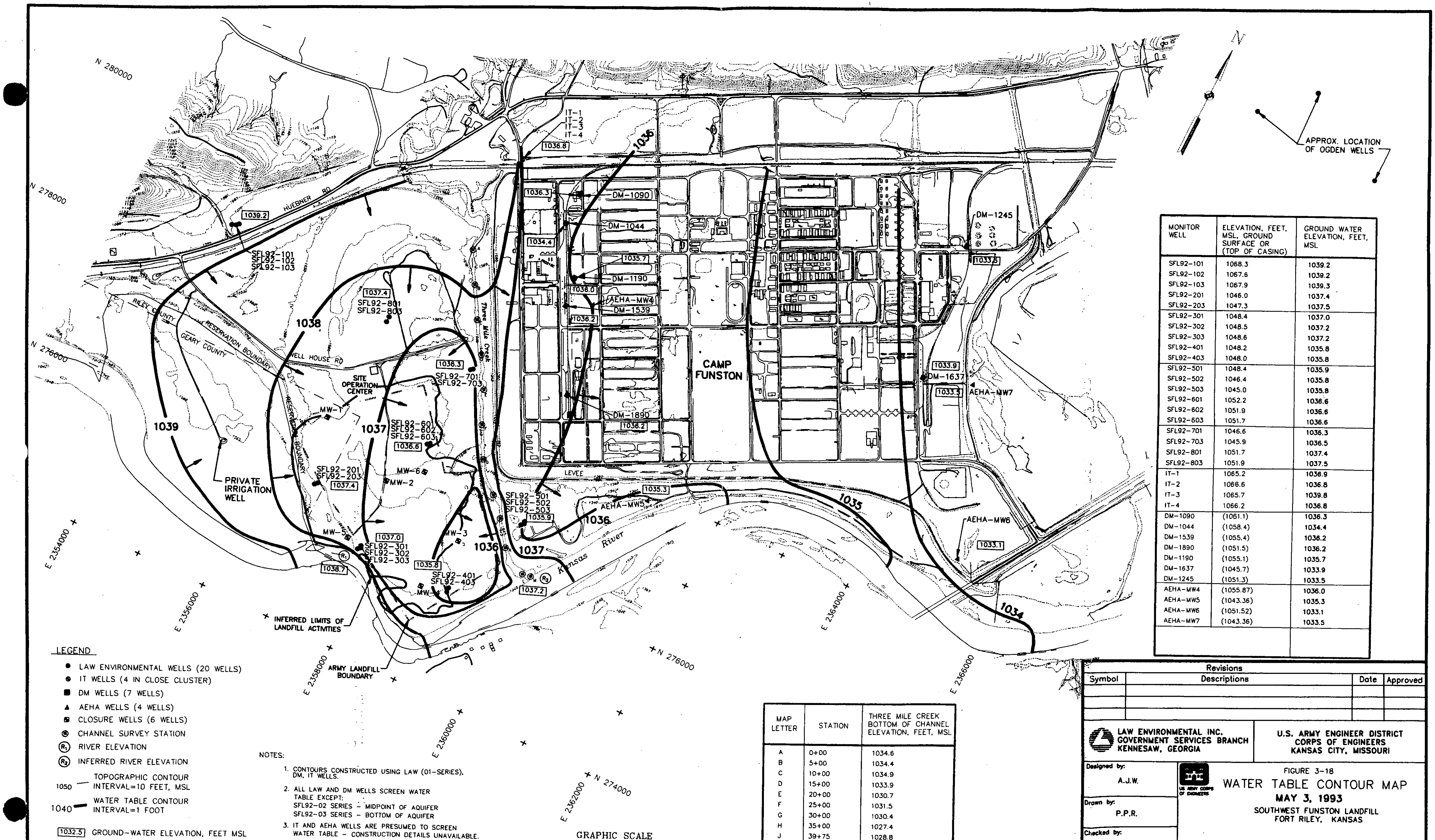
WATER TABLE CONTOUR MAP

APRIL 12, 1993

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS

Scale: AS NOTED
Date: MARCH 08, 1994
Dwg. No.
Sheet number:

riley/base/1530bas1.dwg
layer: 4-12



MONITOR WELL	ELEVATION, FEET, MSL, GROUND SURFACE OR (TOP OF CASING)	GROUND WATER ELEVATION, FEET, MSL
SFL92-101	1068.3	1039.2
SFL92-102	1067.6	1039.2
SFL92-103	1067.9	1039.3
SFL92-201	1046.0	1037.4
SFL92-203	1047.3	1037.5
SFL92-301	1048.4	1037.0
SFL92-302	1048.5	1037.2
SFL92-303	1048.6	1037.2
SFL92-401	1048.2	1035.8
SFL92-403	1048.0	1035.8
SFL92-501	1048.4	1035.9
SFL92-502	1046.4	1035.8
SFL92-503	1045.0	1035.8
SFL92-601	1052.2	1036.6
SFL92-602	1051.9	1036.6
SFL92-603	1051.7	1036.6
SFL92-701	1046.6	1036.3
SFL92-703	1045.9	1036.5
SFL92-801	1051.7	1037.4
SFL92-803	1051.9	1037.5
IT-1	1065.2	1036.9
IT-2	1066.6	1036.8
IT-3	1065.7	1039.8
IT-4	1066.2	1036.8
DM-1090	(1061.1)	1036.3
DM-1044	(1058.4)	1034.4
DM-1539	(1055.4)	1036.2
DM-1890	(1051.5)	1036.2
DM-1190	(1055.1)	1035.7
DM-1637	(1045.7)	1033.9
DM-1245	(1051.3)	1033.5
AEHA-MW4	(1055.87)	1036.0
AEHA-MW5	(1043.36)	1035.3
AEHA-MW6	(1051.52)	1033.1
AEHA-MW7	(1043.36)	1033.5

LEGEND

●	LAW ENVIRONMENTAL WELLS (20 WELLS)
⊕	IT WELLS (4 IN CLOSE CLUSTER)
■	DM WELLS (7 WELLS)
▲	AEHA WELLS (4 WELLS)
▣	CLOSURE WELLS (6 WELLS)
◉	CHANNEL SURVEY STATION
(R1)	RIVER ELEVATION
(R2)	INFERRED RIVER ELEVATION
1050 —	TOPOGRAPHIC CONTOUR INTERVAL=10 FEET, MSL
1040 ━	WATER TABLE CONTOUR INTERVAL=1 FOOT
1032.5	GROUND-WATER ELEVATION, FEET MSL
⟶	GROUND-WATER FLOW DIRECTION

NOTES:

1. CONTOURS CONSTRUCTED USING LAW (01-SERIES), DM, IT WELLS.
2. ALL LAW AND DM WELLS SCREEN WATER TABLE EXCEPT:
   SFL92-02 SERIES - MIDPOINT OF AQUIFER
   SFL92-03 SERIES - BOTTOM OF AQUIFER
3. IT AND AEHA WELLS ARE PRESUMED TO SCREEN WATER TABLE - CONSTRUCTION DETAILS UNAVAILABLE.
4. TOP OF CASING ON DM AND AEHA WELLS APPROX. 2.5 FEET ABOVE GROUND SURFACE.
5. DM WELL 1044 CONTAINED APPROX. 2.5 FEET OF HYDROCARBON-WATER ELEVATION LOCALLY DEPRESSED. NOT CONTOURED.

MAP LETTER	STATION	THREE MILE CREEK BOTTOM OF CHANNEL ELEVATION, FEET, MSL
A	0+00	1034.6
B	5+00	1034.4
C	10+00	1034.9
D	15+00	1033.9
E	20+00	1030.7
F	25+00	1031.5
G	30+00	1030.4
H	35+00	1027.4
J	39+75	1028.8
K	44+75	1028.5
L	48+30 CREEK	1031.4
M	48+30 MOUTH	1032.1

Revisions

Symbol	Descriptions	Date	Approved

LAW ENVIRONMENTAL INC.
GOVERNMENT SERVICES BRANCH
KENNESAW, GEORGIA

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

US ARMY CORPS OF ENGINEERS

FIGURE 3-18

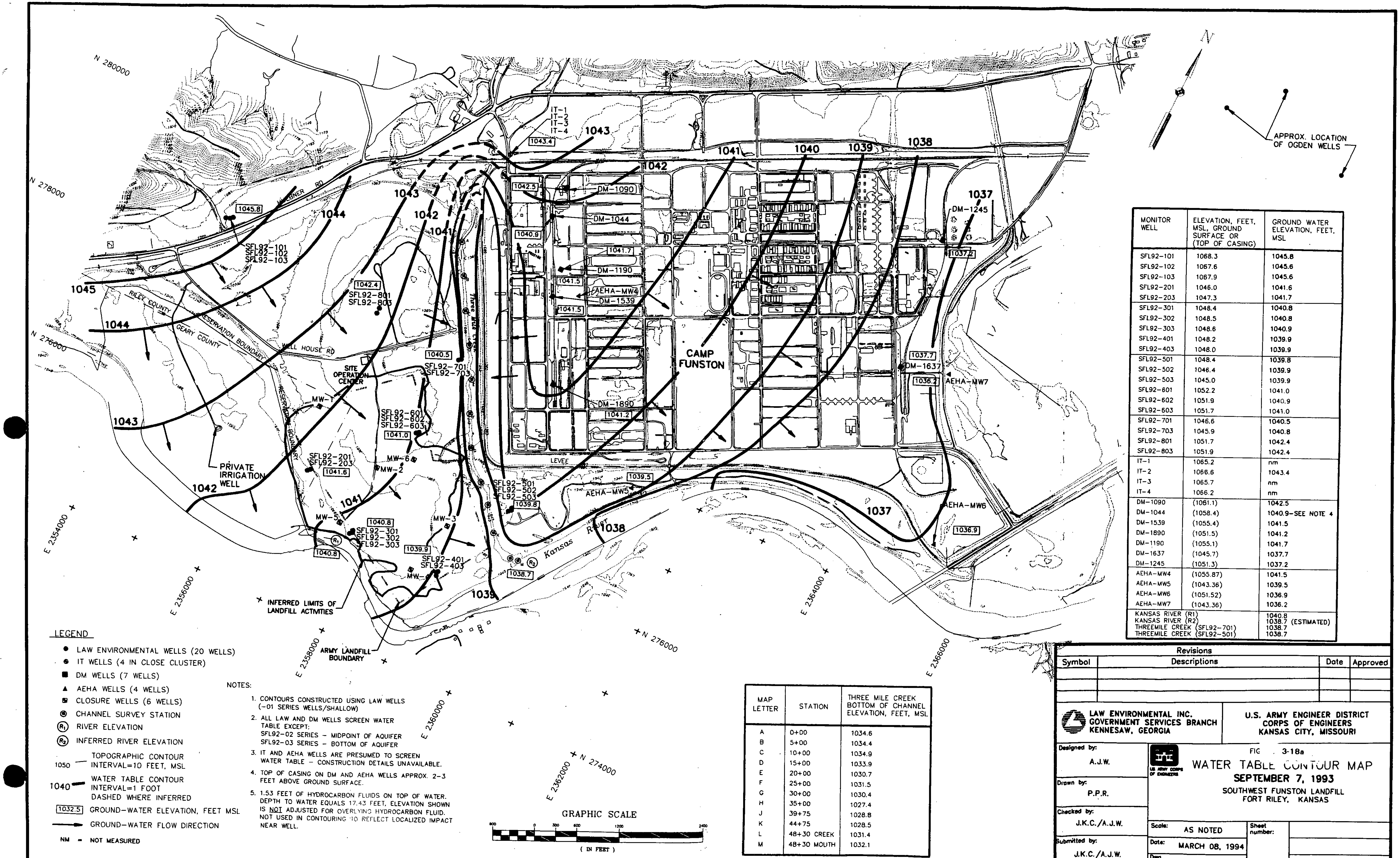
WATER TABLE CONTOUR MAP

MAY 3, 1993

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS

Designed by: A.J.W.
Drawn by: P.P.R.
Checked by: J.K.C./A.J.W.
Submitted by: J.K.C./A.J.W.
Scale: AS NOTED
Date: MARCH 08, 1994
Dwg. No.
Sheet number:

riley/base/1530bas1.dwg
layer: 5-3



MONITOR WELL	ELEVATION, FEET, MSL, GROUND SURFACE OR (TOP OF CASING)	GROUND WATER ELEVATION, FEET, MSL
SFL92-101	1068.3	1045.8
SFL92-102	1067.6	1045.6
SFL92-103	1067.9	1045.6
SFL92-201	1046.0	1041.6
SFL92-203	1047.3	1041.7
SFL92-301	1048.4	1040.8
SFL92-302	1048.5	1040.8
SFL92-303	1048.6	1040.9
SFL92-401	1048.2	1039.9
SFL92-403	1048.0	1039.9
SFL92-501	1048.4	1039.8
SFL92-502	1046.4	1039.9
SFL92-503	1045.0	1039.9
SFL92-601	1052.2	1041.0
SFL92-602	1051.9	1040.9
SFL92-603	1051.7	1041.0
SFL92-701	1046.6	1040.5
SFL92-703	1045.9	1040.8
SFL92-801	1051.7	1042.4
SFL92-803	1051.9	1042.4
IT-1	1065.2	nm
IT-2	1066.6	1043.4
IT-3	1065.7	nm
IT-4	1066.2	nm
DM-1090	(1061.1)	1042.5
DM-1044	(1058.4)	1040.9-SEE NOTE 4
DM-1539	(1055.4)	1041.5
DM-1890	(1051.5)	1041.2
DM-1190	(1055.1)	1041.7
DM-1637	(1045.7)	1037.7
DM-1245	(1051.3)	1037.2
AEHA-MW4	(1055.87)	1041.5
AEHA-MW5	(1043.36)	1039.5
AEHA-MW6	(1051.52)	1036.9
AEHA-MW7	(1043.36)	1036.2
KANSAS RIVER (R1)		1040.8
KANSAS RIVER (R2)		1038.7 (ESTIMATED)
THREEMILE CREEK (SFL92-701)		1038.7
THREEMILE CREEK (SFL92-501)		1038.7

LEGEND

- ● LAW ENVIRONMENTAL WELLS (20 WELLS)
- ◉ IT WELLS (4 IN CLOSE CLUSTER)
- ■ DM WELLS (7 WELLS)
- ▲ AEHA WELLS (4 WELLS)
- ▣ CLOSURE WELLS (6 WELLS)
- ◎ CHANNEL SURVEY STATION
- (R1) RIVER ELEVATION
- (R2) INFERRED RIVER ELEVATION
- 1050 — TOPOGRAPHIC CONTOUR INTERVAL=10 FEET, MSL
- 1040 ━ WATER TABLE CONTOUR INTERVAL=1 FOOT DASHED WHERE INFERRED
- [1032.5] GROUND-WATER ELEVATION, FEET MSL
- ──► GROUND-WATER FLOW DIRECTION
- NM = NOT MEASURED

NOTES:

1. CONTOURS CONSTRUCTED USING LAW WELLS (-01 SERIES WELLS/SHALLOW)
2. ALL LAW AND DM WELLS SCREEN WATER TABLE EXCEPT:
   SFL92-02 SERIES - MIDPOINT OF AQUIFER
   SFL92-03 SERIES - BOTTOM OF AQUIFER
3. IT AND AEHA WELLS ARE PRESUMED TO SCREEN WATER TABLE - CONSTRUCTION DETAILS UNAVAILABLE.
4. TOP OF CASING ON DM AND AEHA WELLS APPROX. 2-3 FEET ABOVE GROUND SURFACE.
5. 1.53 FEET OF HYDROCARBON FLUIDS ON TOP OF WATER. DEPTH TO WATER EQUALS 17.43 FEET, ELEVATION SHOWN IS NOT ADJUSTED FOR OVERLYING HYDROCARBON FLUID. NOT USED IN CONTOURING TO REFLECT LOCALIZED IMPACT NEAR WELL.

MAP LETTER	STATION	THREE MILE CREEK BOTTOM OF CHANNEL ELEVATION, FEET, MSL
A	0+00	1034.6
B	5+00	1034.4
C	10+00	1034.9
D	15+00	1033.9
E	20+00	1030.7
F	25+00	1031.5
G	30+00	1030.4
H	35+00	1027.4
J	39+75	1028.8
K	44+75	1028.5
L	48+30 CREEK	1031.4
M	48+30 MOUTH	1032.1

Revisions			
Symbol	Descriptions	Date	Approved

LAW ENVIRONMENTAL INC.
GOVERNMENT SERVICES BRANCH
KENNESAW, GEORGIA

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

US ARMY CORPS OF ENGINEERS

FIG 3-18a

WATER TABLE CONTOUR MAP
SEPTEMBER 7, 1993

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS

Designed by:	A.J.W.
Drawn by:	P.P.R.
Checked by:	J.K.C./A.J.W.
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Scale:	AS NOTED
Date:	MARCH 08, 1994
Dwg. No.	
Sheet number:	

3.6.2.3 Groundwater/Kansas River Interaction - Variations in Kansas River stage prior to the first five measurement dates are shown in Figure 3-19. For reference, the observed water level at well SFL92-301 is also shown for each measurement date given. The gage height data in Table 3-5 were converted to river stage values at the SFL near well SFL92-301 by field measurements as follows. The elevation established for well control at well SFL92-301 was used as a datum to determine river elevation at the bank near SFL92-301 using a survey level and rod measurements on the river surface during the April and May 1993 measurement events. Based on these measurements, a relationship between the gage height readings at the Kansas River gage (USGS Station No. 06879100, Table 3-5) and the elevation of the river near SFL92-301 has been estimated to within about 5 percent as:

Gage Height + 1034.7 (gage datum) - 8 = Elevation at SFL

This relationship is correlated to independent calculations by CEMRK for related unpublished studies (Van Saun, 1993). Supporting calculations for the elevation adjustment are summarized in Appendix S.

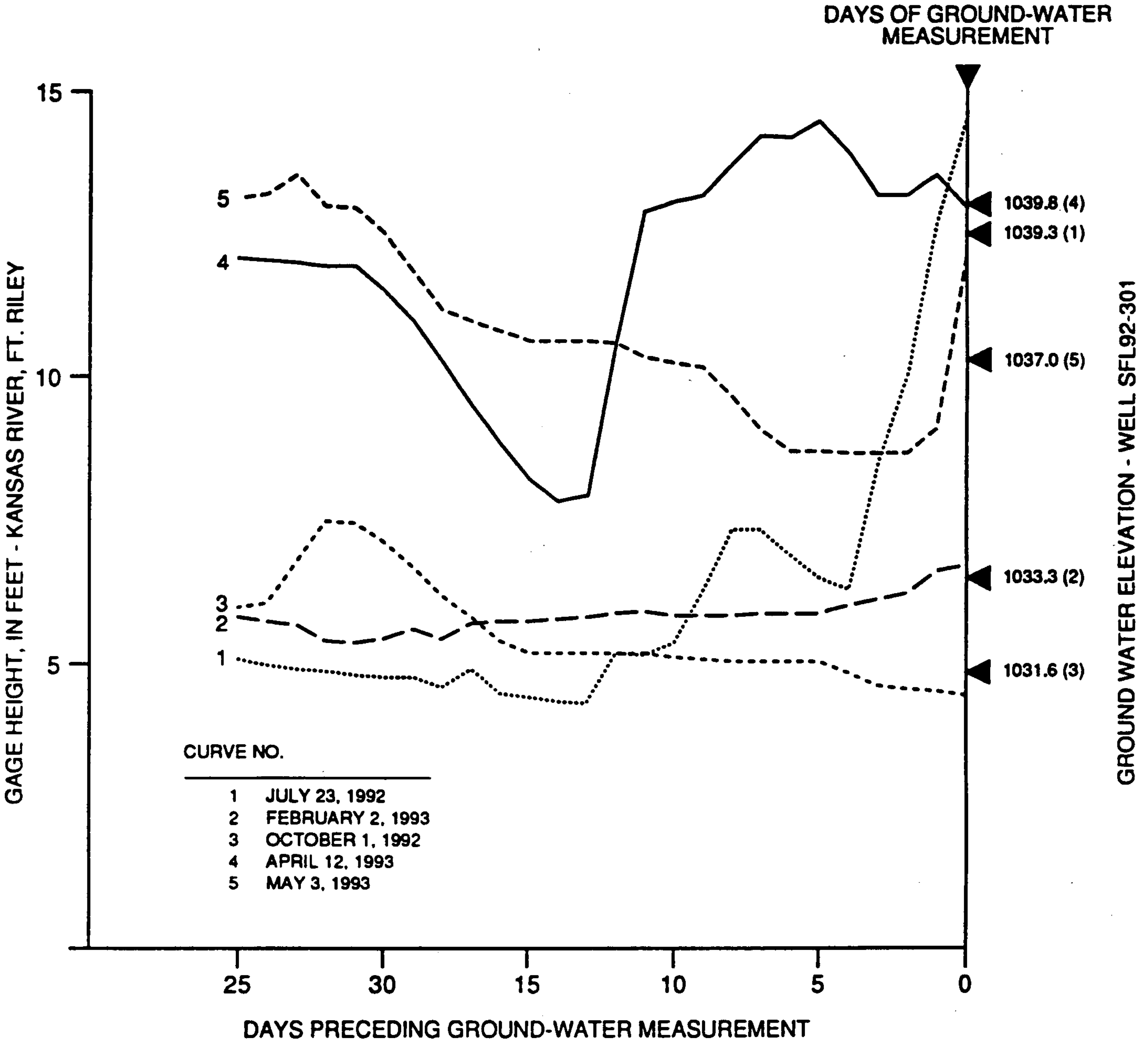
Groundwater levels at well SFL92-301 appear to be similar to the river levels when the river experiences slight changes in stage over the preceding three to four days (Curves 2, 3, and 4). When the river stage changes rapidly (Curves 1 and 5), the groundwater levels in well SFL92-301 are lower by several feet, creating steeper hydraulic gradients between the river and the aquifer. Based on these observations, there appears to be good hydraulic connection between the river and the aquifer.

Curve 1 shows the rapid rise in river stage during five days prior to the July 23, 1992, measurement. The river stage exceeded the groundwater elevations by 1.9 feet on July 23. Curves 3, 2, and 4 show the October 1992, February 1993, and April 1993 measurements, respectively, where relatively little river-stage variations occurred prior to each groundwater measurement. The river stage and groundwater elevation (at SFL92-301) differ by 0.3 feet or less on these three measurement dates. Curve 5 shows the rapid rise in river stage prior to the May 1993 measurement, when the river stage exceeded the SFL92-301 groundwater elevation by 1.7 feet. Based on interpretations of Figure 3-19 data, it generally appears that groundwater

FIGURE 3-19

KANSAS RIVER PROFILES PRIOR TO AND ON THE DAY OF GROUNDWATER MEASUREMENTS AT WELL SFL92-301

FT. RILEY, KANSAS



GAGE HEIGHT + 1034.7 (GAGE DATUM) - 8 = ELEVATION AT SFL elevations in the vicinity of well SFL92-301 may lag the river stage changes by at least several days. Time-series observations at the wells, that could be used to examine this lag phenomenon with greater accuracy, are not available.

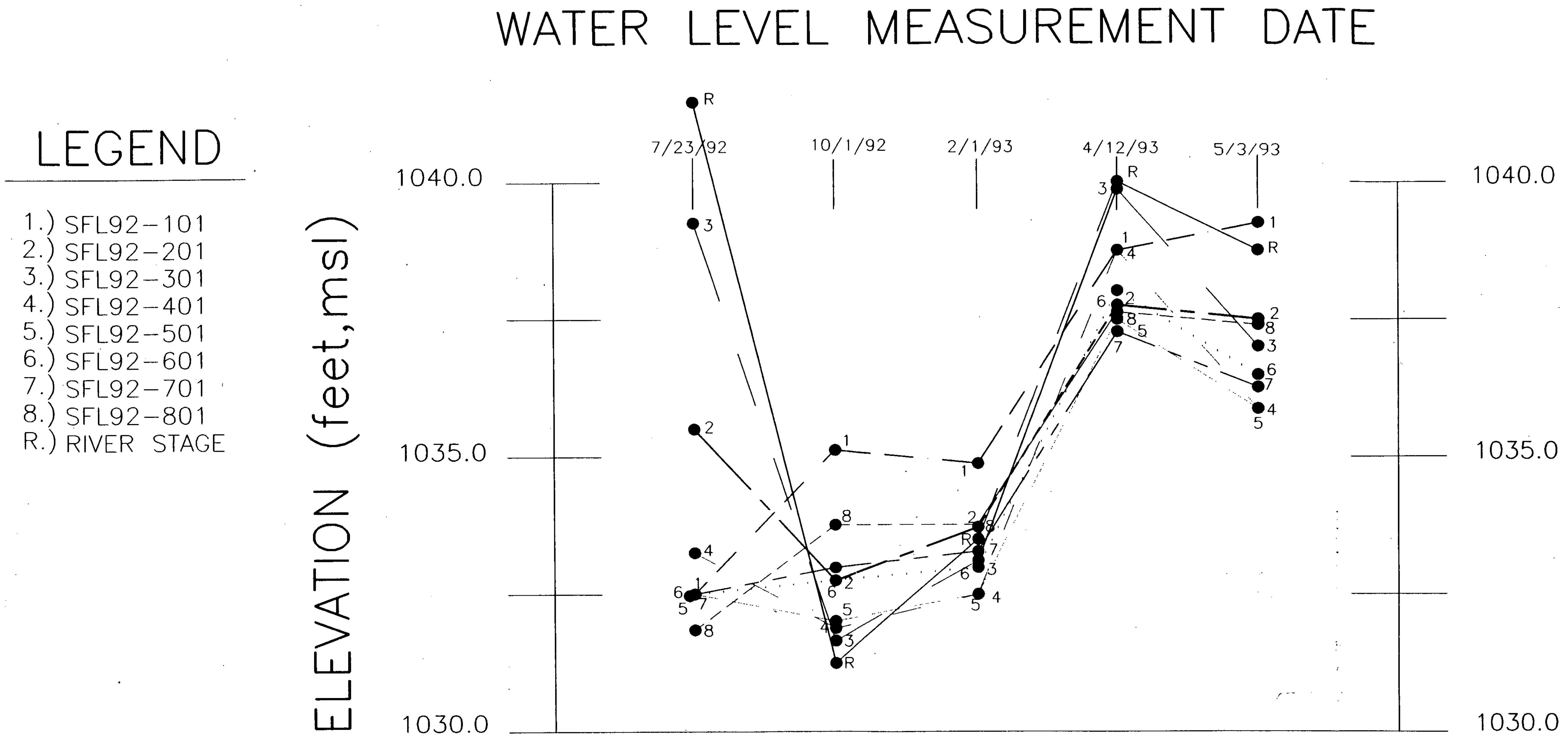
The relation among groundwater elevations at the eight shallow wells (SFL92-101 through 801) for the first five measurement dates is shown in Figure 3-20. The July 1992 data represent an extreme event in which the river stage exceeded the average measured groundwater elevation by 7.4 feet. The October 1992 event is a relatively low-water event in which the river stage was 1.5 feet below the average measured groundwater elevation. The October 1992 and February 1993 events have similar groundwater elevations but the river stage is higher in February than in October. The later Spring 1993 events show generally elevated groundwater and river levels.

The data shown in Figure 3-20 indicate that groundwater levels at well SFL92-101 react to Kansas River stage more slowly than do the groundwater levels at other wells closer to the river. Also, it appears that the average groundwater level is higher in the Spring than in the Fall and Winter. Compared to precipitation patterns, there may be a seasonal lag in the response of groundwater elevations associated with the infiltration/recharge process through the unsaturated zone.

Although groundwater flow directions at the SFL site vary in space and time, the net groundwater flow direction will be toward the Kansas River on a long-term basis. To estimate the net flow condition across the SFL site, estimates of average groundwater elevation and average river stage were determined from available data and a net gradient across the site was calculated. From Table 3-3, the mean annual discharge of the Kansas River at Fort Riley was calculated to be 2,805 cfs. Based on a rating curve for the river (USGS, 1993b), this discharge corresponds to a gage height reading of 7.1 feet at Fort Riley. The corresponding stage elevation at the SFL is 1033.8 feet according to the relationship described above. Based on the five available groundwater measurements at SFL92-101, the average groundwater elevation at a distance of about 5,000 feet from the Kansas River was estimated to be 1,036.1 feet. Across the SFL site, these estimated average elevations result in an estimated average gradient of 0.0005 feet/foot. Based on hydraulic conductivity values of 10 and 500 feet/day and an effective porosity of the alluvial soils of 0.30, the velocity of net groundwater flow across the SFL site to the river may range from 0.02 to 0.83 feet/day.

Based upon the available data, general comments regarding groundwater flow beneath the SFL are as follows:

- Water levels in areas distant from the Kansas River (i.e., further away from the river than the area encompassing wells SFL92-201, SFL92-301, and SFL92-401) appear to fluctuate in response to an annual cycle, highest in spring and lowest in other parts of the year. As a result, the groundwater gradient in areas distant from the river would be expected to remain relatively stable as the groundwater table moves up and down in response to precipitation cycles.



	7/23/92	10/1/92	2/1/93	4/12/93	5/3/93
RIVER	1041.1	1031.3	1033.4	1040.0	1038.7
101	1032.4	1035.1	1034.9	1038.7	1039.2
201	1035.6	1032.8	1033.6	1037.7	1037.4
301	1039.3	1031.6	1033.3	1039.8	1037.0
401	1034.3	1031.8	1032.5	1038.7	1035.8
501	1032.5	1031.9	1032.5	1037.5	1035.9
601	1032.5	1032.8	1033.0	1038.0	1036.6
701	1032.3	1033.0	1033.2	1037.2	1036.3
801	1031.8	1033.7	1033.7	1037.6	1037.4
AVERAGE WELL	1033.8	1032.8	1033.3	1038.2	1037.0
RIVER-AVERAGE WELL	7.4	-1.5	0.1	1.9	1.7

Revisions

Symbol	Descriptions	Date	Approved

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GOVERNMENT SERVICES BRANCH
KENNESAW, GEORGIA

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

Designed by:

Drawn by:

Checked by:

Submitted by:

US ARMY CORPS OF ENGINEERS

FIGURE 3-20

COMPARISON OF GROUNDWATER LEVELS TO RIVER STAGE

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS

Scale: NTS
Date: 9/20/93
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Sheet number:

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- The highest elevations of the hydrologic system in the SFL vicinity appear to be the Kansas River upstream of the SFL under transient conditions and the groundwater surface near well SFL92-101. Groundwater flow would, on average, be toward the south and east toward Threemile Creek and the Kansas River as represented on the potentiometric surface maps. Groundwater flowing beneath the SFL is expected to discharge to Threemile Creek and the Kansas River.

  Due to the effects of transient conditions in Threemile Creek and the Kansas River, groundwater flow under Threemile Creek could possibly occur under certain circumstances. It is highly unlikely that groundwater flow under Threemile Creek would continue for a substantial distance parallel to the Kansas River toward Ogden, as the expected regional groundwater flow direction is toward the Kansas River.

- Groundwater gradients near the Kansas River (i.e., within the area encompassing wells SFL92-201, SFL92-301, and SFL92-401) fluctuate in response to changes in river stage.

- During times of relatively low groundwater levels, northerly groundwater flow develops as the river raises groundwater levels in the southern portion of the site. During these periods, very little discharge of groundwater to the Kansas River would be expected. The July 1992 period may represent such a condition.

- When the Kansas River stage drops to relatively low elevations, southerly groundwater flow develops and groundwater would be expected to discharge to the river along the southern edge of the SFL. The October 1992 period may represent such a condition.

It should be noted that limited groundwater level data are currently available. Different groundwater surface configurations, other than those represented by the available data (Figures 3-14 through 3-18a) are likely to exist in the SFL site area at various times.

3.6.2.4 Rainfall Infiltration/Volume Estimates - This section discusses the rate of stormwater infiltration through the existing surface soil overlying the landfill material. Moisture passing through the surficial soil becomes a potential source of leachate. Precipitation on the landfill will either be intercepted by the vegetative cover or surface depressions, infiltrate the soil, or run off. Water that does not run off will eventually evaporate, transpire through the vegetation, be stored in the soil matrix, or percolate downward. Soil moisture that percolates below the evaporative (root) zone will potentially come in contact with the landfill contents.

This section evaluates the effects of precipitation and does not consider surface inundation from floodwater. Flooding of the landfill surface will typically occur over short periods and the frequency of these occurrences is relatively small. For further discussion, see Sections 3.3.1 and 3.3.4. The anticipated contribution of moisture to the surface soil caused by flooding is minor compared to that of precipitation and, therefore, is not evaluated. The effect of the water table saturating part of the landfill contents during flood conditions is discussed in Section 3.6.2.5.

The Hydrologic Evaluation of Landfill Performance (HELP) model was used in evaluating percolation through the landfill surface soil. This model was developed by the U.S. Army Corps of Engineers Waterways Experiment Station for the USEPA Hazardous Waste Engineering Research Laboratory. The purpose of the model is to provide a tool for evaluating water movement across, into, through, and out of landfills. The HELP model uses earlier models including the Hydrologic Simulation on Solid Waste Disposal Sites (HSSWDS) model, also developed by the Waterways Experiment Station, and the Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS) model developed by the United States Department of Agriculture. The original version of the HELP model was released in 1984 and Version 2.0 (used in this study) was released in 1988.

In general, the model performs a water balance calculation over a specified period of time using daily weather data, soil characteristics, and a physical description of the landfill profile as input. The hydrologic processes are simulated in six-hour time increments. Each time increment relies on the conditions of the previous increment. Surface processes that are simulated by the model include runoff, interception, infiltration, snow accumulation, and snow melt. Subsurface processes simulated for this study include percolation and evapotranspiration.

A minimum 24-inch, uncompacted soil layer was evaluated for this study. The soil thickness matches the closure requirements as described in the SFL Closure Plan (Wilson and Company, 1982). Construction drawings or other available data for Fort Riley has been reviewed and does not include information to verify the minimum soil thickness. The existing topography generally matches the grading proposed in the closure plan (Wilson and Company, 1982). The grading plan generally indicates 1 percent slope to be constructed over a mostly level surface. To achieve this grade, the majority of the landfill would have been covered with more than 2 feet of soil, except near the edge of the cover. The actual soil thickness is not critical as long as the soil extends below the evaporative (root) zone. As stated above, moisture below this zone will eventually percolate downward. A 20-year simulation was performed so that the model would approach steady-state conditions.

The HELP model accepts three sources of weather data. The user may enter data, access an internal library of data for certain areas, or have the model synthetically generate data using a synthetic weather generator developed by the USDA Agriculture Research Service. For this study, 20 years of daily weather data were synthetically generated (including precipitation, temperature, and solar data) based on default parameters for Topeka, Kansas, and corrected for the site using the average monthly precipitation and monthly mean daily temperature data from Marshall Field (see Section 3.2).

The HELP model simulates vegetative growth using a Simulator for Water Resources in Rural Basins (SWRRB) developed by the USDA Agriculture Research Service. The vegetative growth model is used in calculating evapotranspiration. The SWRRB requires a maximum leaf area index and evaporative zone depth as input. The HELP model default leaf area index values are for typical turfed conditions on closed landfills. The SFL site is not maintained on a regular basis and the vegetation is a mixture of grass and weed. Therefore, default values may not be representative of the actual site conditions. However, site-specific data are not available to estimate a leaf area index. Two values of maximum leaf area index were assumed to characterize the vegetation on the landfill surface. The two values, 2 and 4, were selected to encompass the anticipated reasonable range of values. The HELP model indicates that the typical maximum achievable leaf area index (without irrigation) is 4.5 for Topeka. Bare ground has a leaf area index of 0. Since the site has abundant vegetative growth and loamy soil, it is assumed that the actual leaf area index approaches the typical maximum value. A value of 2 is considered a reasonable low estimate. The evaporative zone depth is required input parameter and is dependent on the leaf area index. The model provides suggested evaporative zone depths corresponding to the default leaf area indices. Evaporative zone depths of 22 and 30 inches were used for leaf area indices of 2 and 4, respectively, based on the model's recommendations. The two leaf area index values and corresponding evaporative zone depths were assumed for several model runs evaluate the sensitivity of the model results on the leaf area index.

The HELP model provides default soil characteristics for a range of soil types classified by the USDA and Unified Soil Classification Systems (USCS). Alternatively, soil characteristics can be manually entered. The required soil parameters are porosity, field capacity, wilting point, and permeability. The soil data are used to simulate runoff, surface infiltration, and percolation. Field classification of the on-site surface soil as well as the local Soil Conservation Service soil survey were used to select a range of soil characteristics that are anticipated to be representative of the actual soil conditions. Based on field information, the surficial soil surrounding the landfill appears to be primarily silt with varying amounts of sand and relatively low clay content. Specifically, the surface soil (0 to 2 feet) type reported on the boring logs (Appendix D) ranges from clayey silt (borings SFL92-103 and SFL92-803) to silty sand (borings SFL92-203, SFL92-403, and SFL92-603). Sand was reported in borings SFL92-503 and SFL92-703 adjacent to Threemile Creek but is not considered representative of the soil covering the landfill.

The soil survey indicates that the local soils (within a one-mile haul distance) are primarily fine sandy loams to silty loams including the shooting range area from which some of the cover soil was borrowed. Soil with a higher clay content is present on the hills to the northeast (USDA-SCS, 1988). However, based on site observation and the boring logs, it appears that clay soil was not used to cover the landfill.

The soil survey provides a range of permeabilities for each listed soil type. The permeability range listed for the local silty to fine sandy loams (Haynie, Eudora, and Muir series) is 0.6 to 2.0 inches per hour (4×10^{-4} to 1.4×10^{-3} cm/sec). Likewise, the available water content (field capacity minus wilting point) is provided for these soils (0.16 to 0.19). In general, fine grained soils exhibit a lower permeability and higher available water content than do coarser grained soils (USDA-SCS, 1988).

Four different sets of soil characteristics were considered. The first soil was a default soil with a USDA classification of silt loam. The second was a default soil with a USDA classification of sandy loam. The third set of soil characteristics were entered to match the upper end of the permeability range and lower end of the available water content range as reported in the soil survey. Conversely, the fourth soil represented the lower end of the permeability range and the upper end of the available water content range given in the soil survey. Model runs were performed with the four soil data sets to evaluate the sensitivity of the model results to the soil data.

The HELP Model uses the SCS Curve Number Method (National Engineering Handbook, SCS) to calculate runoff. SCS curve numbers were input by two methods. Runs were first performed using a curve number that the model calculated from the minimum infiltration rate corresponding to the selected default soil type. The curve number provided by the model (about 70 to 80) was characteristic of a C or D hydrologic soil group. The soil survey indicates that the local loam soils are a B hydrologic soil group. A curve number of 60 was then entered to override the calculated value. The curve number of 60 is representative of a B hydrologic soil with brush and grass as a vegetative cover.

The input parameters for the HELP model are summarized in Table 3-9. Table 3-10 provides a summary of the HELP model simulations. As shown in Table 3-10, the average infiltration rate of moisture passing through the surface soil and potentially coming in contact with the underlying landfill contents is estimated to be 2 to 3 inches per year (50,000 to 80,000 gallons per acre per year) based on the HELP model results. A range of values is provided in Table 3-10 because a series of model runs were performed. The model simulations were based on different combinations of assumed high and low leaf area index values and assumed soil parameters for coarse-grained soil (sandy loam) and fine-grained soil (silty loam). The results of the sensitivity analysis indicate that the model is more sensitive to the vegetative cover conditions than soil type, and is mostly insensitive to the SCS curve number. It appears that the resulting percolation rate assuming a leaf area index of 2 (reasonable minimum value) is 60 percent higher than that assuming an leaf area index of 4 (reasonable maximum value). The percolation results varied about 20 percent depending on soil type. The lower percolation rates were obtained assuming a silty loam while the higher rates were obtained assuming a sandy loam. The runoff results were minimal for the assumed curve numbers and, therefore, the percolation results were not significantly impacted by the curve number.

A discussion of the input parameter selection, as well as a sensitivity analysis of critical parameters, is provided in Appendix O. The data files for the model runs are also provided in Appendix O.

3.6.2.5 River Influx/Volume Estimates - This section describes conditions of potential river-water influx to landfill waste areas and provides estimates of the river influx volumes for comparison to the rainfall infiltration volume estimates discussed above.

TABLE 3-9

SUMMARY OF HELP MODEL INPUT DATA
Southwest Funston Landfill
Fort Riley, Kansas

Input Parameter	Entered Value	Source
Climatological data	Synthetically generated for Topeka, Kansas	Internal subroutine
Average monthly precipitation	See Section 3.2	Marshall Airfield, Ft. Riley, 1961-1992
Mean monthly temperature	See Section 3.2	Marshall Airfield, Ft. Riley, 1961-1992
Latitude of site	N 39° 5'	Ogden, Kansas USGS Quadrangle Map
Leaf area index	Varied, see Table 3-10	Default values
Evaporative zone	Varied, see Table 3-10	Default values
Growing season	Julian days 113 to 292 (March 23 to October 19)	Default values for Topeka, Kansas
Curve number (CN)	60	Urban Hydrology for Small Watersheds, SCS TR-55, 1986 and National Engineering Handbook, SCS, 1969
Soil data	Varied, see Table 3-10	Soil Survey of Riley County and Part of Geary County, Kansas, SCS, 1975; on-site soil boring logs; and default values
Layer description	24-inch, uncompacted, vertical percolation layer	Southwest Funston Landfill Closure Plan and Specifications for Fort Riley, Kansas, Wilson & Co., 1982
Model duration	20 years	Not applicable

TABLE 3-10

SUMMARY OF HELP MODEL SIMULATIONS
Southwest Funston Landfill
Fort Riley, Kansas

RUN	INPUT SOIL DATA					INPUT VEGETATIVE DATA		AVERAGE ANNUAL PERCOLATION (INCHES)(6)
	POROSITY (VOL/VOL)	FIELD CAP (VOL/VOL)	WILTING PT (VOL/VOL)	HYD COND (CM/SEC)	SOURCE OF DATA	LAI(5)	EVAPORATION ZONE (INCHES)(4)	
14	0.45	0.19	0.08	0.00216	(1)	2	22	2.7
15	0.50	0.28	0.14	0.00057	(2)	2	22	2.3
16	0.45	0.21	0.05	0.00140	(3)	2	22	3.5
17	0.45	0.29	0.10	0.00040	(3)	2	22	2.9
18	0.50	0.28	0.14	0.00080	(2)	4	30	1.4
20	0.50	0.19	0.08	0.00302	(1)	4	30	1.7

(1) Default values from model for a sandy loam (SM based on USCS).
(2) Default values from model for a silty loam (ML based on USCS).
(3) Based on permeability and available water content ranges for predominant soils that are local to the site listed in the SCS soil survey.
(4) Default values based on assumed leaf area index (LAI).
(5) Default data indicates a leaf area index (LAI) of 4.5 as the maximum typical achievable LAI (without irrigation) in Topeka, Kansas.
(6) Moisture passing through the surface soil cover.

3.6.2.5.1 Water-Level Observations - A comparison of the monitoring well groundwater elevations and river elevations has shown that groundwater elevations within the SFL are influenced by the Kansas River stage (Section 3.6.2.3). During periods of elevated river levels, the Kansas River and Threemile Creek are believed to recharge the aquifer within the SFL. Fluctuations of the local water table within the SFL area due to changes in the Kansas River elevation are expected to cause groundwater to periodically come in contact with landfill wastes, potentially resulting in leachate production.

Water-level data are limited to six sampling events during the period July 1992 to September 1993. During the sampling period, precipitation and river levels were above average for several months. Also, considerable variation in the Kansas River stage and the monitoring well water levels was observed during the period. These conditions indicate dynamic interactions between the river and the shallow aquifer at the SFL site.

The observed site conditions were used to predict the typical seasonal variations of groundwater elevations expected at the site due to precipitation. Historical Kansas River stream gage records were used to determine the annual average high water elevation and duration in the Kansas River. These site observations, available historical data for rainfall, and Kansas River gage heights were used to estimate the average annual infiltration volume into the SFL from the Kansas River and Threemile Creek. These calculations are provided in Appendix P.

3.6.2.5.2 Estimated River Influx at the SFL - River-water influx effects caused by high water in the Kansas River will be greatest when groundwater levels at the SFL are low, such as observed during the July 23, 1992, sampling event. Under these conditions, there is a steep gradient from the river and Threemile Creek into the aquifer which causes river water to flow into the aquifer at the SFL. By contrast, when high water occurs in the Kansas River and when groundwater levels are seasonally high, such as observed during the May 3, 1993 sampling event and the April 12, 1993 water level measurement event, the gradient which drives the flow from the river into the aquifer is greatly reduced or may not exist.

Water levels at the SFL which are below elevation 1034 feet msl will not be considered in the analysis of annual influx volumes from the river, because the bottom of the trenches excavated to place waste materials at the SFL is estimated to be at an average elevation of 1034 feet msl. Therefore, inflow under these conditions (i.e., SFL water levels below 1034 feet msl) would not be expected to come into contact with buried materials and generate leachate.

To estimate the average annual influx from the Kansas River into the SFL, the average annual elevation and duration of high water in the river was determined. Average gradients from the Kansas River and Threemile Creek into the landfill area of the shallow aquifer during periods of high flow in the Kansas River were also estimated, using the observed conditions. From this information, an annual influx volume from the river into the landfill was calculated, assuming that the riverbank face allows water to flow laterally into the surrounding soils.

To calculate the average annual duration and elevation of high water in the Kansas River at the SFL, 29 years of daily mean gage records at the Riley Gage (1964-1992) were used. Water year 1993 records are not currently available and could not be included in the analyses. The observed water levels in the Kansas River and well SFL92-301 on July 23, 1992 (Figure 3-14) and May 3, 1993 (Figure 3-18) (periods of high stage in the Kansas River) indicate an approximate two feet head loss occurs between the river and landfill trenches which were estimated to be at least 100 feet from the riverbank. Because the average elevation of trench bottoms in the SFL is estimated at 1034 feet msl, water levels in the Kansas River below 1036 feet msl at the SFL were not considered in the analysis of stream flow records. Daily mean gage records were used because use of peak daily readings would overestimate the infiltration value (because the flow from the river into the aquifer is not immediate). To calculate the average high water duration per year, the total number of days per year that the gage reading exceeded 9.31 at the Riley Gage was counted and divided by 29 years, for an average of 39 days per year. The gage height of 9.31 is equivalent to an elevation of 1036 feet msl at SFL based on the previously described relationship between SFL water levels and gage heights.

Next, the average gage height which is expected during the 39 days per year of high water was calculated by summing the gage heights which exceeded 9.31 and dividing this sum by the number of readings counted to derive an average height of gage. A total of 1,129 readings were added and an average gage height of 11.64 was calculated. This was translated into a river stage at the SFL of 1038.3 feet msl.

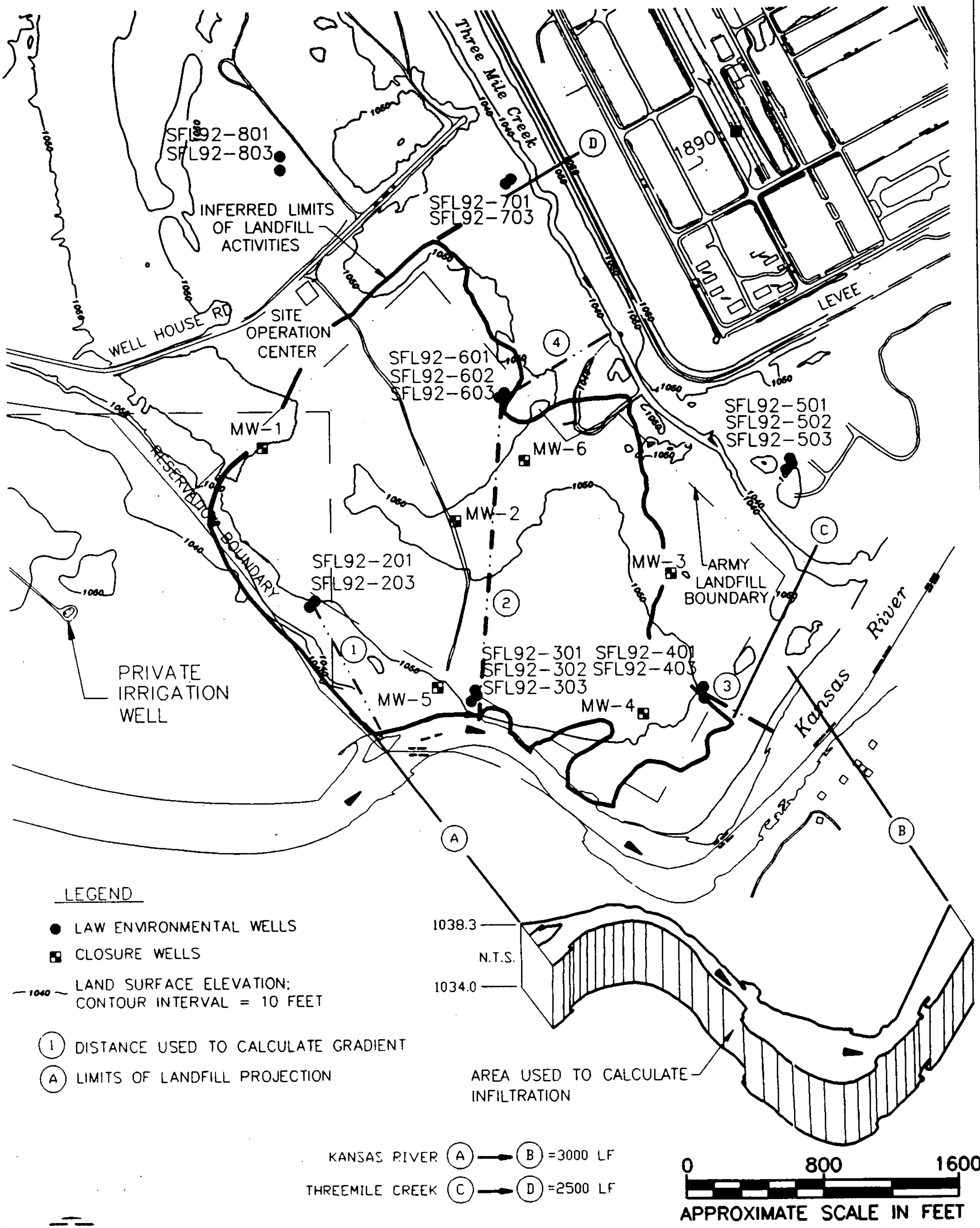
To estimate the average gradient from the Kansas River and Threemile Creek into the landfill, the water table potentiometric maps developed from the first five sampling events (Figures 3-14 to 3-18) were reviewed. Well locations used to calculate the gradient from the river into the landfill are shown on Figure 3-21. The average gradients from the river water surface to wells SFL92-201, SFL92-601, and SFL92-401 were determined using the potentiometric maps for July 23, 1992, April 12, 1993, and May 3, 1993. The maps dated October 1, 1992 and February 1, 1993 were not used because the Kansas River is below elevation 1034 feet msl. The average gradient along the Kansas River into the SFL was calculated to be 0.0037 feet/foot. For Threemile Creek, the average gradient from Threemile Creek to SFL92-601 was calculated using the same procedure and found to be 0.0020 feet/foot. These calculations are presented in Appendix P.

To define the cross-sectional areas of flow from the Kansas River and Threemile Creek into the landfill, projections of the landfill boundary along the Kansas River and Threemile Creek were used. Figure 3-21 shows the cross-sectional area used to calculate flow from the Kansas River into the landfill. This cross-sectional area is defined by the projections of the landfill boundaries normal to the equipotential lines and extended to the Kansas River. The same procedure was used to estimate the cross-sectional area for Threemile Creek, but this area is not depicted on the figure. The length of these projections along the streambed geometry multiplied by the vertical height of the average river stage elevation above 1034 feet msl (1038.3 to 1034, which is equal to 4.3 feet) defines the flow area used to calculate infiltration. An estimated range of

Figure 3-21

INFILTRATION PROJECTION AREA AND GRADIENT FOR RIVER INFILTRATION CALCULATIONS SOUTHWEST FUNSTON LANDFILL

FORT RILEY, KANSAS



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hydraulic conductivity values, as described earlier in Section 3.6.2.2.1 (10 to 500 feet/day), were used to calculate river influx. To calculate annual influx from the Kansas River and Threemile Creek, the Darcy equation for groundwater flow was used. The 39-day flow volume was determined assuming the average river stage and average gradient persisted during a total of 39 days per year. An estimate of maximum annual influx was also made assuming that the low July 23, 1992, groundwater conditions existed whenever the Kansas River stage was high (high gradients into the aquifer). Influx estimates range from 60,700 to 3,040,000 cubic feet per year. These values are equivalent to 0.14 to 6.94 inches per year (3,770 to 189,000 gallons per acre per year) over the estimated 120 acre landfill area.

3.6.2.6 Impact of Regional Water Table Fluctuations on Potential Volume of Leachate - Under current conditions, there are three significant mechanisms which interact to result in groundwater contacting waste in the landfill. The three mechanisms are:

- Infiltration through the landfill cap
- River influx to the landfill during high water conditions
- Increases in the regional water table elevation which result in groundwater being above 1034 feet MSL at the landfill

The first two mechanisms were evaluated in Sections 3.6.2.4 and 3.6.2.5, based on historical averages. Historical average information on seasonal fluctuations of the groundwater elevations within the SFL do not exist; however, an evaluation of the impact of regional water table fluctuations on the volume of water in contact with the fill material can be made using only the limited information collected during the RI. There is uncertainty in this approach because on-site data may not reflect long term historical averages. Increases in the regional water table elevation are defined as groundwater elevation changes which result from infiltration on a regional basis and groundwater elevation changes which result when the Kansas River and Threemile Creek are not discharge points (i.e., the river elevation is at or above the groundwater elevation and therefore the river prevents groundwater discharges). Direct quantification of the regional water table fluctuation is difficult and not practical with existing information. Therefore, to evaluate this mechanism, an estimate of the total volume of water in contact with the fill observed during July 1992 through May 1993 was calculated and compared to the projected annual average volumetric contributions of river influx and infiltration through the landfill cap.

Potentiometric surface maps from July 1992, October 1992, February 1993, April 1993, and May 1993 (Figures 3-14 through 3-18) were used to calculate the total estimated volumes of groundwater in contact with the fill materials on the dates of field measurements. The calculated values do not include the effects of the Kansas River flooding which occurred in June and July, 1993. The groundwater volume in contact with landfill materials was calculated using the following equation:

Groundwater Volume (ft^3) =

Area of the water table above elevation 1034 ft msl (ft^2) x
average thickness of the water table above elevation 1034 msl x
landfill material in-place porosity

The waste porosity was assumed to be 0.52, which is the municipal waste porosity average value specified in the documentation for the HELP model. The documentation does not provide a range of values, and waste porosity can vary significantly and is site specific. For the estimate, this average value was used.

Using this calculation, 2,116,000 ft^3 of water was in contact with the waste fill on July 23, 1992. In October 1992 and February 1993, groundwater elevations in the vicinity of the SFL were below 1034 feet msl; therefore, the water table was below the assumed bottom elevation of the waste material. The 2,116,000 ft^3 of water in contact with the fill materials had receded and drained into the Kansas River and Threemile Creek between July and October 1992. In April 1993, 12,600,080 ft^3 of water was in contact with the fill, and in May 1993, 6,960,000 ft^3 of water was in contact with the fill. The landfill areas (above 1034 feet msl) were not observed to be saturated in February 1993, because groundwater levels in February were all measured below 1,034 feet msl. In April 1993, however, 12,600,000 ft^3 of water was estimated to saturate the landfill above elevation 1,034 feet msl. Since 6,960,000 ft^3 of water was estimated to saturate landfill materials in May 1993, it is estimated from the observed conditions that 5,640,000 ft^3 of water drained from the SFL fill during this period. This drained volume is calculated as the difference in saturation volumes calculated between April and May 1993. These calculations are included in Appendix P.

The pattern of a rising water table in the SFL observed during the spring and summer, followed by a draining and lowering of the water table during fall and winter is consistent with average regional rainfall information. However data is limited to five water level measurements during a single unusually wet year for the Fort Riley area, when elevated river levels occurred frequently, and river stages often persisted above 1,036 feet msl. Seven independent periods of Kansas River stages above 1,036 feet msl were observed between May 1992 and May 1993, and the river level exceeded 1,036 feet msl for about four months during the study period. The observed fluctuations interpreted as seasonal fluctuations are also believed to be influenced by the water levels in the Kansas River. During July 1992, April 1993 and May 1993 river water levels exceeded 1,036 feet msl, and the high river levels and water table elevations occurred simultaneously during the study period. These extended high river stages probably prevented the regional groundwater from discharging into the Kansas River and Threemile Creek, which act as hydraulic boundaries to the water table. Above average rainfall was also recorded during the study period, which was likely to elevate the regional water table.

Using information from April 1993, approximately 12,600,000 ft^3 of water was in contact with the landfill material. Consistent with the observed pattern discussed above, this would be expected to drain from the landfill at least on a yearly basis. Thus, during this July 1992 to

May 1993 period, at least 14,700,000 ft^3 of water potentially contacted the fill material which is the sum of the July 1992 event and the April 1993 event. This water would be due to all three of the mechanisms discussed above. Comparing this total to the "typical" average values for infiltration through the SFL cap (1,089,000 ft^3/year) and range of river influx values (60,700 to 3,040,000 ft^3/year) indicates that a significant portion of the total water in contact with the fill (from at least 72 to 92 percent) is due to regional water table fluctuations. It is noted that the average estimated annual infiltration volume through the landfill cover is being compared to the regional water table observed during an unusually wet year for the Kansas area, which will overestimate the regional water table effects used in the comparison of these two mechanisms which both influence groundwater levels at the SFL. However, the comparison shows that the regional water table and the hydraulic boundary created by the fluctuating water table near the Kansas River will have a more significant influence on SFL water levels than infiltration through the landfill surface.

3.6.2.7 Unsaturated Zone/Capillary Fringe - The processes involved with rainfall infiltration and water movement through the unsaturated zone and subsequent movement through the capillary fringe before reaching the water table include the potential for altering the groundwater chemistry in the vicinity of the water table. These hydraulic processes, often referred to simply as groundwater recharge, are complex, transient processes that may explain variable groundwater chemistry patterns and transport processes. The infiltration process likely involves spatially varying moisture conditions and pressure head distributions, due to natural soil heterogeneity and non-uniform ground-surface conditions. However, we envision that infiltration can be conceptualized as the propagation of a wetting front following the introduction of water at ground surface. In the idealized case, propagation of the wetting front can be viewed as a type of "piston flow" (Bouwer, 1978).

For a given set of soil conditions, the capillary fringe extends from the water table to the limit of capillary rise (Bear, 1979). In principle, the capillary fringe is fully saturated. The pressure head in the capillary fringe is less than atmospheric because the pressure head decreases upward, under capillary forces, below the zero-pressure condition which occurs at the water table. The thickness, or height, of the capillary fringe depends on soil properties and the degree of homogeneity, mainly on pore size distribution (Bear, 1979).

The case of a uniform pore-size distribution with a unit upward vertical gradient of pressure head, and zero horizontal pressure gradients, is idealized. Under field conditions, local flow is likely to occur in the capillary fringe due to non-ideal saturation because of trapped air and some partial saturation in large pores. Vertical flow as well as horizontal flow may therefore occur under actual conditions present in the capillary fringe (deMarsily, 1986). However, flow in the capillary fringe is usually neglected during analysis of groundwater flow at or below the water table (deMarsily, 1986), apparently due to the relative insignificance of low flow rates in the capillary fringe. That is, although generally understood to have a nonuniform pore-size distribution under field conditions and taken to be practically saturated, in many applications the capillary fringe is assumed to have only immobile water.

The unsaturated zone and the capillary fringe may contain solutes that contribute to the chemical character of the saturated zone due to transport processes associated with infiltration and recharge. Under infiltration conditions, the rise of the phreatic (water table) surface occurs because of an increase in pressure head in the capillary fringe up to zero pressure (atmospheric pressure). Because the capillary fringe is essentially saturated, the fringe will become part of the water-table flow regime as a result of the increased pressure without any significant addition of water at the top of the fringe. Solutes that may have been present in the capillary fringe, held in an essentially immobile or static condition, will become mobile as the phreatic surface rises to include some portion of the capillary fringe. The rise of the water table is not caused by the transport of water to the phreatic surface; the zone above the phreatic surface is already, in practical terms, saturated. Rather, the rise of the water table is caused by changes in pressure head that raise the hydraulic head in the capillary fringe to atmospheric pressure.

Therefore, a rise in the water table does not result, in a strict sense, from the arrival of new water at the water table derived from rainfall infiltration. Rather, water is redistributed throughout the unsaturated zone and the water table and capillary fringe respond accordingly. Water previously resident in the unsaturated zone moves downward under an infiltration "wetting front" and pressure heads increase in accordance with increasing moisture contents (Freeze and Cherry, 1979). Increases in pressure propagate downgradient to the capillary fringe. The increase in pressure head in the capillary fringe causes the phreatic surface to rise to the new location where pressure is atmospheric. The capillary fringe, as a zone of saturation below atmospheric pressure, rises into the overlying (previously unsaturated) soil as water from overlying pores is added to the top of the fringe due to propagation of the wetting front and associated changes in moisture content within the vertical profile.

Infiltration events, with an associated wetting front, move solutes that may be present in the unsaturated zone downward through the soil profile. Under an ideal wetting front, water in unsaturated pores will be propagated as "piston flow" in which resident water and solutes are pushed ahead of infiltrating water. However, processes of diffusion and hydrodynamic dispersion cause solutes to move in a non-piston manner without an abrupt solute front. Not all solutes that may be present in the unsaturated zone move uniformly under the influence of a propagating wetting front. However, the general concepts presented here are applicable to solute transport and potential effects on the water-table aquifer. A water-table rise is associated with a pressure front and solutes entering the water-table aquifer under a rising-water table event are likely to be solutes recently located within or near the capillary fringe.

3.6.2.8 Hydraulic Conductivity - Hydraulic conductivity is a coefficient of proportionality describing the rate at which water can move through a permeable medium. Field measurements for hydraulic conductivity were collected and analyzed using slug-in and slug-out procedures in each of the 20 newly installed monitoring wells at the SFL. These results were used to evaluate the hydraulic conductivity of the alluvial aquifer and to estimate groundwater flow velocities at the study area. Appendix K presents the raw slug test data and graphical, curve-fitting analyses for each well that was tested. The hydraulic conductivity values are summarized in Table 3-11.

The slug-out test method provides a more reliable measure of hydraulic conductivity (K) than the slug-in test method for wells where the well screen and sand pack intervals are not entirely saturated during static groundwater conditions prior to a slug test. The slug-out method was used to calculate the average permeability across the SFL site. The lowest K values measured by the slug-out tests method were those recorded in the shallow and intermediate wells, with an average of 5.15×10^{-3} ft/min. The highest K values were recorded in the deep monitoring wells with an average value of 1.52×10^{-2} ft/min. The overall average K value of this aquifer underlying the study area, using the slug-out data, was calculated to be 9.19×10^{-3} ft/min. This value for permeability falls within the range of "clean sands" (Freeze and Cherry, 1979).

3.7 DEMOGRAPHICS AND LAND USE

The following section describes the demography of Fort Riley and discusses the current and future land uses.

3.7.1 Demography

Fort Riley is situated along the north bank of the Kansas River in north central Kansas and comprises approximately 150 square miles (101,000 acres). According to the 1990 Economic Impact Survey, the military installation has a population of 17,164 military personnel and dependents. Approximately 30 to 40 percent of the Fort Riley installation consists of troop housing and support facilities which are in the southern portion of Fort Riley and include the Main Post, Camp Forsyth, Custer Hill, Camp Whitside, Camp Funston, and Marshall Army Air Field. The remainder of the installation consists of troop/family housing, numerous training acres, gunnery complexes, small arms firing ranges, drop zones, tank trails, and an impact area. The impact area is used for live tank firings and mortars, demolition practices as well as live artillery firings, and combined training of troops with Air Force support for helicopter live fire (DEH, 1993f).

Fort Riley is in both Riley and Geary counties. In Riley County, the median age is 23.8; 6.3 percent of the county is age 65 or older (as of 1990). In Geary County, the median age is 26.5;

TABLE 3-11

SUMMARY OF HYDRAULIC CONDUCTIVITY (SLUG TEST) DATA
Southwest Funston Landfill
Fort Riley, Kansas

MONITORING WELL ID	SLUG IN DATA (ft./min.)	SLUG OUT DATA (ft./min.)
SFL92-101	5.89×10^{-2}	7.09×10^{-4}
SFL92-102	1.22×10^{-3}	9.49×10^{-4}
SFL92-103	3.65×10^{-3}	1.22×10^{-2}
SFL92-201	3.20×10^{-3}	1.69×10^{-3}
SFL92-203	7.61×10^{-3}	6.32×10^{-3}
SFL92-301	1.47×10^{-2}	1.69×10^{-3}
SFL92-302	1.01×10^{-2}	4.91×10^{-3}
SFL92-303	1.27×10^{-2}	2.89×10^{-2}
SFL92-401	4.04×10^{-3}	1.26×10^{-2}
SFL92-403	2.67×10^{-2}	1.41×10^{-2}
SFL92-501	NT	3.53×10^{-3}
SFL92-502	7.20×10^{-3}	6.43×10^{-3}
SFL92-503	1.70×10^{-2}	1.28×10^{-2}
SFL92-601	4.29×10^{-3}	6.13×10^{-3}
SFL92-602	6.94×10^{-3}	9.26×10^{-3}
SFL92-603	1.04×10^{-2}	1.22×10^{-2}
SFL92-701	3.68×10^{-3}	5.06×10^{-3}
SFL92-703	1.52×10^{-2}	2.49×10^{-2}
SFL92-801	5.18×10^{-3}	8.75×10^{-3}
SFL92-803	1.19×10^{-2}	1.05×10^{-2}
AVERAGE K VALUE	1.18×10^{-2}	9.19×10^{-3}
STANDARD DEVIATION	1.3×10^{-2}	7.4×10^{-3}

NT - Not Taken due to insufficient water column in well
K - Hydraulic Conductivity

NOTES

- Raw slug test data are presented in Appendix K; individual well ID numbers in Appendix K are labeled MW instead of SFL.
- Last digit of monitoring well ID signifies relative depths of well screens, i.e., xx1 - shallow, xx2 - intermediate, xx3 - deep. Shallow wells screen across the water table. Intermediate wells screen approximately halfway between the water table and the bottom of the alluvial aquifer. Deep wells screen the lower 10 feet of the alluvial aquifer.

7.7 percent of the county is age 65 or older (as of 1990). Fort Riley is adjacent to the cities of Junction City to the southwest and Ogden to the east. The city of Manhattan is approximately seven miles east of Fort Riley. The population of Manhattan is 37,712; the population of Ogden is 1,500; and the population of Junction City is 21,000.

Directly west of Fort Riley is Milford State Park which offers camping, boating, fishing, swimming, and showers. Milford State Park is on the eastern side of Milford Lake, which has approximately 16,400 acres of surface water and 165 miles of shoreline. East of Fort Riley and north of Manhattan is Tuttle Creek Lake which also offers camping, boating, fishing, swimming, and showers. Tuttle Creek Lake has approximately 13,350 acres of surface water and 104 miles of shoreline.

3.7.2 Current and Future Land Use

Agriculture is the primary land use in the area, comprising approximately 70 percent of the total land use. Urban areas comprise less than five percent of the total land use. To the north and east of Fort Riley are agricultural areas and rangeland. To the southeast and south are agricultural and residential areas.

The primary and secondary land uses of Fort Riley include several military housing and administrative (cantonment) areas as described below:

CANTONMENT	PRIMARY/SECONDARY LAND USE
Main Post	Administration/Housing
Camp Funston	Tenant Activities/Bivouac
Marshall Army Airfield	Airfield Operations/Equipment Maintenance
Camp Forsyth	Tenant Activities/Community Services
Camp Whitside	Medical Services/Supply and Storage
Colyer Family Housing	Family Housing/Community Services
Custer Hill Troop Housing	Equipment Maintenance/Troop Housing and Support
Custer Hill Family Housing	Family Housing/Community Services
Milford Reservoir Army Recreation Area	Recreation/Training

The Main Post is the site of the original fort and is situated on a terrace overlooking the Kansas River valley floodplain. It includes a wide variety of intermixed land uses which reflect its early development as a complete installation. Within the Fort Riley boundary, historical sites, outdoor ranges, and training lands comprise the post. The Main Post at Fort Riley has been designated as a Federal Historic District (Historic Preservation Specialist, Fort Riley 1993). This designation places a limitation on future development of the Main Post in that all new construction projects must be designed with due consideration for the present historical buildings. Non-historic buildings may be remodeled on the outside as well as the inside, as long as the exterior is in character with the Historical Preservation Plan.

Camp Funston, adjacent to and east of the SFL, served as a mobilization cantonment site for World War I and World War II. The camp is located on the river valley floor about three miles east of the Main Post. The gently sloping site allowed development of a grid pattern mobilization camp with a headquarters area and parade field along its central axis. Camp Funston experienced repeated flooding and was damaged by the 1951 flood. This resulted in the construction of a dike to protect it from a 100-year (1 percent probability) flood. Due to the 1951 flood, combat unit troops were relocated to Custer Hill.

The use of Camp Funston since that time has involved primarily tenant units not requiring or desiring close contact with other Fort Riley units. National Guard/Army Reserve units training at Fort Riley are regularly bivouacked in the open areas of Camp Funston. Many of the temporary World War II mobilization buildings have been removed in recent years. The remaining mobilization buildings supported the U.S. Army Correctional Activity (USACA), the property disposal unit and a few community services located there due to the availability of space. Temporary land uses, such as weapons fielding sites, are often located at Camp Funston due to the availability of open land served by the World War II concrete street system. The USACA was deactivated in the summer of 1992. Many of the former barracks and other buildings are being demolished. Some administrative buildings are being used for offices and community services.

The Kansas National Guard (KSNG) and the 89th Army Reserve Command (ARCOM) are major land users in the western portion of Camp Funston. Both units utilize their areas as equipment storage and maintenance sites. The KSNG is constructing a regional vehicle maintenance shop east of its existing compound. The remaining open area between the KSNG/ARCOM site and the central administration/parade area is available for bivouac use.

The central administration area and parade fields are used to support USACA administrative space requirements and the recreational needs of personnel stationed or bivouacked at Camp Funston.

The USACA's main compound was located in the camp's eastern half. The property disposal operation, refuse hauling contractor, and Old Trooper University are also located in the eastern half of Camp Funston due to the availability of land in this area. The post military police dog kennel is located near the southeast corner of Camp Funston near the sanitary sewer lift station. This site was selected to be isolated from other Camp Funston units.

Along the eastern edge of Camp Funston is an open area separating it from an adjoining residential area located off-post in the town of Ogden. The on-post open area is used by

USACA as a physical training area. The open area serves as an important buffer between the industrial-type land uses in the eastern half of Camp Funston and the residential neighborhoods of Ogden.

3.8 ECOLOGY

The SFL site is located within the Flint Hills region of the Central Plains. The ecological region is known as a tall grass prairie. Site-specific ecological characteristics include non-virgin tall grasses, shrubs, trees, riparian coverage, and surface waters. This section discusses the results of the macroinvertebrate sampling activities and the threatened and endangered species survey performed by the U.S. Fish and Wildlife Service.

3.8.1 Aquatic Ecosystem

The quality of an aquatic ecosystem is often monitored primarily by its associated water quality, sediment types, canopy coverage and shoreline vegetation, benthic macroinvertebrate population, and fish population. Many of these characteristics were observed at the sample stations located on Threemile Creek and the Kansas River.

As discussed in Section 2.1.8.1, a macroinvertebrate study was planned for inclusion in this investigation. However, because unanticipated high river flows occurred while the artificial substrata samplers were deployed, it was determined that the results of this study would be non-representative and the study was aborted. The following discussion of the aquatic ecosystems at SFL is based primarily on a site reconnaissance performed by Law personnel while retrieving the macroinvertebrate samples.

Threemile Creek provided a limited aquatic habitat. The creek averaged approximately 15 feet in width and 3 feet in depth. The creek was partly to mostly shaded and most of the shoreline supported vegetation. Stream-banks were relatively unstable and stream sediments throughout much of the creek consisted primarily of silt, mud/muck, sand, and organic material. Benthic macroinvertebrates were observed at each station on Threemile Creek. Although no *in-situ* water quality monitoring was conducted, it was apparent that Threemile Creek supports aquatic life, including small fish. The U.S. Fish and Wildlife survey provided in Appendix R characterizes the fish communities in Threemile Creek to include shiner, minnow and sunfish varieties of fish (Appendix R, subsection Appendix E).

The Kansas River also provided limited aquatic habitat. The river ranged from approximately 500 to 700 feet in width and depth ranged from 3 feet to well over 9 feet. The river was mostly open and some of the shoreline supported vegetation. River-banks ranged from relatively stable to unstable and river sediments were a combination of sand and silt, with accumulations of organic materials in areas with slower-moving water. Benthic macroinvertebrates were observed at each station on the Kansas River. Water quality monitoring was not conducted as part of this study, but it was apparent that the Kansas River supports aquatic life. Fish were visually observed at several locations on the Kansas River. The U.S. Fish and Wildlife survey provided in Appendix R characterizes the fish communities of the Kansas River to include varieties of gars, sturgeons, minnows, suckers, catfish, and perch.

3.8.2 Threatened and Endangered Species Survey

In an effort to evaluate the status of threatened or endangered species and their habitats in the vicinity of the SFL, Law personnel conducted a literature search and review followed by a site reconnaissance to verify the presence or absence of habitats which could potentially support threatened or endangered species.

A site reconnaissance of the SFL and adjacent areas was conducted on September 3, 1992. Three habitat types predominate the area:

- Densely vegetated drainage features
- Grassland/prairie habitats
- Riverine habitats

The densely vegetated drainage features are dominated by:

- Cotton wood (*Populus deltoides*)
- Sycamore (*Platanus occidentalis*)
- Box elder (*Acer negundo*)
- Hackberry (*Celtis occidentalis*) as canopy cover
- Redbud (*Cercis canadensis*)
- Dogwood (*Cornus* sp.)
- Greenbrier (*Smilax* sp.)
- Poison ivy (*Rhus radicans*)
- Virginia creeper (*Parthenocissus quinquefolia*)
- Seedling overstory species

The grassland/prairie habitats include various grass species including switchgrass *(Panicum virginatum)*, Indian grass *(Sorgastrum nutans)*, thistle *(Carduus nutans)*, Johnson grass *(Sorghum halepense)*, and sunflower *(Helianthus* sp.).

The riverine habitat is associated with the Kansas River. Shoreline vegetation is similar to that of other drainage features in the area (see listing above). The Kansas River also provides habitats such as large sand bars, sand/silt shoreline, and shallow water flats.

As previously discussed in Section 2.1.8, a recent survey conducted by the U.S. Fish and Wildlife Service (1992) provided much of the necessary background information regarding the potential for threatened and endangered species on site. According to this report, nine federally-listed threatened and endangered species, along with 12 federal category 2 candidate species and an additional six state-listed threatened species, could potentially occur on Fort Riley (Appendix R). Category 2 candidate species are those which the U.S. Fish and Wildlife Service is seeking additional information regarding their biological status to determine if listing of these species is warranted. Such species are not considered in this report. Also, on January 24, 1993, Fort Riley provided information that a peregrine falcon was identified by Natural Resource personnel on the east side of the SFL site, near the Manhattan Airport.

Based on the literature search and review and the habitat survey, the following conclusions have been made concerning the potential occurrence of federal and state threatened and endangered species at the SFL:

SPECIES	HABITAT
Piping Plover (FT, ST)	Open unvegetated beach or sandbar
Least Tern (FE, SE)	Sparsely vegetated sandbars in a wide channel with good visibility
Bald Eagle (FE, SE)	Near water bodies (rivers, lakes, etc.) utilizing riparian forest; recorded sightings
Peregrine Falcon (FE, SE)	Large river or waterfowl management areas, cropland, meadows and prairies, river bottoms, marshes, and lakes. Sighting by Fort Riley Natural Resource personnel near Manhattan Airport.
Whooping Crane (FE, SE)	Wetland, riverine base sandbars, shallow water, slow river flow
Eskimo Curlew (FE, SE)	Wet meadows, fields, pastures, drier parts of salt and brackish marshes
Western Prairie Fringed Orchid (FT)	Tallgrass prairie and sedge meadow (fire adapted)
Prairie Mole Cricket* #	Tallgrass prairie, ungrazed or unmowed native tallgrass with silt-sandy loam soils
Regal Fritillary Butterfly* #	Prairie meadows (wet), moist tallgrass prairie, virgin grassland where violets act as host plants
Sturgeon Chub* (ST)	Areas of shallow strong currents and gravel bottoms, turbulent areas where shallow water flows across sandbars
Texas Horned Lizard*	Dry-flat areas with sandy, loamy, or rocky surfaces with little vegetation
Loggerhead Shrike* # (FT)	Grassland or shrubby fields with scattered woody vegetation for perching and nesting

SPECIES	HABITAT
Long-billed Curlew	Great Plains grasslands, marshes, mud flats, sandbars
White-faced Ibis* (ST)	Small ponds with stands of cattail or bulrush
Western Snowy Plover* (ST)	Unvegetated riverine
Eastern Spotted Skunk* (ST)	Open level cultivated farmland, upland sites with preference for fallen logs and brushpiles
Eastern Hognose Snake (ST)	Undated reported sightings, suitable habitat present along river
Topeka Shiner* (ST)	Turbulent areas in rivers where shallow water flows across sand bars
American Burying Beetle # (FE, SE)	Tallgrass prairie, ungrazed or unmowed native tallgrass with silt-sandy loam soils
Black Tern	Wetland areas
Henslow's Sparrow* #	Native grassland with few trees
Hairy False Mallow* #	Rocky outcrops and dry areas in prairies

Sources: Fort Riley, 1992; Kansas Threatened and Endangered Species Listing (10/15/92).
Underlined species are known to occur on Fort Riley.
* Candidate species for federal endangerment listing.
# Species with suitable habitat at the SFL site.

FE - Federally endangered	SE - State endangered
FT - Federally threatened	ST - State threatened

4.0 NATURE AND EXTENT OF CONTAMINATION

The objective of the investigation performed at the SFL was to evaluate the nature, extent, and source of contamination at the site. The following sections discuss the results of the soil gas survey and the chemical analytical program with comparison to historical and water supply data. Complete analytical results, both historical and current, are provided in Appendices B and L. An evaluation of data quality for the current investigation and a comparison to data quality objectives were provided in the Quality Control Summary Reports prepared for each round of sampling. These reports were published as separate documents (Law, 1992c; Law, 1993a; Law, 1993b; Law, 1993c).

4.1 CONTAMINANT SOURCES

Primary and potential contaminant sources are discussed below.

4.1.1 Primary Contaminant Source

According to historical data, groundwater chemistry results, and waste generation data obtained during the RI, the SFL is the primary source of contamination. A discussion of the military operations and site activities related to specific chemical constituents detected in the soils and groundwater samples from the SFL area is presented below. The history of the SFL was presented in Section 1.2.2.

Motor vehicle maintenance shops typically generated metal-laden waste oils, spent degreasing solvents (such as petroleum naphtha), tetrachloroethene, carbon tetrachloride and antifreeze (ethylene glycol). These wastes may have been disposed in the SFL.

Liquid wastes similar to, but more dilute than the oils and solvents generated by vehicle maintenance, were generated at the vehicle wash racks. Liquids flushed into the wash racks were discharged to a sedimentation basin and then through an oil/water separation unit. The sediment sludge and separator sludge were then disposed in the SFL.

During the operation of SFL, wastewater entering the sewer collection system on Fort Riley was routed to one of the three Wastewater Treatment Plants (WWTPs) on the installation. The three WWTPs included the Main Post Water Pollution Control, Camp Forsyth, and Custer Hill. A fourth WWTP (Camp Funston) was also in use until the early to middle 1970s. The WWTPs were trickling filter units and utilized anaerobic sludge digestion and sludge drying on open sand beds. Dried sludge from the four WWTPs was disposed in the SFL.

Other than waste paper, the print shop wastes were primarily rags soaked with ink and tetrachloroethene. Wastes were placed in the dumpster and sent to the SFL for disposal.

Wastes generated at the furniture repair shop, including solvent/paint sludge, acetone, tetrachloroethene and cellulose nitrate were placed in dumpsters and deposited in the SFL (USATHAMA, 1984).

Paint-related wastes typically associated with Fort Riley painting facilities included: paint sludge, acetone (solvent), cellulose acetate (thinner), and cellulose acetate butyrate (thinner) and paint booth air filters.

The Oil Analysis Laboratory was initiated in the mid-70s and provided physical and chemical information on vehicle lubricants. Historically, trichloroethane and trichlorotrifluoroethane have been used as solvents in the various analyses. These wastes may have been disposed in the SFL.

Biologically hazardous solid wastes were reported to have been autoclaved prior to disposal in the landfill. Waste mercury from accidental spills and instrument breakage was deposited into the landfill.

Based on mixing and application practices (Entomology Special Study No. 44-015-75/76), wastes from the Pesticide Storage Facility that were disposed in the SFL were probably limited to used storage containers, unsalvageable equipment, and contaminated rags.

The Fort Riley former Dry Cleaning Facility operated in Building 181 from the 1930s to 1983. Stoddard (naphtha) solvent was used at the facility prior to 1966. After 1966, tetrachloroethene was used as the dry cleaning solvent. According to the Central Issue Facility Action Officer, paper/carbon filters removed from solvent distilling machines during the facility's operation, also were disposed in the dumpsters, which would have resulted in disposal at SFL during its operation.

4.1.2 Potential Contaminant Sources

The area north of Well House Road at the SFL is also a potential source of contamination. This area was identified as possibly containing several small areas of subsurface metallic debris (Section 3.4.1). Based upon the aerial photograph the area did not present any evidence of obvious landfilling activities. Personal communication with DEH personnel did not reveal any evidence of landfilling activity north of Well House Road. However, there was an indication of localized activity (trenching and grading) in the 1951, 1954, and 1960 aerial photographs (Section 1.2.2.2). The results of the chemical testing in this area (well cluster 8) indicate the presence of volatile organic contaminants in the groundwater that may be due to localized contamination or plume movement from other areas.

The former Fire Training Area, northeast of the SFL proper, was identified as a potential source of contamination due to the use of fuels and possible use of solvents to ignite materials used in training fire fighters. However, results of the current investigation do not indicate that the Fire Training Area is a current source of subsurface contamination. The former Fire Training Area was used from the mid 1950s to 1982. The fire department burned JP-4, diesel fuel, fuel oil, gasoline, and other fuels for training purposes. In 1982, the soil at the training area was removed to a depth of 6 inches (AEHA, 1989). It is not known at this time where this soil was disposed. Results of chemical testing of soil gas, soils, and groundwater (well cluster 7) do not indicate the presence of contaminants in this area. This may be due to migration of volatile organic compounds from the area, biodegradation of constituents and the removal of the top six inches of soil. The surface soil was likely to have been contaminated by fire training activities and may have acted as a continuous source of subsurface contamination through the infiltration of rainwater.

The farmland southwest of the SFL was identified as another potential source of contaminants due to the use of herbicides, pesticides, and fertilizers. The results of the chemical testing of the Irrigation Well indicate that no herbicides or pesticides are present in the groundwater. However, nitrate concentrations from the Irrigation Well were higher than those from the SFL background monitoring well, possibly due to the use of fertilizers. The farmland does not appear to be a current source of groundwater contamination; however, it may contribute nitrate to groundwater in the vicinity of SFL.

Another potential source of contamination is the Camp Funston area. The literature search identified equipment maintenance areas in the western portion of Camp Funston for both the Kansas National Guard and the 89th Army Reserve Command. Constituents associated with equipment maintenance are metal-laden waste oils, spent degreasing solvents, and anti-freeze. The area also has a history of rail yard operations, including petroleum product loading, unloading and storage. At least 28 underground storage tanks (USTs), some of which were reported to be leaking, were removed in the past four years. Other USTs were removed in the 1970s. Many of the tanks were known to have contained petroleum products, while the contents of others were unknown (USACE, 1993). Results of chemical testing of groundwater (well cluster 5) indicate the presence of volatile organic compounds in the area south of Camp Funston between the levee and the river and east of the Threemile Creek. Well cluster 5 is located is downgradient of Camp Funston.

The WWTPs located upstream of the SFL are potential sources of contaminants to surface water and sediment in the vicinity of SFL. The Custer Hill WWTP releases effluent to Forsyth Creek, a tributary to Threemile Creek, upstream of the SFL. The Camp Funston WWTP releases effluent to the Republican River prior to its convergence with the Smokey Hill River. Additionally, the Main Post WWTP effluent is discharged to the Kansas River upstream of the SFL. These effluents may potentially influence surface water and sediment quality and add metals concentrations to Threemile Creek and the Kansas River.

4.2 SAMPLING PROGRAM AND ANALYTICAL RESULTS

Samples were collected in accordance with the project Field Sampling Plan (Law, 1992b). The analytical methods chosen were appropriate to identify and quantify contaminants of concern at this site with the exception of ethylene glycol. Currently methodology cannot distinguish between ethylene and propylene glycols. Current ARARs do not exist for this parameter. Methylene chloride results which are less than ten times the concentration of the associated laboratory method blank are considered to be laboratory contamination (USEPA, 1992a). Therefore, these results are not discussed as a contaminant throughout this section because they are not site-related. The following sections include a description of the sampling program, including sample locations, and summarize the analytical programs used to evaluate the nature and extent of contamination at this site. Sampling procedures are provided in Section 2.1.5 and the project Work Plans (Law, 1991; Law, 1992a; Law, 1992b).

4.2.1 Soil Gas Investigation

In late October and early November 1991, a soil gas survey was conducted at the SFL by Target Environmental Services (TARGET). Appendix J presents detailed procedures, analytical detection limits, and all results obtained during the soil gas investigation. The sampling locations were selected after reviewing historical photographs, maps, surface features, the physical properties of suspected contaminants and the initial results of the geophysical survey. The objective of this survey was to delineate potential volatile organic contaminant plumes in soil overlying or near potential volatile contaminant sources. Potential contaminant sources were identified as areas where disposal activity was tentatively identified in historical photographs or where magnetic or electromagnetic anomalies were indicated during the geophysical survey (Figure 3-8). The soil gas results and geophysical results (Section 3.4.1) were considered in selecting monitoring well locations.

The depth of sample collection points was limited due to difficult field conditions consisting of saturated surface soils resulting from poor weather (snow, sleet, and rain). A sample depth of 10 feet was proposed, but because TARGET could not utilize the truck-mounted hydraulic probe, a manual sample rod was employed to take samples at a depth of 4 feet. This change in sampling depth may have resulted in lower vapor concentrations being measured in the soil gas analyses because the samples were collected at a distance further from the presumed location of source material within the landfill than originally planned.

4.2.1.1 Soil Gas Sampling and Field Testing - Soil gas samples were collected at a total of 61 locations at the SFL site, as shown on Figure 2-5. Sample 68 was the background sample which was collected near the upgradient well cluster north of Heubner Road (Figure 2-3). Sampling procedures are presented in Section 2.1.5.1 and Appendix J with greater detail. Samples were analyzed on site in TARGET's climate-controlled mobile laboratory. All of the samples collected during the field phase of the survey were subjected to dual analyses. One analysis was conducted according to a modified EPA Method 601 (USEPA, 1986a) on a gas chromatograph (GC) equipped with an electron capture detector (ECD), using direct injection rather than purge and trap sample introduction. The 11 specific analytes standardized for this analysis were:

- 1,1-Dichloroethene
- Methylene chloride
- Trans-1,2-dichloroethene
- 1,1-Dichloroethane
- Cis-1,2-dichloroethene
- Chloroform
- 1,1,1-Trichloroethane
- Carbon tetrachloride
- Trichloroethene
- 1,1,2-Trichloroethane
- Tetrachloroethene

The chlorinated hydrocarbons in this suite were chosen because of their common usage in degreasing solvents and/or their degradational relationship to commonly used compounds.

The second analysis was conducted according to modified EPA Method 602 (USEPA, 1986a) on a GC equipped with a flame ionization detector (FID), using direct injection instead of purge and trap sample introduction. The analytes selected for standardization in this analysis were:

- Benzene
- Toluene
- Ethylbenzene
- Meta- and para-xylene
- Ortho-xylene

These compounds were chosen because of their usefulness for indicating the presence of fuel products or petroleum-based solvents. Total FID volatiles are also reported as the summation of all positive responses for each sample analysis.

Any vinyl chloride results detected in the ECD analysis were sent to the laboratory for quantitation by a GC with mass spectrometry detection. Using the ECD and TARGET's analytical parameters, vinyl chloride elutes with the system ejection peak. This ejection peak is of uniform size throughout a data set unless another compound, such as vinyl chloride is present, which elutes at the same time. By examining the ECD chromatograms and looking for ejection peaks which are larger than those observed during the initial standard calibration of the instrument, those samples which potentially contain vinyl chloride can be identified. Using the

FID, numerous compounds including methanol and butene, co-elute with vinyl chloride. From past experience, the elution time of vinyl chloride using TARGET's analytical parameters, is known. The size of the peak which would represent 10 micrograms per liter (μg/L) is also known. By examining the FID chromatograms and looking for a peak of a certain minimum size at the specific retention time, those samples which potentially contain vinyl chloride can be identified. The combination of FID and ECD chromatograms for a particular sample can be used in the above manner to qualitatively identify concentrations of vinyl chloride above 10 μg/L. The suspect samples can then be analyzed quantitatively, if required, by gas chromatography/mass spectroscopy (GC/MS).

Table 4-1 provides a summary list of positive detections for soil gas samples. The tabulated results for all analyses of the soil gas samples are reported in μg/L in Appendix J. Although "micrograms per liter" is analogous to "parts per billion" in water analyses, it is not for gas analyses due to the difference in the mass of equal volumes of water and gas matrices. The "xylene" concentrations reported are the sum of the meta-, para-, and ortho-xylene concentrations for each sample.

4.2.1.2 Soil Gas Results - The total FID volatiles results revealed a moderate level at the western survey boundary, with a lower level to the north, and isolated, very low levels occurring in several other samples throughout the site. Benzene was detected once in sample 44 located at the western boundary of the SFL. Ethylbenzene was detected in samples 43 and 44 located at the western boundary of the SFL and sample 53 located in the northeast portion of the landfill. The occurrences of toluene and xylenes were limited for the most part to the western survey boundary. The FID chromatogram signatures of samples 43 and 44, which have the highest levels of total FID volatiles, exhibited a pattern of peaks that is characteristic of diesel fuel/fuel oil. Soil gas contours for total FID volatiles, toluene, and xylenes are provided in Figures 4-1 through 4-3.

The GC/ECD analysis revealed a moderately low level of tetrachloroethene in sample 44 from the western survey boundary. Very low levels occur to the north. A soil gas contour for tetrachloroethene is provided in Figure 4-4. The trichloroethene occurrence was similar to that of tetrachloroethene. Isolated very low levels of 1,1,1-trichloroethane were present on the southern survey boundary (sample 13) and in the north central survey area (sample 56). Figure 4-5 provides a soil gas contour for 1,1,1-trichloroethane. A moderate level of cis-1,2-dichloroethene occurred in sample 44, with a lower level to the north (sample 43). A moderate level of methylene chloride and relatively low levels of 1,1-dichloroethane, trans-1,2-dichloroethene, and 1-1-dichloroethene were present only at station 44. Chloroform and carbon tetrachloride were not detected.

Discussions with TARGET personnel indicated that the soil gas analysis by GC/ECD did not qualitatively detect vinyl chloride. Therefore, confirmation of vinyl chloride by GC/MS detection was not performed.

TABLE 4-1

POSITIVE RESULTS FOR SOIL GAS SAMPLES (μg/L)
Southwest Funston Landfill
Fort Riley, Kansas

SAMPLE	11DCE(a)	CH_2Cl_2(a)	t12DCE(a)	11DCA(a)	c12DCE(a)	111TCA(a)	TCE(a)	PCE(a)	BENZENE(b)	TOLUENE(b)	ETHYLBENZENE(b)	XYLENES(b)	TOTAL FID VOLATILES(c)
12	--	--	--	--	--	--	--	--	--	--	--	--	9.3
12R	--	--	--	--	--	--	--	--	--	--	--	--	11
13	--	--	--	--	--	0.14	0.24	5.2	--	--	--	1.3	2.8
21	--	--	--	--	--	--	--	--	--	--	--	--	3.6
22	--	--	--	--	--	--	--	--	--	--	--	--	8.0
22R	--	--	--	--	--	--	--	--	--	--	--	--	6.5
28	--	--	--	--	--	--	--	--	--	--	--	--	2.3
34	--	--	--	--	--	--	--	--	--	--	--	--	1.1
39	--	--	--	--	--	--	--	--	--	--	--	--	4.2
42	1.3	--	--	--	--	--	--	0.6	--	--	--	--	--
43	--	--	--	--	5.9	--	0.65	0.25	--	5.4	10	20	270
44	--	25	3.7	2.2	3.3	--	6.4	11	3.2	530	47	130	1300
47	--	--	--	--	--	--	--	--	--	--	--	--	6.4
53	--	--	--	--	--	--	--	--	--	--	4.5	9.1	69
56	--	--	--	--	--	0.75	--	--	--	--	--	--	1.2
59	--	--	--	--	--	--	--	--	--	--	--	--	3.2
63	--	--	--	--	--	--	--	--	--	--	--	--	5.0

R = Replicate
(a) Analysis performed using GC/ECD.
(b) Analysis performed using GC/FID.
(c) Calculated using the sum of the areas of all integrated chromatogram peaks on the FID and the instrument response factor for toluene.

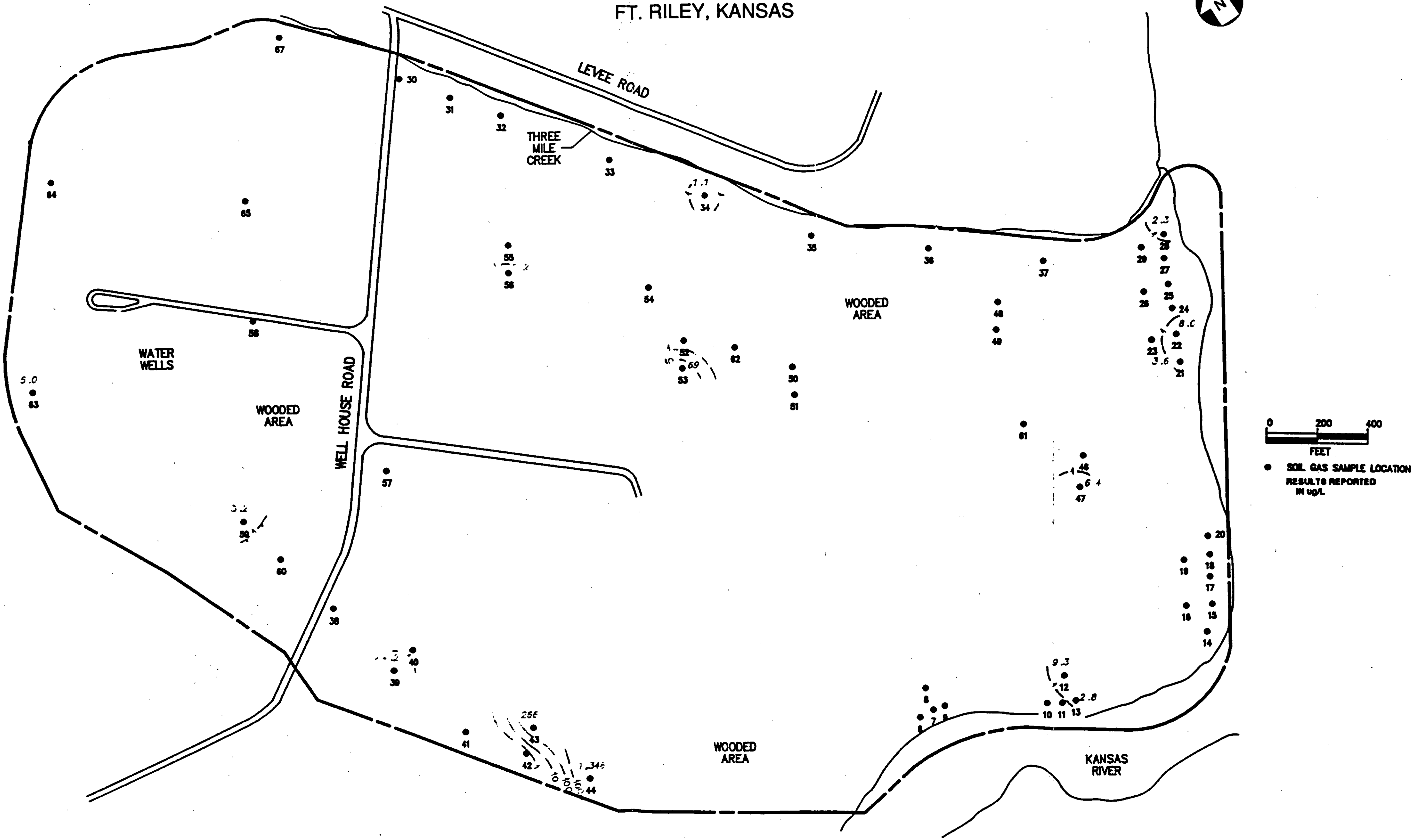
All results are reported in μg/L.

11DCE = 1,1-dichloroethene
t12DCE = trans-1,2-dichloroethene
c12DCE = cis-1,2-dichloroethene
111TCA = 1,1,1-trichloroethane
TCE = trichloroethene
PCE = tetrachloroethene

CH_2Cl_2 = methylene chloride
11DCA = 1,1-dichloroethane

Source: Soil Gas Survey, Southwest Funston Landfill, Ft. Riley Army Base, Ft. Riley Kansas, November 1991, performed by Target Environmental Services, Inc.

FIGURE 4-1
TOTAL FID ISOPLETH - SOIL GAS
SOUTHWEST FUNSTON LANDFILL
FT. RILEY, KANSAS



SOURCE: TARGET ENVIRONMENTAL SERVICES, INC.

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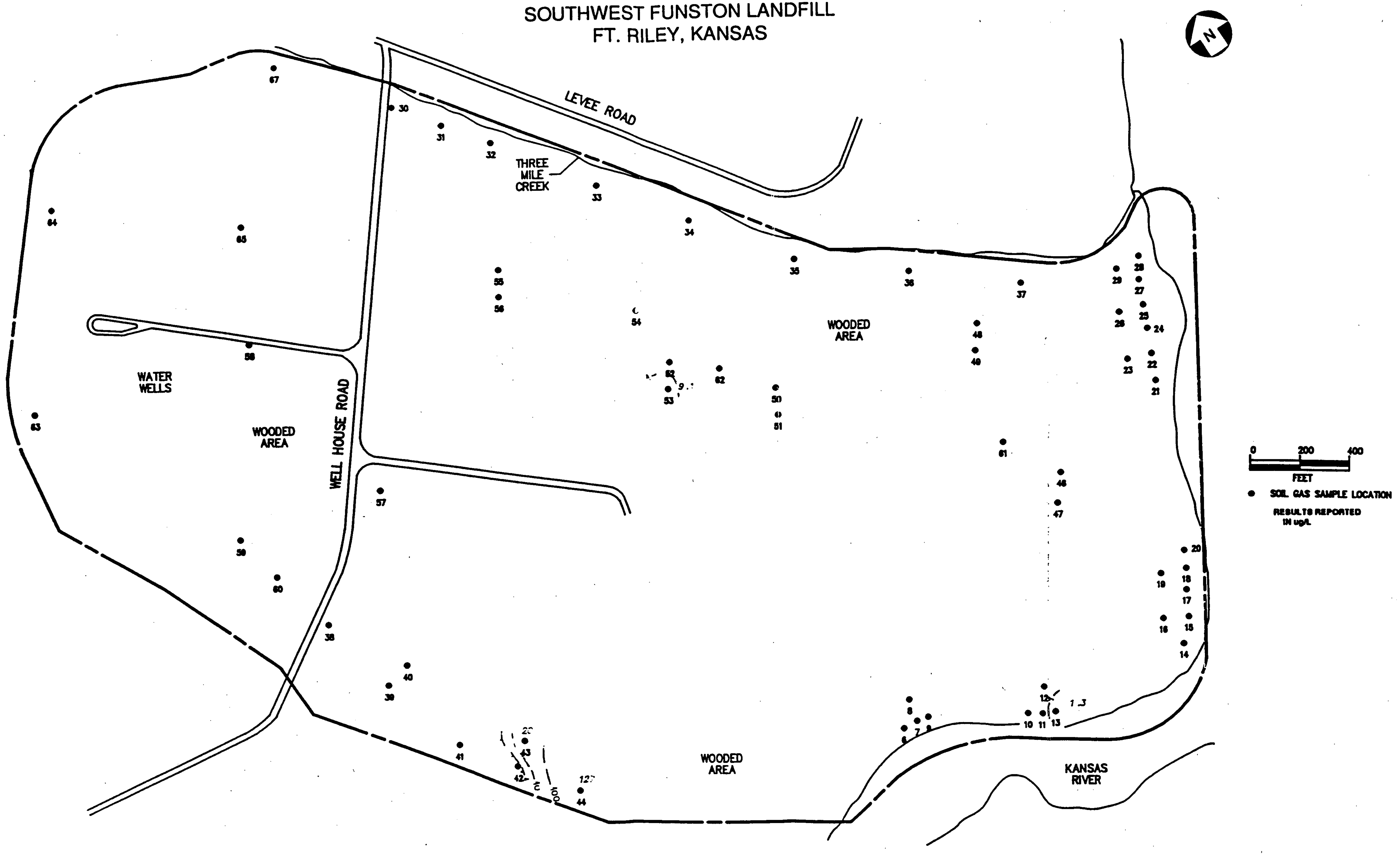
FIGURE 4-2

XYLENES ISOPLETH - SOIL GAS

SOUTHWEST FUNSTON LANDFILL
FT. RILEY, KANSAS



SOURCE: TARGET ENVIRONMENTAL SERVICES, INC.

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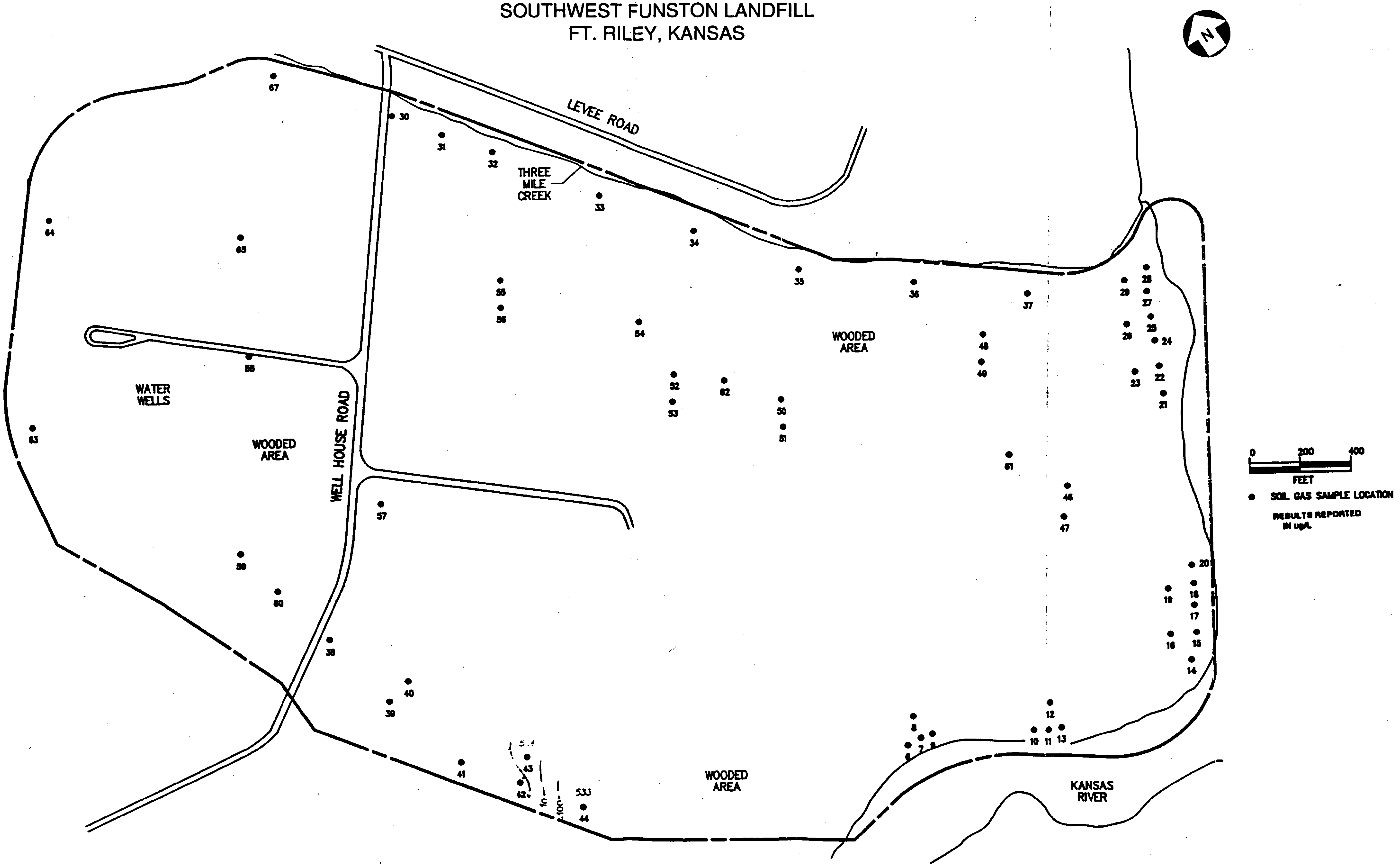
FIGURE 4-3

TOLUENE ISOPLETH - SOIL GAS

SOUTHWEST FUNSTON LANDFILL
FT. RILEY, KANSAS



SOURCE: TARGET ENVIRONMENTAL SERVICES, INC.

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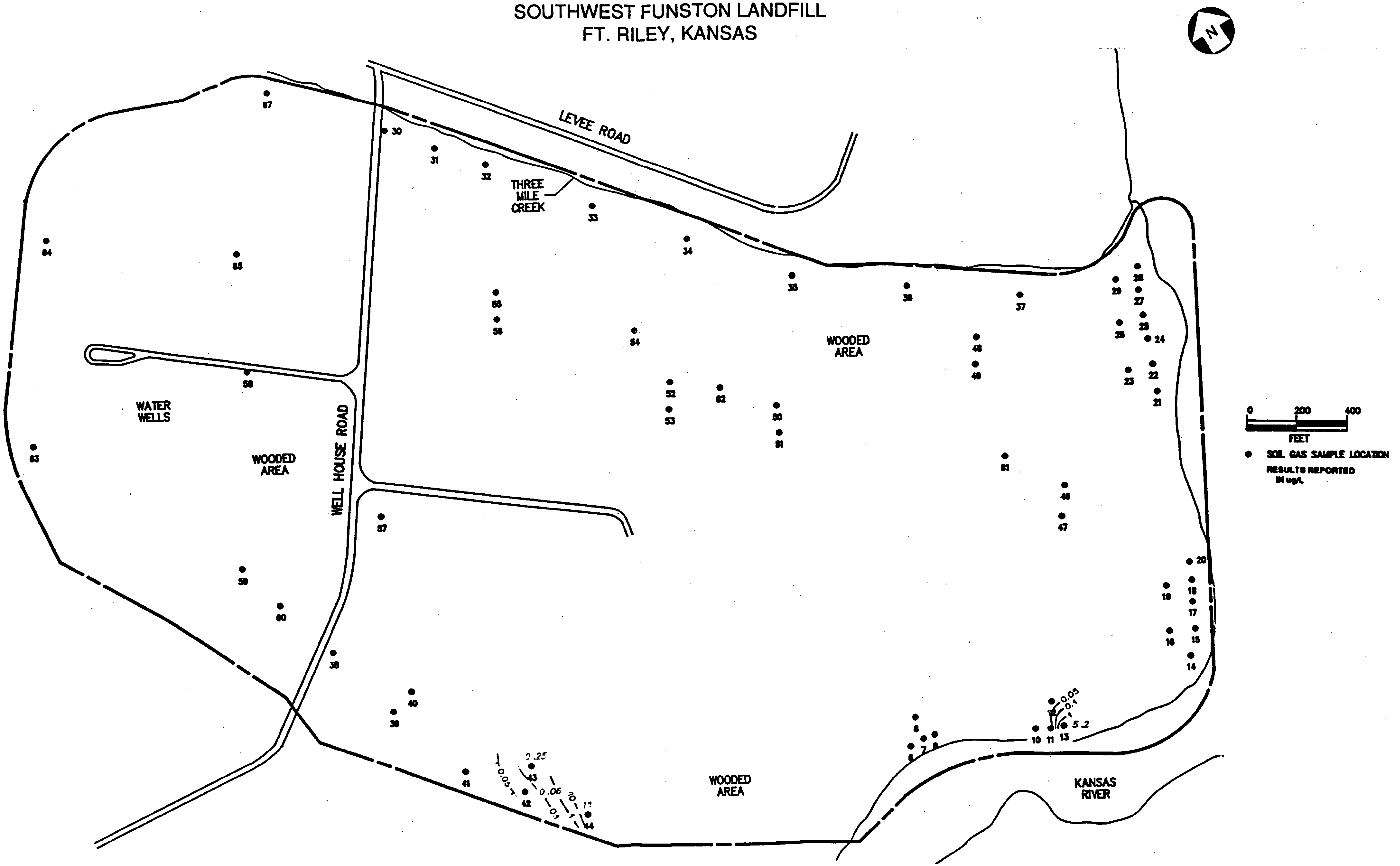
FIGURE 4-4

TETRACHLOROETHENE ISOPLETH - SOIL GAS

SOUTHWEST FUNSTON LANDFILL
FT. RILEY, KANSAS



SOURCE: TARGET ENVIRONMENTAL SERVICES, INC.

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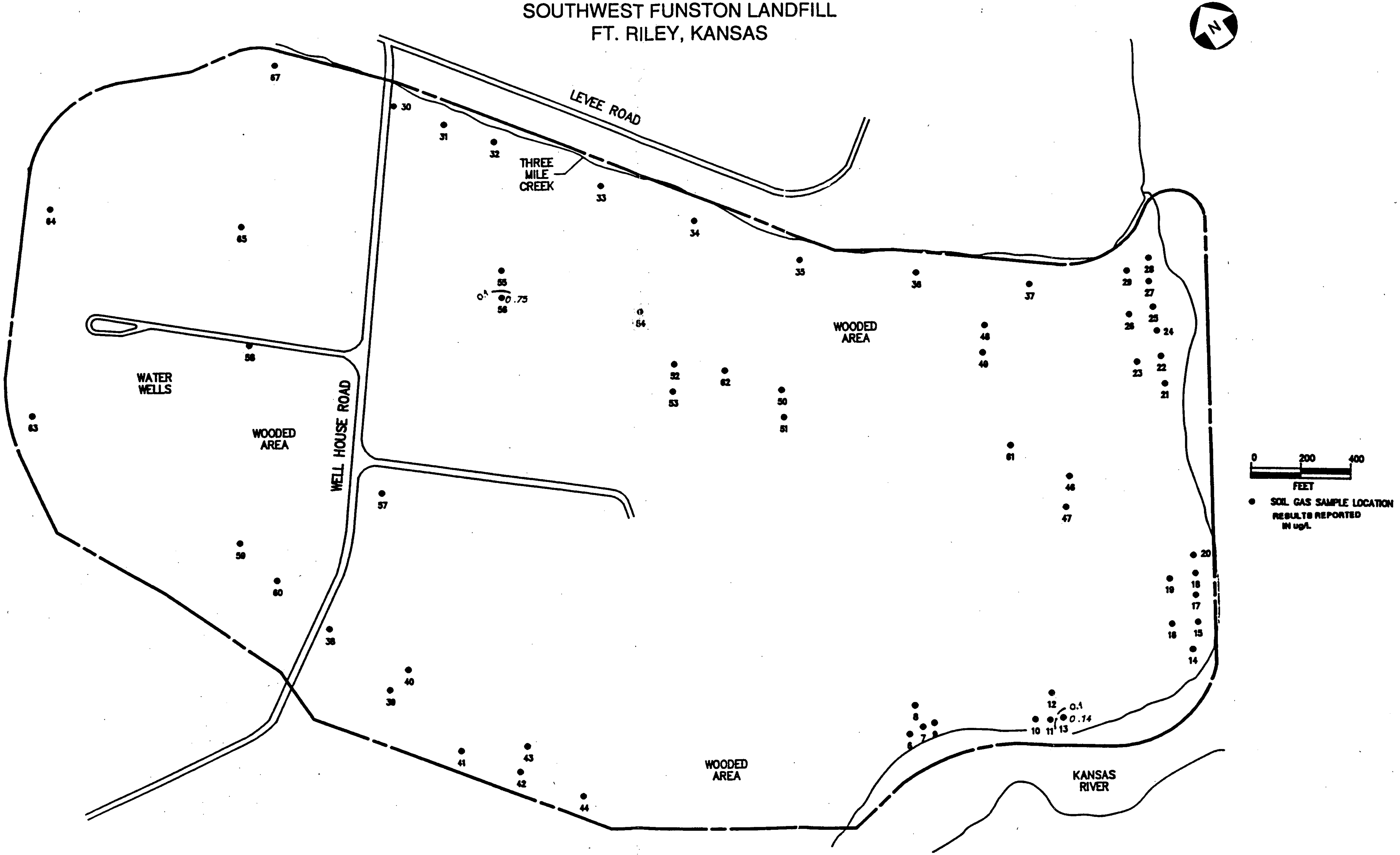
FIGURE 4-5

1,1,1 - TRICHLOROETHANE ISOPLETH - SOIL GAS

SOUTHWEST FUNSTON LANDFILL
FT. RILEY, KANSAS



SOURCE: TARGET ENVIRONMENTAL SERVICES, INC.

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4.2.1.3 Soil Gas QA/QC Summary - Quality control samples consisted of field control blanks, laboratory duplicates and laboratory blanks. Two field control blanks exhibited contamination. Field control sample 1 contained 0.16 μg/L of tetrachloroethene as a result of incomplete decontamination of the sampling equipment prior to start of field activities. Subsequent samples contained no measurable levels of tetrachloroethene indicating that soil gas samples were not affected.

Field control sample 5 contained 4.8 μg/L of total FID volatiles and 0.08 μg/L of tetrachloroethene as a result of carryover in the sampling equipment following the collection of sample 44. Field control sample 45 was collected after field control sample 5 and contained no measurable levels of FID volatiles or tetrachloroethene indicating that subsequent soil gas samples were not spuriously contaminated.

Laboratory blanks exhibited no measurable levels of contaminants indicating that laboratory procedures did not bias sample results.

Laboratory duplicate/replicate results yielded relative percent differences (RPDs) at less than 20 indicating satisfactory method precision.

4.2.1.4 Interpretation of Soil Gas Results - The soil gas data indicated that diesel fuel and chlorinated compounds were present in the subsurface along the western boundary. Monitoring well cluster 2 was placed here to confirm results. Chlorinated compounds were not detected in the groundwater from this cluster; however, petroleum hydrocarbons were detected in the first quarterly sampling event. Methylene chloride and carbon disulfide were detected in the soil from the boring.

Soil gas samples 12 and 13, located at the southwestern border of the landfill, exhibited FID volatiles and chlorinated compounds (tetrachloroethene, trichloroethene and 1,1,1-trichloroethane). Monitoring well cluster 3 was placed here to confirm results. The groundwater and soil samples collected from this location did not contain these chlorinated compounds at measurable concentrations.

Soil gas samples exhibited FID volatiles where geophysical results indicated EM anomalies near the southeast boundary of the SFL. Monitoring well cluster 4 was placed here to confirm results. The results of the groundwater analyses did not yield positive petroleum hydrocarbon results. However, trichlorofluoromethane was detected once at trace concentrations. In addition, there were no positive volatile organic results from the soil sample analyses.

Monitoring well cluster 6 was placed where soil gas samples 34 and 53 exhibited FID volatiles and fuel-related compounds. Groundwater results consistently indicated the presence of the fuel-related compound benzene at this location as well as several chlorinated volatile compounds. However, no volatile organic compounds were detected in the soil samples.

Soil gas samples 30 and 31 were placed where fire training activities took place. The soil gas results contained no measurable levels of fuel-related compounds. This may be due to migration of volatile organic compounds from the area, biodegradation of constituents and the removal of the top six inches of soil. The surface soil was likely to have been contaminated by fire training activities and may have acted as a continuous source of subsurface contamination through infiltration of rainwater. However, to the south of this area, soil gas sample 56 contained 1,1,1-trichloroethane where the geophysical survey exhibited an EM anomaly. Monitoring well cluster 7 was placed in the area of the EM anomaly and soil gas sample 56 to confirm results. Trichloroethene was detected once in cluster 7 at a low (4.3 μg/L) concentration. Methyl chloride was detected in the soil at a depth of 14 to 22 feet.

4.2.2 Groundwater Investigation

The baseline groundwater sampling was performed in July of 1992 and the first, second, and third quarter sampling events were performed in November 1992, February 1993 and May 1993. Groundwater samples were analyzed for the parameters listed in Table 4-2. This list was selected to encompass those analytes suspected or known to exist at the SFL. Complete analytical results with detection limits for each sample are provided in Appendix L.

Four modifications to the analytical program were initiated during the groundwater monitoring. Two changes were made to meet drinking water criteria, another to evaluate remedial alternatives, and a fourth in response to sample results. Vinyl chloride was analyzed by EPA Method 8260 which has a method detection limit of 2 μg/L and a practical quantitation limit of 10 μg/L. Results which fall between 2 and 10 μg/L are considered estimated quantitation. The Maximum Contaminant Level (MCL) for vinyl chloride is 2 μg/L. To quantitate vinyl chloride below the MCL in the first quarterly sampling event, any result which fell between 2 and 10 μg/L was to be subsequently analyzed by Method 524.2 which can achieve a detection limit of 0.3 μg/L. However, none of the samples contained vinyl chloride in this concentration range, so confirmation was not necessary.

The second modification to the analytical program was begun to meet the thallium MCL of 2 μg/L. Thallium was originally analyzed by EPA Method 6010, which has a laboratory-established detection limit of 63 μg/L. To achieve a detection limit of 1 μg/L, thallium was analyzed by EPA Method 7841 in the third quarterly sampling event. In addition, several water quality parameters were added in the first and second quarterly sampling events to aid in the evaluation of remedial alternatives. Finally, the dissolved metals analysis was discontinued in the third quarter because total and dissolved metal concentrations in all previous sampling rounds were similar and the total metals results are used in risk assessment.

Groundwater samples were measured in the field for pH, temperature, specific conductance, and turbidity. Groundwater sampling was conducted on a quarterly basis to monitor seasonal

TABLE 4-2

GROUNDWATER/SOIL ANALYTICAL PARAMETERS
Southwest Funston Landfill
Fort Riley, Kansas

ANALYSIS	EPA METHOD
LENL:	
Volatile Organics	8260
Semi-Volatile Organics	3550/8270 (Soil) 3510/8270 (Groundwater)
Chlorinated Pesticides/PCBs	3550/8080 (Soil) 3510/8080 (Groundwater)
ICP Metals[a]	3050/6010 (Soil) 3005/6010 (Groundwater)
GFAA Metals:	
Arsenic	3050/7060 (Soil) 7060 (Groundwater)
Lead	3020/7421 (Groundwater)
Selenium	3050/7740 (Soil) 7740 (Groundwater)
Mercury	7471 (Soil) 7470 (Groundwater)
Total Recoverable Petroleum Hydrocarbons (TRPH)	3550/418.1 (Soil) 418.1 (Groundwater)
SWLO:	
Acid Herbicides	8150
Organophosphorus Pesticides	3550/8140 (Soil) 3510/8140 (Groundwater)
Wet Chemical Inorganics:	
Chloride	300 (Groundwater only)
Sulfate	300 (Groundwater only)
Nitrate	300 (Groundwater only)
Bicarbonate	SM403 (Groundwater only)
Sulfide	SM427 (Groundwater only)
Cyanide, total	412D
Cyanide, amenable	412F (Groundwater only)
Total Organic Carbon (TOC)	415.1

[a] = ICP metals include: aluminum, antimony, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, potassium, silver, sodium, thallium, vanadium, zinc.

LENL = Law Environmental National Laboratories
SWLO = Southwest Laboratory of Oklahoma

References: USEPA, 1986a; USEPA, 1983a; SM, 1985.

fluctuation impacts on the analytical results. Table 4-3 provides the results of the field measurements. The pH values ranged from 6.07 to 9.45 with the majority of values between 6.0 to 7.0 pH units. Specific conductance readings ranged from 533 to 2370 μmhos/cm. Temperatures of the groundwater samples were between 47.2 to 70.8°F. Temperatures varied seasonally with the lowest values being observed during the winter months. Turbidity values ranged from 0.2 to 29.8 NTUs. All readings were below the 30 NTU sampling criteria established for this project. The following subsections provide discussion and comparison of historical groundwater data, water supply well data, and the analytical data collected from this investigation. The interpretation of analytical results with respect to hydrogeological conditions is provided in Section 4.3.

4.2.2.1 Groundwater Sampling - Twenty monitoring wells were installed during 1992 at eight cluster locations to further investigate the SFL, as shown on Figure 2-3. These locations were selected based on field analytical data for soil gas and geophysical survey data. Four of the eight locations (1,3,5 and 6) contained clusters of one shallow, one intermediate, and one deep well. The four remaining locations (2,4,7 and 8) consisted of one shallow and one deep well.

A privately owned irrigation well exists west of the old channel of the Kansas River. Because of its proximity to the SFL, this well was also sampled. Groundwater samples collected from this well were analyzed for the same parameters as the groundwater samples collected from the SFL monitoring wells. Data collected from the irrigation well was used to assess the potential impacts to human health and the environment and to evaluate a possible route of exposure through food grown with water from the irrigation well.

4.2.2.2 Baseline (July 1992) Groundwater Analysis Results - Both organic and inorganic constituents were detected in the groundwater samples collected during the baseline sampling event at the SFL during the RI. Table 4-4 presents positive analytical results of the baseline groundwater analyses. To provide information concerning background concentrations of contaminants, a background well cluster, consisting of SFL92-101, SFL92-102 and SFL92-103, was installed. Methylene chloride was the only organic compound detected in these upgradient monitoring wells. The additional analytes which were detected include naturally occurring metals and inorganics.

During baseline sampling of the monitoring wells at the SFL, groundwater flow was away from Threemile Creek and the Kansas River. Additional groundwater flow details are presented in Section 3.6.2.2.1.

TABLE 4-3

RESULTS OF FIELD MEASUREMENT PARAMETERS
Southwest Funston Landfill
Ft. Riley, Kansas

PARAMETER	SFL92-101	SFL92-102	SFL92-103	SFL92-201	SFL92-203	SFL92-301	SFL92-302	SFL92-303
pH								
Baseline	6.98	7.07	6.90	6.67	6.95	7.24	6.90	6.81
First Quarter	7.23	7.40	7.10	6.56	7.35	7.00	7.20	7.30
Second Quarter	8.56	7.52	9.45	6.60	7.07	6.97	6.75	7.08
Third Quarter	7.04	7.25	7.34	8.68	8.93	8.75	8.14	8.77
Specific Conductance (μmhos/cm)								
Baseline	811	719	830	1112	1590	691	1250	1130
First Quarter	688	602	533	1970	1804	1495	1168	1364
Second Quarter	897	751	720	1628	1726	1364	1231	1370
Third Quarter	968	785	658	1168	1566	746	554	716
Temperature (°F)								
Baseline	62.4	61.8	63.6	59.1	60.1	63.3	61.4	69.7
First Quarter	56.5	55.2	51.0	49.9	52.7	58.3	54.4	54.0
Second Quarter	55.0	47.2	47.2	57.0	56.8	60.9	53.6	57.1
Third Quarter	64.1	59.0	60.4	69.8	67.6	58.7	56.7	60.6
Turbidity (NTU)								
Baseline	1.9	1.9	2.12	3.5	4.5	5.0	4.5	15.6
First Quarter	2.92	1.9	2.5	5.6	3.3	0.2	0.7	7.7
Second Quarter	1.6	2.0	1.0	9.4	4.5	1.7	1.9	3.3
Third Quarter	2.18	0.86	0.30	12.8	7.14	3.20	3.87	4.07

TABLE 4-3

RESULTS OF FIELD MEASUREMENT PARAMETERS
Southwest Funston Landfill
Ft. Riley, Kansas

PARAMETER	SFL92-401	SFL92-403	SFL92-501	SFL92-502	SFL92-503	SFL92-601	SFL92-602	SFL92-603
pH								
Baseline	6.73	6.88	6.90	7.11	6.90	6.07	6.80	7.24
First Quarter	6.65	6.56	6.96	7.07	7.37	6.80	7.00	7.10
Second Quarter	6.45	6.59	6.85	6.98	7.03	6.36	6.54	6.89
Third Quarter	6.84	7.12	8.42	8.21	7.51	8.17	8.32	8.66
Specific Conductance (μmhos/cm)								
Baseline	1594	1668	1448	1215	1250	2250	1078	1107
First Quarter	2100	1970	1696	1659	1497	1940	1225	898
Second Quarter	1797	1754	1630	1405	1434	2370	1738	1465
Third Quarter	1339	1337	1113	1094	1187	1933	1320	1260
Temperature (°F)								
Baseline	62.3	61.5	61.7	63.0	61.4	70.8	69.9	66.2
First Quarter	52.6	49.9	54.4	56.1	54.5	52.1	47.2	50.0
Second Quarter	56.7	56.9	58.1	54.3	59.0	59.1	58.2	56.9
Third Quarter	68.5	70.5	67.9	64.4	60.8	61.8	62.2	61.9
Turbidity (NTU)								
Baseline	2.87	3.0	9.7	1.5	4.5	4.3	8.8	1.7
First Quarter	2.4	5.6	3.4	2.4	3.6	0.65	3.8	0.5
Second Quarter	9.0	9.0	4.8	11.0	7.1	2.8	6.3	0.2
Third Quarter	4.50	5.93	11.40	0.81	6.17	3.30	6.0	1.99

TABLE 4-3

RESULTS OF FIELD MEASUREMENT PARAMETERS
Southwest Funston Landfill
Ft. Riley, Kansas

PARAMETER	SFL92-701	SFL92-703	SFL92-801	SFL92-803	IRRIGATION WELL
pH					
Baseline	7.25	7.04	7.11	6.93	7.22
First Quarter	7.65	4.30 *	7.00	7.00	--
Second Quarter	7.05	7.07	7.06	7.47	--
Third Quarter	6.96	6.96	6.96	7.04	--
Specific Conductance (μmhos/cm)					
Baseline	780	910	849	1046	1050
First Quarter	1080	1327	1015	617	--
Second Quarter	855	963	1102	919	--
Third Quarter	807	871	1020	983	--
Temperature (°F)					
Baseline	58.4	61.7	62.2	66.8	63.5
First Quarter	53.4	50.1	47.7	47.7	--
Second Quarter	53.6	53.8	54.9	54.2	--
Third Quarter	59.2	60.1	64.8	64.3	--
Turbidity (NTU)					
Baseline	2.0	22.2	9.0	9.74	2.5
First Quarter	8.9	29.8	3.3	2.5	--
Second Quarter	4.5	4.0	2.4	2.3	--
Third Quarter	17.40	7.19	0.97	1.38	--

* The accuracy of the pH meter calibration was in question due to the cold weather.

TABLE 4-4

POSITIVE RESULTS FOR BASELINE (JULY 1992) GROUND-WATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER				Sample	Duplicate						
	SFL92101	SFL92102	SFL92103	SFL92201	SFL92202	SFL92203	SFL92301	SFL92302	SFL92303	SFL92401	SFL92403
Date Collected	07-20-92	07-20-92	07-20-92	07-22-92	07-22-92	07-22-92	07-23-92	07-22-92	07-22-92	07-22-92	07-22-92
VOLATILE ORGANICS:											
1,1,1,2-Tetrachloroethane, μg/L	--	--	--	--	--	--	--	--	--	--	--
1,1,2,2-Tetrachloroethane, μg/L	--	--	--	--	--	--	--	--	--	--	--
1,1,2-Trichlorethane, μg/L	--	--	--	--	--	--	--	--	--	--	--
1,2,3-Trichloropropane, μg/L	--	--	--	--	--	--	--	--	--	--	--
1,2-Dibromoethane, μg/L	--	--	--	--	--	--	--	--	--	--	--
1,2-Dichloropropane, μg/L	--	--	--	--	--	--	--	--	--	--	--
2-Hexanone, μg/L	--	--	--	--	--	--	--	--	--	--	--
Benzene, μg/L	--	--	--	--	--	--	--	--	--	--	--
Bromoform, μg/L	--	--	--	--	--	--	--	--	--	--	--
Chlorodibromomethane, μg/L	--	--	--	--	--	--	--	--	--	--	--
Ethyl methacrylate, μg/L	--	--	--	--	--	--	--	--	--	--	--
Methacrylonitrile, μg/L	--	--	--	--	--	--	--	--	--	--	--
Methyl chloride, μg/L	--	--	--	--	--	--	--	--	--	--	--
Methyl isobutyl ketone, μg/L	--	--	--	--	--	--	--	--	--	--	--
Methylene bromide, μg/L	--	--	--	--	--	--	--	--	--	--	--
Methylene chloride, μg/L	21(T)	18(T)	16(T)	--	15(B2)(T)	8.0(B2)(T)	26(B2)	--	--	6.8(B2)(T)	8.1(B2)(T)
Pentachloroethane, μg/L	--	--	--	--	--	--	--	--	--	--	--
Styrene, μg/L	--	--	--	--	--	--	--	--	--	--	--
Trichlorofluoromethane, μg/L	--	--	--	--	--	--	--	--	--	--	--
Vinyl chloride, μg/L	--	--	--	--	--	--	--	--	--	--	--
Xylenes (total), μg/L	--	--	--	--	--	--	--	--	--	--	--
cis-1,3-Dichloropropene, μg/L	--	--	--	--	--	--	--	--	--	--	--
trans-1,2-Dichloroethene, μg/L	--	--	--	--	--	--	--	--	--	--	--
trans-1,4-Dichloro-2-butene, μg/L	--	--	--	--	--	--	--	--	--	--	--
PESTICIDES/PCBs, μg/L:	--	--	--	--	--	--(H)	--	--	--	--	--
SEMI-VOLATILE ORGANICS, μg/L:	--	--	--	--	--	--	--	--	--	--	--
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS, mg/L:	--	--	--	--	--	--	--	--	--	--	--
DISSOLVED FURNACE METALS:											
Arsenic, μg/L	7.0	3.3	--	--	--	19	2.6	23	21	--	2.7
Selenium, μg/L	--	--	1.9	--	--	--	--	--	--	--	--
DISSOLVED ICP METALS:											
Aluminum, μg/L	--	--	--	--	--	140	--	--	--	--	170
Barium, μg/L	340	240	210	300	290	210	89	87	160	1000	800
Beryllium, μg/L	1.6	1.5	1.3	1.6	1.7	1.4	--	--	1.0	1.9	2.2
Cadmium, μg/L	--	--	--	--	--	--	--	--	--	--	--
Calcium, μg/L	160000	140000	120000	170000	170000	140000	62000	46000	110000	200000	200000
Iron, μg/L	1600	55	--	17000	17000	4600	2200	2800	2800	18000	17000
Magnesium, μg/L	23000	22000	26000	27000	27000	25000	8400	7000	19000	37000	36000
Manganese, μg/L	1000	310	270	1600	1600	1500	420	470	1100	2200	2400
Potassium, μg/L	8000	4700	3200	9000	8900	8200	9600	5500	7100	12000	9700
Sodium, μg/L	12000	15000	20000	45000	44000	150000	59000	86000	110000	100000	100000
Zinc, μg/L	16(B1)	91	14(B1)	9.8(B1)	11(B1)	19(B1)	10(B1)	10(B1)	9.8(B1)	13(B1)	22(B1)
TOTAL FURNACE METALS:											
Arsenic, μg/L	7.1	3.7	2.0	--	--	19	2.6	25	24	--	2.6
Selenium, μg/L	--	--	2.1	--	--	1.0	--	--	--	--	--

TABLE 4-4

POSITIVE RESULTS FOR BASELINE (JULY 1992) GROUND-WATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	SFL92101	SFL92102	SFL92103	Sample SFL92201	Duplicate SFL92202	SFL92203	SFL92301	SFL92302	SFL92303	SFL92401	SFL92403
Date Collected	07-20-92	07-20-92	07-20-92	07-22-92	07-22-92	07-22-92	07-23-92	07-22-92	07-22-92	07-22-92	07-22-92
TOTAL ICP METALS:											
Aluminum, µg/L	--	460	120	--	--	110	--	110	210	--	--
Barium, µg/L	350	250	220	290	300	220	68	82	160	1000	830
Beryllium, µg/L	1.8	1.5	1.8	1.6	1.8	2.0	--	--	1.0	1.9	1.9
Cadmium, µg/L	--	--	--	--	--	--	--	--	--	--	--
Calcium, µg/L	160000	140000	120000	170000	170000	140000	60000	44000	110000	200000	210000
Cobalt, µg/L	--	--	--	--	--	--	--	--	--	--	--
Copper, µg/L	--	--	--	--	--	--	--	--	--	--	--
Iron, µg/L	1700	550	110	17000	17000	4400	2200	2700	3000	18000	17000
Magnesium, µg/L	23000	23000	26000	27000	27000	25000	8200	6800	19000	36000	37000
Manganese, µg/L	1000	320	290	1600	1600	1500	410	440	1100	2200	2400
Potassium, µg/L	8000	4700	3300	8800	8900	8000	9500	5300	7200	11000	9900
Sodium, µg/L	12000	16000	21000	44000	44000	140000	58000	85000	110000	100000	100000
Vanadium, µg/L	--	--	--	--	--	--	--	--	--	--	--
Zinc, µg/L	18(B1)	14(B1)	16(B1)	7.8(B1)	6.6(B1)	14(B1)	8.9(B1)	14(B1)	18(B1)	11(B1)	11(B1)
DISSOLVED MERCURY, µg/L:	--	--	--	0.6	--	--	--	--	--	--	--
TOTAL MERCURY, µg/L:	--	--	--	--	--	--	--	--	--	--	--
ACID HERBICIDES:	--	--	--	--	--	--	--	--	--	--	--
ORGANOPHOSPHORUS PESTICIDES, µg/	--	--	--	--	--	--	--	--	--	--	--
EXPLOSIVES, µg/L:	--	--	--	--	--	--	--	--	--	--	--
WET CHEMICAL INORGANICS:											
Chloride, mg/L	7.50	11.20	12.80	60.10	60.50	279.00	58.70	73.20	149.00	139.00	139.00
Nitrate, mg/L	--	3.80	4.40	--	--	--	--	--	--	--	--
Sulfate, mg/L	69.10	40.60	38.30	78.00	78.40	196.00	72.60	72.60	127.00	76.50	74.90
Sulfide, mg/L	12.10(E)	26.20(E)	27.50(E)	42.60(E)	41.60(E)	23.70(E)	40.60(E)	51.20(E)	53.10(E)	25.00(E)	27.70(E)
Bicarbonate, mg/L	576.00	541.00	523.00	603.00	603.00	255.00	209.00	193.00	322.00	831.00	793.00
Total organic carbon, mg/L	3.30(M1)	--	--	3.00(M1)	3.20(M1)	--	3.90(M1)	2.60(M1)	--	7.50(M1)	6.70(M1)
Total cyanide, µg/L	--	--	--	--	--	--	--	--	--	--	--
Amenable cyanide, µg/L	--(M2)	--(M2)	--(M2)	--(M2)	--(M2)	--(M2)	--(M2)	--(M2)	--(M2)	--(M2)	--(M2)

B1 – Sample results are less than 5 times the amount detected in the method blank. Result is estimated.
B2 – Sample results are less than 10 times the amount detected in the method blank. Result is estimated.
E – MS/MSD RPD exceeds control limit. Estimated result due to poor precision.
H – Holding times exceeded. Result biased low.
M2 – Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.
L – Laboratory control sample recovery is low. Sample result is biased low.
M1 – Matrix spike recovery is high due to sample matrix effect. Sample result is biased high.
M2 – Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.
T – Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.
-- Not detected

TABLE 4-4

POSTIVE RESULTS FOR BASELINE (JULY 1992) GROUND-WATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	SFL92501	SFL92502	Sample SL92503	Duplicate SFL92504	SFL92601	SFL92602	SFL92603	SFL92701	SFL92703	SFL92801	SFL92803	IRRWELL
Date Collected	07-21-92	07-21-92	07-23-92	07-23-92	07-23-92	07-21-92	07-21-92	07-21-92	07-21-92	07-20-93	07-20-93	07-23-92
VOLATILE ORGANICS:												
1,1,1,2-Tetrachloroethane, μg/L	5.2	--	6.0	--	--	--	--	--	--	--	--	--
1,1,2,2-Tetrachloroethane, μg/L	--	--	6.3	--	--	--	--	--	--	15	12	--
1,1,2-Trichlorethane, μg/L	--	--	--	--	--	--	--	--	--	8.8	--	--
1,2,3-Trichloropropane, μg/L	30	--	34	--	--	--	--	--	--	--	--	--
1,2-Dibromoethane, μg/L	21	--	24	--	--	--	--	--	--	--	--	--
1,2-Dichloropropane, μg/L	--	--	--	--	--	--	--	--	--	4.1	3.6	--
2-Hexanone, μg/L	--	--	--	--	--	--	--	--	--	22	18	--
Benzene, μg/L	--	--	--	--	8.9	--	--	--	--	2.4	--	--
Bromoform, μg/L	--	--	--	--	--	--	--	--	--	8.0	6.4	--
Chlorodibromomethane, μg/L	--	--	--	--	--	--	--	--	--	5.2	--	--
Ethyl methacrylate, μg/L	22	--	24	--	--	--	--	--	--	--	--	--
Methacrylonitrile, μg/L	29	--	30	--	--	--	--	--	--	--	--	--
Methyl chloride, μg/L	11	--	11	--	--	--	--	--	--	--	--	--
Methyl isobutyl ketone, μg/L	--	--	--	--	--	--	--	--	--	22	19	--
Methylene bromide, μg/L	19	--	22	--	--	--	--	--	--	--	--	--
Methylene chloride, μg/L	--	6.2(T)	--	--	--	--	--	6.3	--	8.4(T)	12(T)	11(B2)
Pentachloroethane, μg/L	12	--	13	--	--	--	--	--	--	--	--	--
Styrene, μg/L	--	--	--	--	--	--	--	--	--	3.1	--	--
Trichlorofluoromethane, μg/L	5.2	--	5.2	--	--	--	--	--	--	--	--	--
Vinyl chloride, μg/L	14	--	--	--	18	--	--	--	--	--	--	--
Xylenes (total), μg/L	8.4	--	9.1	--	--	--	--	--	--	--	6.3	--
cis-1,3-Dichloropropene, μg/L	--	--	--	--	--	--	--	--	--	5.9	5.4	--
trans-1,2-Dichloroethene, μg/L	8.7	7.9	--	--	--	--	--	--	--	--	--	--
trans-1,4-Dichloro-2-butene, μg/L	18	--	20	--	--	--	--	--	--	--	--	--
PESTICIDES/PCBs, μg/L:	--	--	--	--	--	--	--	--	--	--	--	--
SEMI-VOLATILE ORGANICS, μg/L:	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS, mg/L:	--	--	--	--	--	--	--	--	--	--	--	--
DISSOLVED FURNACE METALS:												
Arsenic, μg/L	2.5	15	23	22	4.0	15	18	5.4	11	14	--	7.0
Selenium, μg/L	--	--	--	--	--	--	--	--	--	--	1.2	--
DISSOLVED ICP METALS:												
Aluminum, μg/L	--	--	--	--	--	--	--	--	--	--	--	--
Barium, μg/L	240	360	300	290	2000	620	260	260	210	240	120	110
Beryllium, μg/L	2.0	1.8	1.5	1.6	3.0	1.4	1.4	--	1.2	1.7	1.4	--
Cadmium, μg/L	--	--	5.1	--	--	--	--	--	--	--	--	--
Calcium, μg/L	210000	180000	160000	160000	330000	150000	140000	97000	120000	150000	120000	63000
Iron, μg/L	11000	10000	9500	9500	35000	18000	5700	3300	1600	2800	51	300
Magnesium, μg/L	32000	33000	31000	31000	67000	22000	26000	19000	24000	22000	30000	9200
Manganese, μg/L	1900	2100	1700	1700	2500	1600	1500	600	970	440	1200	560
Potassium, μg/L	9600	8700	10000	10000	15000	12000	9900	7100	10000	9200	4700	6100
Sodium, μg/L	68000	73000	73000	74000	64000	43000	71000	67000	42000	27000	39000	130000
Zinc, μg/L	10(B1)	15	22(B1)	8.7(B1)	11(B1)	11(B1)	18(B1)	10(B1)	10(B1)	10(B1)	16(B1)	16(B1)
TOTAL FURNACE METALS:												
Arsenic, μg/L	--	14	24	24	3.9	16	18	4.5	12	14	--	8.3
Selenium, μg/L	1.0	--	1.0	--	--	1.0	2.2	1.6	1.1	--	1.2	1.1

TABLE 4-4

POSTIVE RESULTS FOR BASELINE (JULY 1992) GROUND-WATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER			Sample	Duplicate								
	SFL92501	SFL92502	SL92503	SFL92504	SFL92601	SFL92602	SFL92603	SFL92701	SFL92703	SFL92801	SFL92803	IRRWELL
Date Collected	07-21-92	07-21-92	07-23-92	07-23-92	07-23-92	07-21-92	07-21-92	07-21-92	07-21-92	07-20-93	07-20-93	07-23-92
TOTAL ICP METALS:												
Aluminum, µg/L	--	NA	--	--	--	110	--	--	150	--	170	--
Barium, µg/L	220	NA	310	300	2000	650	300	260	220	260	120	160
Beryllium, µg/L	2.0	NA	1.7	1.7	3.2	1.6	2.3	1.0	1.2	1.6	1.4	1.4
Cadmium, µg/L	--	NA	--	--	--	--	--	--	--	--	--	--
Calcium, µg/L	210000	NA	160000	160000	330000	160000	140000	91000	120000	150000	120000	67000
Cobalt, µg/L	--	NA	--	--	--	--	10	--	--	--	--	--
Copper, µg/L	--	NA	--	--	--	--	--	--	--	--	--	--
Iron, µg/L	12000	NA	10000	10000	35000	20000	5800	3100	1600	2700	230	2300
Magnesium, µg/L	32000	NA	31000	31000	68000	24000	27000	18000	24000	22000	30000	9800
Manganese, µg/L	1900	NA	1800	1700	2500	1700	1500	560	960	430	1200	610
Potassium, µg/L	9800	NA	10000	10000	15000	12000	10000	6700	10000	9400	4800	6500
Sodium, µg/L	69000	NA	75000	74000	63000	46000	73000	63000	43000	28000	39000	140000
Vanadium, µg/L	--	NA	--	--	--	--	--	--	--	--	--	--
Zinc, µg/L	17(B1)	NA	12(B1)	8.2(B1)	8.6(B1)	14(B1)	20(B1)	6.8(B1)	18(B1)	14(B1)	19(B1)	13(B1)
DISSOLVED MERCURY, µg/L:	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL MERCURY, µg/L:	--	NA	--	--	--	--	--	--	--	--	--	--
ACID HERBICIDES:	--	--	--	--	--	--	--	--	--	--	--	--
ORGANOPHOSPHORUS PESTICIDES, µg/	--	--	--	--	--	--	--	--	--	--	--	--
EXPLOSIVES, µg/L:	--	--	--	--	--	--	--	--	--	--	--	NA
WET CHEMICAL INORGANICS:												
Chloride, mg/L	91.30	102.00	100.00	99.40	110.00	55.3	78.10	58.20	38.8	24.90	33.60	38.20
Nitrate, mg/L	--	--	--	--	--	--	--	--	--	--	4.00	12.50
Sulfate, mg/L	152.00	91.1	80.90	80.50	--	62.3	99.40	63.50	122.0	95.40	104.00	93.40
Sulfide, mg/L	76.60(E)	26.0(E)	13.30(E)(F)	27.40(E)	11.70(E)	26.6(E)	37.80(E)	26.30(E)	25.0(E)	39.00(E)	38.20(E)	NA
Bicarbonate, mg/L	683.00	407.00	598.00	619.00	1360.00	574.0	531.00	407.00	657.00	523.00	450.00	362.00
Total organic carbon, mg/L	5.40(M1)	6.20(M1)	3.40(M1)	3.30(M1)	10.70(M1)	3.5(M1)	4.60(M1)	4.60(M1)	--	3.60(M1)	2.80(M1)	NA
Total cyanide, µg/L	--	--	--	--	--	--	--	--	--	--	--	NA
Amenable cyanide, µg/L	--(M2)	--(M2)	--(M2)	--(M2)	--(M2)	--(M2)	--(M2)	--(M2)	--(M2)	--(M2)	--(M2)	NA

B1 – Sample results are less than 5 times the amount detected in the method blank. Result is estimated.
B2 – Sample results are less than 10 times the amount detected in the method blank. Result is estimated.
E – MS/MSD RPD exceeds control limit. Estimated result due to poor precision.
F – Field duplicate RPD exceeds control limit. Estimated due to poor precision.
M1 – Matrix spike recovery is high due to sample matrix effect. Sample result is biased high.
M2 – Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.
T – Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.
NA – Not analyzed
-- Not detected

4.2.2.2.1 Volatile Organics - The only organic compounds detected during the baseline sampling at SFL were volatile organic compounds (VOCs). Methylene chloride was detected in 13 of the samples at concentrations ranging from 6.8 to 28 μg/L and was detected in samples from both upgradient and downgradient locations. However, 12 of the 13 samples were associated with method blanks and/or trip blanks contaminated with methylene chloride. Therefore, only one of the 13 methylene chloride detections is considered to be possibly site-related. Two of the three method blanks associated with the groundwater samples contained methylene chloride at concentrations of 11 and 16 μg/L indicating that the methylene chloride in the samples associated with these blanks was a result of laboratory contamination. No other organic compounds were detected at clusters 1, 2, 3, 4, or 7. The highest concentrations of VOCs exist in the 5 and 8 well clusters. Figure 4-6 provides well locations with corresponding positive organic analytical results.

Several VOCs were detected in monitoring well SFL92-501, including:

- 1,1,1,2-tetrachloroethane
- 1,2,3-trichloropropane
- 1,2-dibromoethane
- Ethyl methacrylate
- Methacrylonitrile
- Methyl chloride
- Methylene bromide
- Pentachloroethane
- Trichlorofluoromethane
- Vinyl chloride
- Xylenes
- Trans-1,2-dichloroethene
- Trans-1,4-dichloro-2-butene

Trans-1,2-dichloroethene was also detected in SFL92-502. In SFL92-503, the same compounds were detected as in SFL92-501 with the addition of 1,1,2,2-tetrachloroethane and the exceptions of vinyl chloride and trans-1,2-dichloroethene. This indicates that the vertical extent of volatile contamination is throughout the uppermost aquifer at this particular location.

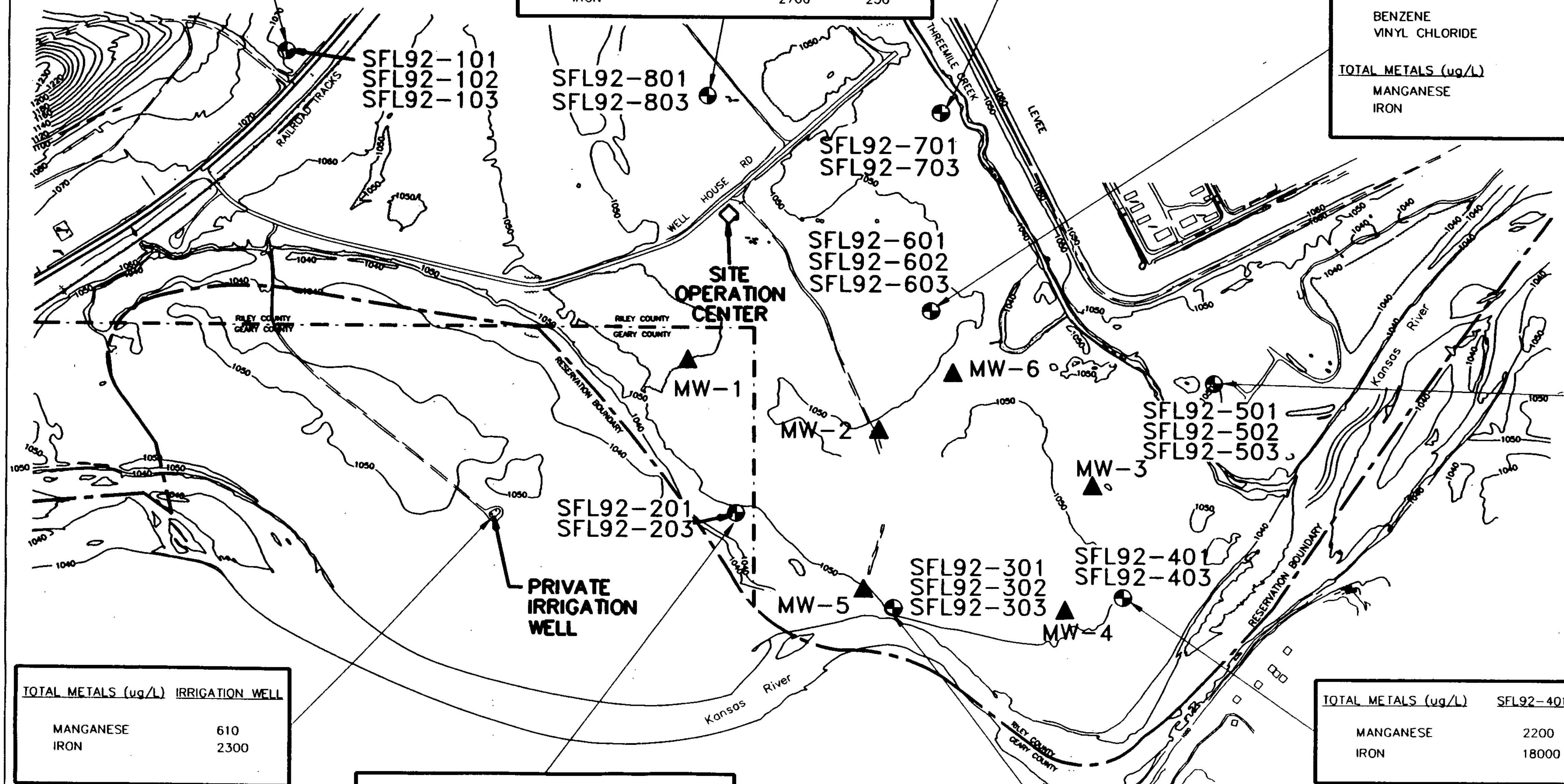
Several VOCs were detected in the groundwater from monitoring well SFL92-801, including:

- 1,1,2,2-tetrachloroethane
- 1,1,2-trichloroethane
- 1,2-dichloropropane
- 2-hexanone
- Benzene
- Bromoform
- Chlorodibromomethane

FIGURE 4-6

GROUND-WATER ANALYTICAL RESULTS*
BASELINE (JULY 1992) INVESTIGATION
SOUTHWEST FUNSTON LANDFILL

FORT RILEY, KANSAS



VOLATILE ORGANICS (ug/L)	SFL92-101	SFL92-102	SFL92-103
METHYLENE CHLORIDE	21 (T)	18 (T)	16 (T)
TOTAL METALS (ug/L)			
ALUMINUM	ND	460	120
IRON	1700	550	110
MANGANESE	1000	320	290

VOLATILE ORGANICS (ug/L)	SFL92-801	SFL92-803
1,1,2,2 TETRACHLOROETHANE	15	12
1,1,2 TRICHLOROETHANE	8.8	--
1,2 DICHLOROPROPANE	4.1	3.6
2-HEXANONE	22	18
BENZENE	2.4	--
BROMOFORM	8.0	6.4
CHLORODIBROMOMETHANE	5.2	--
METHYLENE CHLORIDE	8.4 (T)	12 (T)
METHYL ISOBUTYL KETONE	22	19
STYRENE	3.1	--
XYLENES	--	6.3
CIS-1,3-DICHLOROPROPENE	5.9	5.4
TOTAL METALS (ug/L)		
MANGANESE	430	1200
IRON	2700	230

VOLATILE ORGANICS (ug/L)	SFL92-701	SFL92-703
METHYLENE CHLORIDE	6.3	ND
TOTAL METALS (ug/L)		
MANGANESE	560	960
IRON	3100	2700

NOTE

*THIS INCLUDES ALL POSITIVE ORGANIC RESULTS AND METALS RESULTS WHICH EXCEED FEDERAL MCLS.

VOLATILE ORGANICS (ug/L)	SFL92-601	SFL92-602	SFL92-603
BENZENE	8.9	ND	ND
VINYL CHLORIDE	18	ND	ND
TOTAL METALS (ug/L)			
MANGANESE	2500	1700	1500
IRON	35000	20000	5800

VOLATILE ORGANICS (ug/L)	SFL92-501	SFL92-502	SFL92-503
1,1,1,2 TETRACHLOROETHANE	5.2	ND	6.0
1,1,2,2 TETRACHLOROETHANE	ND	ND	6.3
1,2,3 TRICHLOROPROPANE	30	ND	34
1,2 DIBROMOETHANE	21	ND	24
ETHYL METHACRYLATE	22	ND	24
METHACRYLONITRILE	29	ND	30
METHYL CHLORIDE	11	ND	11
METHYLENE BROMIDE	19	ND	22
METHYLENE CHLORIDE	ND	6.2 (T)	ND
PENTACHLOROETHANE	12	ND	13
TRICHLOROFLUOROMETHANE	5.2	ND	5.2
VINYL CHLORIDE	14	ND	ND
XYLENES	8.4	ND	9.1
TRANS-1,2-DICHLOROETHENE	8.7	7.9	ND
TRANS-1,4-DICHLORO-2-BUTENE	18	ND	20
TOTAL METALS (ug/L)			
MANGANESE	1900	NA	1800
IRON	12000	NA	10000

TOTAL METALS (ug/L)	IRRIGATION WELL
MANGANESE	610
IRON	2300

TOTAL METALS (ug/L)	SFL92-201	SFL92-203
MANGANESE	1600	1500
IRON	17000	4400

TOTAL METALS (ug/L)	SFL92-301	SFL92-302	SFL92-303
MANGANESE	410	440	1100
IRON	2200	2700	3000

TOTAL METALS (ug/L)	SFL92-401	SFL92-403
MANGANESE	2200	2400
IRON	18000	17000

0 800 1600

APPROXIMATE SCALE IN FEET

LEGEND

- ⊕ CLUSTERED WELL LOCATION
- ▲ EXISTING CLOSURE WELLS
- —1050— CONTOUR INTERVAL (10 ft)
- +++++ RAILROAD TRACKS
- NA – NOT ANALYSED
- ND – NOT DETECTED
- T – SAMPLE RESULTS ARE LESS THAN 10 TIMES AMOUNT IN TRIP BLANK.

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- Methylene chloride
- Methyl isobutyl ketone
- Styrene
- Cis-1,3-dichloropropene

The same constituents were detected in the deeper well SFL92-803 with the addition of xylenes and the exceptions of 1,1,2-trichloroethane, benzene, chlorodibromomethane, and styrene. This indicates that the vertical extent of volatile organic contamination ranges from the upper to the lower portions of the water column.

Low levels (<20 μg/L) of VOCs were detected in the groundwater collected from monitoring well SFL92-601. Compounds detected include benzene and vinyl chloride. No positive results were detected in the intermediate or deep wells indicating that groundwater contamination is limited to the upper portion of the aquifer at this location. In addition, groundwater from well SFL92-701 contained low levels of methylene chloride (not associated with a contaminated method blank).

4.2.2.2.2 Inorganics - Many metals are naturally occurring in groundwater. To evaluate the impact of the SFL to the groundwater a comparison must be made between metal concentrations upgradient and downgradient of the site. Small variances (less than 25 percent) in concentrations may be the result of the analytical uncertainty inherent in the analytical methodology; therefore, these will not be discussed. The analytical uncertainty value is derived from the accuracy data quality objective and control limits established for this project.

Arsenic, selenium, aluminum, barium, beryllium, calcium, iron, magnesium, manganese, potassium, sodium, zinc, and mercury were detected in the groundwater samples collected at the SFL. Table 4-5 presents the metals results exceeding background concentrations as detected in wells SFL92-101, SFL92-102, and SFL92-103. Metal concentrations found in the background wells did not significantly (greater than 25 percent) vary between the baseline sampling event and the subsequent quarterly sampling. This indicates that these wells are suitable to establish background levels of metals. As shown in Table 4-5, total concentrations of arsenic, barium, beryllium, calcium, cobalt, iron, magnesium, manganese, potassium, and sodium in groundwater samples exceeded the background concentrations at the SFL.

Cadmium and mercury were detected once in dissolved aliquots but not in the corresponding total analysis of samples SFL92-503 and SFL92-201, respectively. Each sample had a field-associated duplicate which did not yield positive cadmium or mercury results. In addition, corresponding sample concentrations for cadmium and mercury from the quarterly sampling events yielded non-detects. Therefore, the dissolved results were rejected due to inconsistent sample results.

TABLE 4-5

METALS RESULTS EXCEEDING BACKGROUND CONCENTRATIONS
BASELINE (JULY 1992) GROUND-WATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

METAL	MAXIMUM BACKGROUND CONC'N*	SAMPLES EXCEEDING MAXIMUM BACKGROUND CONCENTRATIONS		MCL
Total Arsenic, µg/L	7.1	SFL92-203	19 µg/L	50
		SFL92-302	25 µg/L	
		SFL92-303	24 µg/L	
		SFL92-502	14 µg/L	
		SFL92-503	24 µg/L	
		SFL92-602	16 µg/L	
		SFL92-603	18 µg/L	
		SFL92-703	12 µg/L	
		SFL92-801	14 µg/L	
Total Selenium, µg/L	2.1	none		50
Total Aluminum, µg/L	460	none		200 (s)
Total Barium, µg/L	350	SFL92-401	1000 µg/L	2000
		SFL92-403	830 µg/L	
		SFL92-601	2000 µg/L	
		SFL92-602	650 µg/L	
Total Beryllium, µg/L	1.8	SFL92-601	3.2 µg/L	4.0
Total Calcium, µg/L	160000	SFL92-403	210000 µg/L	NA
		SFL92-501	210000 µg/L	
		SFL92-601	330000 µg/L	
Total Cobalt, µg/L	ND	SFL92-603	10 µg/L	NA
Total Iron, µg/L	1700	SFL92-201	17000 µg/L	300 (s)
		SFL92-203	140000 µg/L	
		SFL92-301	2200 µg/L	
		SFL92-302	2700 µg/L	
		SFL92-303	3000 µg/L	
		SFL92-401	18000 µg/L	
		SFL92-403	17000 µg/L	
		SFL92-501	12000 µg/L	
		SFL92-503	10000 µg/L	
		SFL92-601	35000 µg/L	
		SFL92-602	20000 µg/L	
		SFL92-603	5800 µg/L	
		SFL92-701	3100 µg/L	
		SFL92-801	2700 µg/L	
		IRRWELL	2300 µg/L	
Total Magnesium, µg/L	26000	SFL92-401	36000 µg/L	NA
		SFL92-403	37000 µg/L	
		SFL92-601	68000 µg/L	

TABLE 4-5

METALS RESULTS EXCEEDING BACKGROUND CONCENTRATIONS BASELINE (JULY 1992) GROUND-WATER SAMPLES

Southwest Funston Landfill
Fort Riley, Kansas

METAL	MAXIMUM BACKGROUND CONC'N*	SAMPLES EXCEEDING MAXIMUM BACKGROUND CONCENTRATIONS		MCL
Total Manganese, µg/L	1000	SFL92-201	1600 µg/L	50 (s)
		SFL92-203	1500 µg/L	
		SFL92-401	2200 µg/L	
		SFL92-403	2400 µg/L	
		SFL92-501	1900 µg/L	
		SFL92-503	1800 µg/L	
		SFL92-601	2500 µg/L	
		SFL92-602	1700 µg/L	
		SFL92-603	1500 µg/L	
Total Potassium, µg/L	8000	SFL92-401	11000 µg/L	NA
		SFL92-601	15000 µg/L	
		SFL92-602	12000 µg/L	
Total Sodium, µg/L	21000	SFL92-201	44000 µg/L	NA
		SFL92-203	140000 µg/L	
		SFL92-301	58000 µg/L	
		SFL92-302	85000 µg/L	
		SFL92-303	110000 µg/L	
		SFL92-401	100000 µg/L	
		SFL92-403	100000 µg/L	
		SFL92-501	69000 µg/L	
		SFL92-503	75000 µg/L	
		SFL92-601	63000 µg/L	
		SFL92-602	46000 µg/L	
		SFL92-603	73000 µg/L	
		SFL92-701	63000 µg/L	
		SFL92-703	43000 µg/L	
		SFL92-801	28000 µg/L	
		SFL92-803	39000 µg/L	
		IRRWELL	140000 µg/L	
Total Zinc, µg/L	18	none		5000 (s)

ND - not detected
NA - not available
MCL - Maximum Contaminant Level
(s) - secondary MCL
* Background concentrations were obtained from SFL92-101, SFL92-102 and SFL92-103.

Sources:
Federal Register, Volume 56, No. 20, January 30, 1991
40 CFR, Section 141.11 (July 1, 1987 Edition)
40 CFR, Section 141.62 (January 31, 1991 Edition)
40 CFR, Volume 56, No. 126, July 1, 1991

Concentrations of all metals except manganese, iron, and aluminum were below the federal MCLs and the Kansas Action Levels. The concentrations of manganese, iron, and aluminum detected at the site in both upgradient and downgradient samples exceeded secondary MCLs which are used to define the aesthetic quality of drinking water and KALs. A further discussion of both federal and state MCLs is provided in Section 6.1.3 of this report.

To further assess the metals results, a comparison between concentrations of metals detected at the SFL and metals from the Fort Riley and Ogden drinking water wells was performed. Direct comparison is not appropriate since drinking water wells are screened over several intervals, and the method of sampling differs. However, the concentrations of metals in the drinking water wells can provide an indication of background metal levels. Table 4-6 provides the range of metals concentrations which were obtained from drinking water wells installed in the alluvial aquifer at the Main Cantonment Area and the Ogden well field. With the exception of iron, aluminum, and manganese, metals concentrations in the Fort Riley and Ogden drinking water wells and the SFL background wells were similar. The comparison in Table 4-6 shows elevated concentrations of arsenic, iron, manganese, potassium, and sodium in many of the monitoring wells installed at the SFL relative to the Fort Riley and Ogden drinking water wells. Aluminum, barium, calcium, cobalt, and magnesium had isolated positive results above Fort Riley and Ogden drinking water wells.

Several other parameters were tested for including chloride, nitrate, sulfate, sulfide, bicarbonate, total organic carbon, and total and amenable cyanide. Sulfide and cyanide were analyzed to encompass the RCRA Appendix IX analyte list. Chloride, nitrate, sulfate, and bicarbonate are standard water quality parameters. Nitrate, sulfate, and chloride have drinking water criteria for groundwater which may potentially be used as a drinking water source. In addition, results of water quality are utilized in the design of treatment facilities. There were positive results for all these parameters, except total and amenable cyanide. The results of these analyses are discussed in the same manner as the metals results because these constituents, except cyanide, can be naturally occurring.

Chloride results were higher than background concentrations in all downgradient wells. Nitrate was detected in the irrigation well at higher concentrations than background, possibly due to the application of fertilizers. Sulfate was detected at concentrations higher than background in SFL92-203, SFL92-303, SFL92-501, SFL92-603, SFL92-801, and SFL92-803. Sulfide exceeded background concentrations in samples SFL92-201, SFL92-301, SFL92-302, SFL92-303, SFL92-501, SFL92-603, SFL92-801, and SFL92-803. In addition, bicarbonate exceeded background concentrations in samples from monitoring wells SFL92-401, SFL92-403, and SFL92-601. Total organic carbon values were elevated in samples from monitoring wells SFL92-401, SFL92-403, SFL92-501, SFL92-502, SFL92-601, SFL92-603, and SFL92-701. The only federal MCL exceeded was the nitrate result from the private irrigation well.

TABLE 4–6

COMPARISON OF BASELINE TOTAL METALS RESULTS TO WATER SUPPLY WELLS
Southwest Funston Landfill
Fort Riley, Kansas

TOTAL METAL, μg/L	FORT RILEY DRINKING WELL(a)	OGDEN WATER WELLS(b)	SOUTHWEST FUNSTON LANDFILL MONITORNG WELLS								IRRIGATION WELL
			CLUSTER 1	CLUSTER 2	CLUSTER 3	CLUSTER 4	CLUSTER 5	CLUSTER 6	CLUSTER 7	CLUSTER 8	
Arsenic	2.0–3.0	1–10	2.0–7.1	19	2.6–25	2.6	14–24	3.9–18	4.5–12	14	8.3
Aluminum	60–70	ND	120–480	110	210–110	ND	ND	110	150	170	ND
Barium	181–321	80–170	220–350	220–290	68–160	830–1000	220–310	300–2000	220–260	120–260	160
Calcium	85600–87300	14700–197000	120000–160000	140000–170000	44000–110000	200000–210000	160000–210000	140000–330000	91000–120000	120000–150000	67000
Cobalt	4.0	ND	ND	ND	ND	ND	ND	10	ND	ND	ND
Iron	32–114	14–380	110–1700	4400–17000	2200–3000	17000–18000	10000–12000	5800–35000	1800–3100	230–2700	2300
Magnesium	19800–20800	21600–37000	23000–26000	25000–27000	6800–19000	36000–37000	32000–310000	24000–68000	18000–24000	22000–30000	9800
Manganese	51–197	7–250	290–1000	1500–1600	410–1100	2200–2400	1800–1900	1500–2500	580–960	430–1200	610
Potassium	600–9140	3420–7200	330–8000	8000–8800	5300–9500	9900–11000	9400–10000	10000–15000	6700–10000	4800–9400	6500
Sodium	35700–36600	20000–66900	12000–21000	44000–140000	58000–110000	100000	69000–75000	48000–73000	43000–63000	28000–39000	140000
Zinc	11–266	4–59	14–18(B1)	7.8–14(B1)	8.9–18(B1)	11(B1)	12–17(B1)	8.6–20(B1)	6.8–18(B1)	14–19(B1)	13(B1)

ND – Not Detected

(B1) – Sample results are less than 5 times the amount detected in method blank. Result is estimated.

(a) – Concentration ranges from Fort Riley drinking water wells installed in the alluvium in the Main Cantonment Area.

(b) – Concentration ranges from Ogden water wells installed in the alluvium.

Sources:
DOD, 1987a
DOD, 1987b
KHEL, 1991a
KHEL, 1991b

4.2.2.3 First Quarter (November 1992) Groundwater Analysis Results - Organic and inorganic constituents were both detected in the groundwater samples collected during the first quarter sampling event of the SFL during the RI. Table 4-7 presents positive analytical results of the first quarter groundwater analyses. The upgradient wells (SFL92-101, SFL92-102 and SFL92-103) did not contain detectable concentrations of organic compounds. The analytes which were detected in the background wells include naturally occurring metals and inorganics. These values were compared to concentrations of the analytes in the downgradient monitoring wells to differentiate between levels of metals and other inorganics.

During the first quarterly sampling event, groundwater flow directions are expected to be similar to the October 1, 1993 water table map (Figure 3-15) based on similar peak river stage conditions between October 1 and November 4 (Table 3-5), i.e., groundwater flow towards Threemile Creek and the Kansas River. Additional discussion of the direction of groundwater flow during this sampling event is presented in Section 3.6.2.2.2.

4.2.2.3.1 Organic Compounds - The only organic compounds detected during the first quarter sampling at SFL were petroleum hydrocarbons detected through analysis of total recoverable petroleum hydrocarbons (TRPH) and VOCs. Detectable concentrations of TRPH above background levels were present only in sample SFL92-302. Methylene chloride was detected in 15 of the samples at concentrations ranging from 6.4 to 32 μg/L in the downgradient wells. Both method blanks associated with the groundwater samples contained methylene chloride at concentrations of 8.2 μg/L and 22 μg/L indicating that the methylene chloride detected was a result of laboratory contamination. Other organic compounds detected included 1,2-dichloroethane in wells SFL92-501, SFL92-502, and SFL92-601 and benzene in wells SFL92-601 and SFL92-602. Figure 4-7 provides well locations with corresponding positive organic analytical results.

4.2.2.3.2 Inorganics - Many metals are naturally occurring in groundwater. In order to evaluate the impact of the SFL to the groundwater, a comparison must be made between metal concentrations upgradient and downgradient of the site. Table 4-8 presents the metals results exceeding background concentrations at the SFL. Total concentrations of arsenic, aluminum, antimony, barium, beryllium, calcium, cadmium, iron, magnesium, nickel, manganese, potassium, sodium and vanadium were detected at concentrations greater than background in the groundwater samples collected at the SFL.

Chromium was detected once in dissolved aliquots above the background level in well SFL92-501 at 20 μg/L, but not detected in the corresponding total metal analysis. Corresponding sample concentrations for chromium from the baseline, second and third quarterly sampling events yielded non-detects. Therefore, the dissolved results were rejected due to inconsistent sample results.

TABLE 4-7

POSITIVE RESULTS FOR FIRST QUARTER (NOV 1992) GROUNDWATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER		SFL92101	SFL92102	SFL92103	SFL92201	SFL92203	SFL92301	SFL92302	SFL92303
	Date Collected	11-02-92	11-02-92	11-03-92	11-03-92	11-03-92	11-03-92	11-03-92	11-03-92
VOLATILE ORGANICS (µg/L):									
1,2-Dichloroethane		--	--	--	--	--	--	--	--
Benzene		--	--	--	--	--	--	--	--
Methylene chloride		--	--	--	7.2 (B2)	6.4 (B2)	7.0 (B2)	6.9 (B2)	--
DISSOLVED FURNACE METALS (µg/L):									
Arsenic		8.1	3.4	--	--	16	--	22	22
Lead		1.2	1.2	--	--	--	--	--	--
Selenium		--	--	1.3	--	--	1.0	--	--
DISSOLVED ICP METALS (µg/L):									
Aluminum		--	--	--	--	--	--	--	130
Antimony		--	--	--	--	--	--	--	--
Barium		390	--	280	380	210	200	240	190
Beryllium		3.0	2.0	1.0	3.0	1.0	2.0	1.0	1.0
Calcium		170000	140000	120000	220000	140000	190000	110000	130000
Chromium		13	--	--	--	--	--	--	10
Iron		580	--	--	18000	5300	100	7400	3300
Magnesium		24000	23000	24000	35000	24000	28000	17000	22000
Manganese		890	230	220	1900	1500	660	1200	1300
Nickel		--	--	--	--	--	--	--	--
Potassium		8300	5400	3500	11000	7900	18000	8200	7400
Sodium		9900	15000	23000	50000	140000	58000	84000	100000
Vanadium		--	--	--	--	--	--	--	--
Zinc		10 (B1)	6.0 (B1)	27 (B1)	4.0 (B1)	10 (B1)	--	12 (B1)	11 (B1)
TOTAL RECOVERABLE FURNACE METALS (µg/L):									
Arsenic		9.3	2.9	--	--	13	2.3	45	21
Lead		-- (M2)	1.1 (M2)	-- (M2)	-- (M2)	-- (M2)	-- (M2)	-- (M2)	-- (M2)
Selenium		1.1 (M2)	1.4 (M2)	1.6 (M2)	-- (M2)	-- (M2)	1.1 (M2)	-- (M2)	-- (M2)
TOTAL RECOVERABLE ICP METALS (µg/L):									
Aluminum		--	230	--	--	350	--	--	--
Antimony		--	--	--	--	--	--	--	--
Barium		370	290	290	400	230	210	230	170
Beryllium		2.0	2.0	1.0	2.0	2.0	2.0	1.0	1.0
Cadmium		--	--	--	--	--	--	--	5.0
Calcium		170000	140000	120000	220000	140000	190000	110000	130000
Iron		500	320	260	19000	5900	63	7700	3600
Magnesium		24000	24000	24000	36000	25000	30000	18000	22000
Manganese		880	250	220	2000	1500	660	1200	1300
Nickel		--	--	--	--	--	--	--	--
Potassium		8400	5700	3400	11000	8000	19000	8300	7500
Sodium		9800	15000	22000	51000	140000	59000	85000	100000
Vanadium		--	--	--	--	--	--	--	--
Zinc		31	11	15	4.0	7.0	--	--	5.0

TABLE 4-7

POSITIVE RESULTS FOR FIRST QUARTER (NOV 1992) GROUNDWATER SAMPLES

Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	SFL92101	SFL92102	SFL92103	SFL92201	SFL92203	SFL92301	SFL92302	SFL92303
Date Collected	11-02-92	11-02-92	11-03-92	11-03-92	11-03-92	11-03-92	11-03-92	11-03-92
PESTICIDES/PCBs (µg/L):	--	-- (H)	--	--	--	--	--	--
EXPLOSIVES (µg/L):	--	--	--	--	--	--	--	--
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L):	-- (E)	-- (E)	3.9 (E)	-- (E)	3.5 (E)	2.2 (E)	14 (E)	-- (E)
WET CHEMICAL INORGANICS (mg/L):								
Total Suspended Solids	2.00 (E)	1.00	2.00	37.00	30.00	3.00	15.00	11.00
Inorganic Chloride	5.20	7.40	9.60	83.40	275.00	63.50	113.00	141.00
Nitrate	--	--	2.50	--	--	2.70	--	--
Sulfate	88.30 (M2)	55.50 (M2)	24.70 (M2)	152.00 (M2)	209.00 (M2)	190.00 (M2)	132.00 (M2)	153.00 (M2)
Bicarbonate	439	398	402	532	199	453	278	284
Ammonia (N)	0.12	--	--	0.55	0.23	0.44	0.36	0.19
Total Kjeldahl Nitrogen	--	--	--	1.10	--	1.10	--	--
Total Organic Carbon	2.50	--	--	5.00	2.20	5.20	3.30	--
Hardness as CaCO3	520.00	432.00	420.00	692.00	NA	580.00	348.00	392.00
Alkalinity as CaCO3	439.00	398.00	402.00	532.00	199.00	453.00	278.00	284.00
Biochemical Oxygen Demand	1.00	1.00	1.10	1.20	--	--	--	--
Chemical Oxygen Demand	--	--	--	20.90	18.50	18.50	--	--
ORGANOPHOSPHORUS PESTICIDES (µg/L):	--	--	--	--	--	--	--	--
HERBICIDES (µg/L):								
Dalapon	-- (L)	-- (L)	-- (L)	-- (L)	-- (L)	-- (L)	-- (L)	-- (L)
SEMI-VOLATILE ORGANICS (µg/L):	--	--	--	--	--	--	--	--

L - Estimated result. Possible false negative or biased low result based on LCS recovery.
B1 - Sample results are less than 5 times the amount detected in method blank. Result is estimated.
B2 - Sample results are less than 10 times the amount detected in method blank. Result is estimated.
H - Holding time exceeded. Results are biased low.
I - Estimated result based on high internal standard recovery. Results may be biased low.
E - Estimated result.
M2 - Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.
R - Result is rejected.
NA - Not analyzed.
-- Not detected.

TABLE 4-7

POSITIVE RESULTS FOR FIRST QUARTER (NOV 1992) GROUNDWATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	SFL92401	SFL92403	SFL92501	SFL92502	SFL92503	SFL92504	SFL92601	SFL92602
Date Collected	11-04-92	11-04-92	11-03-92	11-03-92	11-03-92	11-03-92	11-05-92	11-05-92
VOLATILE ORGANICS (μg/L):								
1,2-Dichloroethane	--	--	6.8	8.1	--	--	16	--
Benzene	--	--	--	--	--	--	5.0	4.9
Methylene chloride	12 (B2)	13 (B2)	--	6.9 (B2)	--	--	7.6 (B2)	32 (B2)
DISSOLVED FURNACE METALS (μg/L):								
Arsenic	--	2.5	--	12	22	21	6.0	18
Lead	--	--	2.1	--	--	--	--	--
Selenium	--	--	--	--	--	--	--	--
DISSOLVED ICP METALS (μg/L):								
Aluminum	--	--	--	--	--	--	--	--
Antimony	--	--	--	--	--	--	--	--
Barium	930	720	220	320	290	310	1700	900
Beryllium	2.0	2.0	2.0	2.0	2.0	2.0	3.0	2.0
Calcium	200000	200000	210000	190000	160000	170000	310000	210000
Chromium	--	--	20 R	--	--	--	--	--
Iron	18000	18000	11000	11000	11000	11000	28000	23000
Magnesium	36000	36000	32000	31000	31000	31000	74000	34000
Manganese	2200	2400	1800	2000	1900	1900	2100	2100
Nickel	--	--	22	--	26	21	34	--
Potassium	11000	9500	11000	8900	8900	9100	14000	12000
Sodium	99000	100000	69000	69000	73000	75000	59000	58000
Vanadium	--	--	--	--	--	--	8.0	9.0
Zinc	6.0	4.0	7.0 (B1)	--	28 (B1)	8.0 (B1)	12	7.0
TOTAL RECOVERABLE FURNACE METALS (μg/L):								
Arsenic	--	2.8	2.0	20	22	42	6.6	20
Lead	-- (M2)	-- (M2)	-- (M2)	-- (M2)	-- (M2)	-- (M2)	-- (M2)	-- (M2)
Selenium	-- (M2)	-- (M2)	1.0 (M2)	-- (M2)	-- (M2)	-- (M2)	-- (M2)	-- (M2)
TOTAL RECOVERABLE ICP METALS (μg/L):								
Aluminum	--	--	--	--	--	--	--	--
Antimony	--	--	--	--	--	--	--	--
Barium	930	700	240	340	310	300	1700	940
Beryllium	2.0	3.0	2.0	2.0	2.0	2.0	4.0	2.0
Cadmium	--	--	--	--	--	--	--	--
Calcium	190000	200000	220000	200000	170000	170000	330000	210000
Iron	18000	18000	11000	11000	12000	12000	28000	24000
Magnesium	36000	35000	33000	32000	32000	32000	77000	36000
Manganese	2100	2400	1900	2100	1900	1900	2100	2100
Nickel	21	--	18	--	--	--	29	20
Potassium	11000	9300	11000	9400	9100	9100	14000	12000
Sodium	100000	100000	71000	72000	76000	76000	61000	61000
Vanadium	--	--	--	--	--	--	9.0	--
Zinc	4.0	--	4.0	--	6.0	4.0	13	12

TABLE 4-7

POSITIVE RESULTS FOR FIRST QUARTER (NOV 1992) GROUNDWATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	SFL.92401	SFL.92403	SFL.92501	SFL.92502	SFL.92503	SFL.92504	SFL.92601	SFL.92602
Date Collected	11-04-92	11-04-92	11-03-92	11-03-92	11-03-92	11-03-92	11-05-92	11-05-92
PESTICIDES/PCBs (µg/L):	--	--	--	--	--	--	--	--
EXPLOSIVES (µg/L):	--	--	--	--	--	--	-- (H)	-- (H)
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L):	-- (E)	-- (E)	2.3 (E)	3.1 (E)	-- (E)	2.0 (E)	-- (E)	-- (E)
WET CHEMICAL INORGANICS (mg/L):								
Total Suspended Solids	40.00	36.00	26.00	24.00	25.00	28.00	60.00	60.00
Inorganic Chloride	149.00	150.00	90.90	100.00	110.00	107.00	144.00	87.90
Nitrate	--	--	--	--	--	--	--	--
Sulfate	89.90 (M2)	97.00 (M2)	168.00 (M2)	144.00 (M2)	85.50 (M2)	83.90 (M2)	11.60 (M2)	48.00 (M2)
Bicarbonate	NA	NA	530	508	467	465	NA	NA
Ammonia (N)	1.52	0.39	0.43	0.30	0.26	0.28	0.25	0.44
Total Kjeldahl Nitrogen	2.50	1.10	--	--	--	1.10 (E)	--	--
Total Organic Carbon	8.50	6.70	4.20	3.60	3.60	3.50	13.60	7.00
Hardness as CaCO3	NA	NA	NA	608.00	520.00	540.00	1120.00	684.00
Alkalinity as CaCO3	NA	NA	530.00	508.00	467.00	465.00	1090.00	654.00
Biochemical Oxygen Demand	--	--	--	1.00	1.00	2.00	19.00	10.00
Chemical Oxygen Demand	47.30	25.70	16.10	18.50	23.30	--	54.50	23.30
ORGANOPHOSPHORUS PESTICIDES (µg/L):	--	--	--	--	--	--	--	--
HERBICIDES (µg/L):								
Dalapon	-- (L)	-- (L)	-- (L)	-- (L)	-- (L)	-- (L)	-- (L)	-- (L)
SEMI-VOLATILE ORGANICS (µg/L):	--	-- (I)	--	--	--	--	--	--

L - Estimated result. Possible false negative or biased low result based on LCS recovery.
B1 - Sample results are less than 5 times the amount detected in method blank. Result is estimated.
B2 - Sample results are less than 10 times the amount detected in method blank. Result is estimated.
H - Holding time exceeded. Results are biased low.
I - Estimated result based on high internal standard recovery. Results may be biased low.
E - Estimated result.
M2 - Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.
R - Result is rejected.
NA - Not analyzed.
-- Not detected.

TABLE 4-7

POSITIVE RESULTS FOR FIRST QUARTER (NOV 1992) GROUNDWATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	SFL92603	SFL92701	SFL92703	SFL92801	SFL92802	SFL92803
Date Collected	11-04-92	11-04-92	11-04-92	11-04-92	11-04-92	11-04-92
VOLATILE ORGANICS (µg/L):						
1,2-Dichloroethane	--	--	--	--	--	--
Benzene	--	--	--	--	--	--
Methylene chloride	10 (B2)	12 (B2)	12 (B2)	12 (B2)	13 (B2)	13 (B2)
DISSOLVED FURNACE METALS (µg/L):						
Arsenic	19	6.5	13	14	12	--
Lead	--	--	--	--	--	--
Selenium	--	1.5	--	--	--	--
DISSOLVED ICP METALS (µg/L):						
Aluminum	--	--	--	--	--	--
Antimony	--	--	--	47 (R)	--	31
Barium	270	200	200	210	210	98
Beryllium	2.0	1.0	1.0	2.0	2.0	1.0
Calcium	160000	94000	130000	160000	160000	120000
Chromium	--	--	--	--	--	--
Iron	8100	1400	2100	2700	2700	--
Magnesium	30000	19000	26000	23000	23000	30000
Manganese	1900	500	1300	440	440	1400
Nickel	--	--	--	--	--	--
Potassium	9600	7500	9800	9600	9600	4300
Sodium	80000	58000	38000	29000	29000	32000
Vanadium	--	--	--	--	--	--
Zinc	--	--	--	7.0	6.0	8.0
TOTAL RECOVERABLE FURNACE METALS (µg/L):						
Arsenic	20	6.2	14	13	14	--
Lead	-- (M2)	-- (M2)	-- (M2)	-- (M2)	-- (M2)	-- (M2)
Selenium	-- (M2)	1.5 (M2)	-- (M2)	1.4 (M2)	-- (M2)	-- (M2)
TOTAL RECOVERABLE ICP METALS (µg/L):						
Aluminum	--	--	250	--	--	--
Antimony	--	--	31	--	--	--
Barium	270	180	160	230	210	100
Beryllium	2.0	1.0	1.0	3.0	2.0	1.0
Cadmium	--	--	--	--	--	--
Calcium	150000	97000	120000	170000	160000	120000
Iron	7900	1400	2200	2700	2700	160 (B1)
Magnesium	29000	19000	23000	23000	23000	31000
Manganese	1900	500	1200	450	430	1400
Nickel	--	--	--	--	--	--
Potassium	9400	7600	8800	9800	9700	4300
Sodium	78000	58000	34000	30000	29000	33000
Vanadium	--	--	--	--	--	--
Zinc	4.0	--	11	8.0	6.0	6.0

TABLE 4-7

POSITIVE RESULTS FOR FIRST QUARTER (NOV 1992) GROUNDWATER SAMPLES

Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	SFL92603	SFL92701	SFL92703	SFL92801	SFL92802	SFL92803
Date Collected	11-04-92	11-04-92	11-04-92	11-04-92	11-04-92	11-04-92
PESTICIDES/PCBs (μg/L):	--	--	--	--	--	--
EXPLOSIVES (μg/L):	--	--	--	--	--	--
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L):	-- (E)	-- (E)	-- (E)	-- (E)	-- (E)	-- (E)
WET CHEMICAL INORGANICS (mg/L):						
Total Suspended Solids	20.00	6.00	46.00	9.00	10.00	2.00
Inorganic Chloride	123.00	51.80	41.50	5.30	26.90	29.10
Nitrate	--	--	--	--	--	2.20
Sulfate	153.00 (M2)	59.50 (M2)	153.00 (M2)	13.90 (M2)	145.00 (M2)	131.00 (M2)
Bicarbonate	NA	NA	NA	NA	NA	NA
Ammonia (N)	0.26	0.42	0.21	0.10	0.16	-- (E)
Total Kjeldahl Nitrogen	--	--	--	--	--	--
Total Organic Carbon	3.10	2.90	--	2.20	2.30	--
Hardness as CaCO3	NA	NA	NA	NA	NA	452.00
Alkalinity as CaCO3	NA	NA	NA	NA	NA	347.00
Biochemical Oxygen Demand	--	--	--	--	--	--
Chemical Oxygen Demand	20.90	11.30	--	--	13.70	--
ORGANOPHOSPHORUS PESTICIDES (μg/L):	--	--	--	--	--	--
HERBICIDES (μg/L):						
Dalapon	-- (L)	-- (L)	-- (L)	-- (L)	-- (L)	-- (L)
SEMI-VOLATILE ORGANICS (μg/L):	--	--	--	--	--	--

L - Estimated result. Possible false negative or biased low result based on LCS recovery.
B1 - Sample results are less than 5 times the amount detected in method blank. Result is estimated.
B2 - Sample results are less than 10 times the amount detected in method blank. Result is estimated.
H - Holding time exceeded. Results are biased low.
I - Estimated result based on high internal standard recovery. Results may be biased low.
E - Estimated result.
M2 - Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.
R - Result is rejected.
NA - Not analyzed.
-- Not detected.

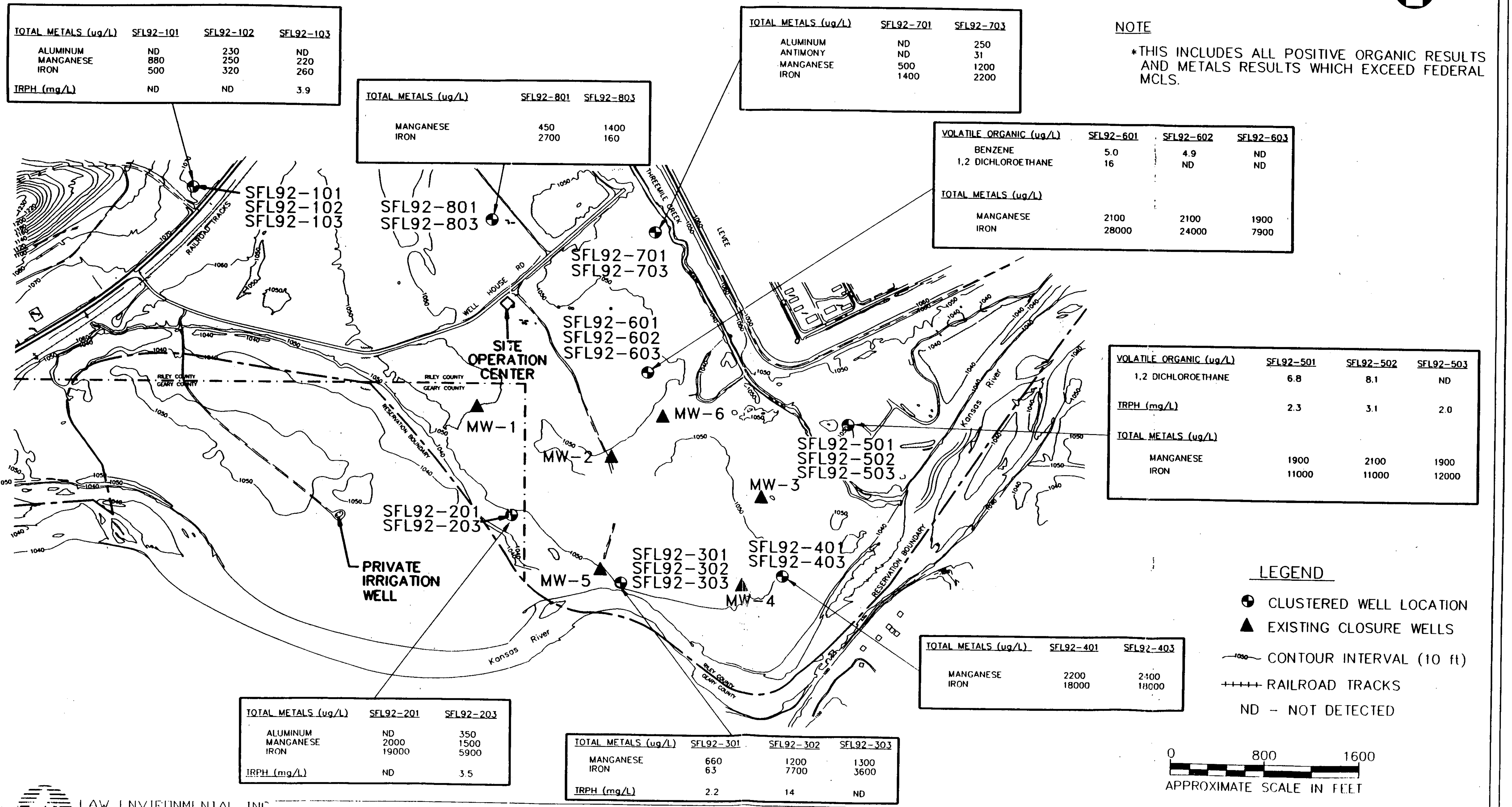
FIGURE 4-7

GROUND-WATER ANALYTICAL RESULTS*
FIRST QUARTER (NOVEMBER 1992)
SOUTHWEST FUNSTON LANDFILL

FORT RILEY, KANSAS

NOTE

*THIS INCLUDES ALL POSITIVE ORGANIC RESULTS AND METALS RESULTS WHICH EXCEED FEDERAL MCLS.



TOTAL METALS (ug/L)	SFL92-101	SFL92-102	SFL92-103
ALUMINUM	ND	230	ND
MANGANESE	880	250	220
IRON	500	320	260
TRPH (mg/L)	ND	ND	3.9

TOTAL METALS (ug/L)	SFL92-801	SFL92-803
MANGANESE	450	1400
IRON	2700	160

TOTAL METALS (ug/L)	SFL92-701	SFL92-703
ALUMINUM	ND	250
ANTIMONY	ND	31
MANGANESE	500	1200
IRON	1400	2200

VOLATILE ORGANIC (ug/L)	SFL92-601	SFL92-602	SFL92-603
BENZENE	5.0	4.9	ND
1,2 DICHLOROETHANE	16	ND	ND
TOTAL METALS (ug/L)			
MANGANESE	2100	2100	1900
IRON	28000	24000	7900

VOLATILE ORGANIC (ug/L)	SFL92-501	SFL92-502	SFL92-503
1,2 DICHLOROETHANE	6.8	8.1	ND
TRPH (mg/L)	2.3	3.1	2.0
TOTAL METALS (ug/L)			
MANGANESE	1900	2100	1900
IRON	11000	11000	12000

TOTAL METALS (ug/L)	SFL92-401	SFL92-403
MANGANESE	2200	2400
IRON	18000	18000

TOTAL METALS (ug/L)	SFL92-201	SFL92-203
ALUMINUM	ND	350
MANGANESE	2000	1500
IRON	19000	5900
TRPH (mg/L)	ND	3.5

TOTAL METALS (ug/L)	SFL92-301	SFL92-302	SFL92-303
MANGANESE	660	1200	1300
IRON	63	7700	3600
TRPH (mg/L)	2.2	14	ND

TABLE 4-8

METALS RESULTS EXCEEDING BACKGROUND CONCENTRATIONS FIRST QUARTER (NOVEMBER 1992) GROUND-WATER SAMPLES

Southwest Funston Landfill

Fort Riley, Kansas

METAL	MAXIMUM BACKGROUND CONC'N*	SAMPLES EXCEEDING MAXIMUM BACKGROUND CONCENTRATIONS		MCL
Total Arsenic, μg,L	9.3	SFL92-203	13 μg/L	50
		SFL92-302	45 μg/L	
		SFL92-303	21 μg/L	
		SFL92-502	20 μg/L	
		SFL92-503	22 μg/L	
		SFL92-602	20 μg/L	
		SFL92-603	20 μg/L	
		SFL92-703	14 μg/L	
		SFL92-801	14 μg/L	
Total Selenium, μg/L	1.6	none		50
Total Aluminum, μg/l	230	SFL92-203	350 μg/L	200 (s)
Total Antimony, μg/L	ND	SFL92-703	31 μg/L	6
Total Barium, μg/L	370	SFL92-401	930 μg/L	2000
		SFL92-403	700 μg/L	
		SFL92-601	1700 μg/L	
		SFL92-602	940 μg/L	
Total Beryllium, μg/L	2.0	SFL92-403	3 μg/L	4.0
		SFL92-601	4 μg/L	
		SFL92-801	3 μg/L	
Total Calcium, μg/L	170000	SFL92-201	220000 μg/L	NA
		SFL92-501	220000 μg/L	
		SFL92-601	330000 μg/L	
Total Cadmium, μg/L	ND	SFL92-303	5 μg/L	5
Total Iron, μg/L	500	SFL92-201	19000 μg/L	300 (s)
		SFL92-203	5900 μg/L	
		SFL92-302	7700 μg/L	
		SFL92-303	3600 μg/L	
		SFL92-401	18000 μg/L	
		SFL92-403	18000 μg/L	
		SFL92-501	11000 μg/L	
		SFL92-502	11000 μg/L	
		SFL92-503	12000 μg/L	
		SFL92-601	28000 μg/L	
		SFL92-602	24000 μg/L	
		SFL92-603	7900 μg/L	
		SFL92-701	1400 μg/L	
		SFL92-703	2200 μg/L	
		SFL92-801	2700 μg/L	

TABLE 4-8

METALS RESULTS EXCEEDING BACKGROUND CONCENTRATIONS FIRST QUARTER (NOVEMBER 1992) GROUND-WATER SAMPLES

Southwest Funston Landfill
Fort Riley, Kansas

METAL	MAXIMUM BACKGROUND CONC'N*	SAMPLES EXCEEDING MAXIMUM BACKGROUND CONCENTRATIONS		MCL
Total Magnesium, μg/L	24000	SFL92-201	36000 μg/L	NA
		SFL92-301	30000 μg/L	
		SFL92-401	36000 μg/L	
		SFL92-403	35000 μg/L	
		SFL92-501	33000 μg/L	
		SFL92-502	32000 μg/L	
		SFL92-503	32000 μg/L	
		SFL92-601	77000 μg/L	
		SFL92-602	36000 μg/L	
		SFL92-803	31000 μg/L	
Total Manganese, μg/L	880	SFL92-201	2000 μg/L	50 (s)
		SFL92-203	1500 μg/L	
		SFL92-302	1200 μg/L	
		SFL92-303	1300 μg/L	
		SFL92-401	2100 μg/L	
		SFL92-403	2400 μg/L	
		SFL92-501	1900 μg/L	
		SFL92-502	2100 μg/L	
		SFL92-503	1900 μg/L	
		SFL92-601	2100 μg/L	
		SFL92-602	2100 μg/L	
		SFL92-603	1900 μg/L	
		SFL92-703	1200 μg/L	
		SFL92-803	1400 μg/L	
Total Nickel, μg/L	ND	SFL92-401	21 μg/L	100
		SFL92-501	18 μg/L	
		SFL92-601	29 μg/L	
		SFL92-602	20 μg/L	
Total Potassium, μg/L	8400	SFL92-201	11000 μg/L	NA
		SFL92-301	19000 μg/L	
		SFL92-401	11000 μg/L	
		SFL92-501	11000 μg/L	
		SFL92-601	14000 μg/L	
		SFL92-602	12000 μg/L	

TABLE 4-8

METALS RESULTS EXCEEDING BACKGROUND CONCENTRATIONS
FIRST QUARTER (NOVEMBER 1992) GROUND-WATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

METAL	MAXIMUM BACKGROUND CONC'N*	SAMPLES EXCEEDING MAXIMUM BACKGROUND CONCENTRATIONS		MCL
Total Sodium, µg/L	22000	SFL92-201	51000 µg/L	NA
		SFL92-203	140000 µg/L	
		SFL92-301	59000 µg/L	
		SFL92-302	85000 µg/L	
		SFL92-303	100000 µg/L	
		SFL92-401	100000 µg/L	
		SFL92-403	100000 µg/L	
		SFL92-501	71000 µg/L	
		SFL92-502	72000 µg/L	
		SFL92-503	76000 µg/L	
		SFL92-601	61000 µg/L	
		SFL92-602	61000 µg/L	
		SFL92-603	78000 µg/L	
		SFL92-701	58000 µg/L	
		SFL92-703	34000 µg/L	
		SFL92-801	30000 µg/L	
		SFL92-803	33000 µg/L	
Total Vanadium, µg/L	ND	SFL92-601	9 µg/L	NA
Total Zinc, µg/L	31	None		5000 (s)

ND - not detected
NA - not available
MCL - Maximum Contaminant Level
(s) - secondary MCL
* Background concentrations were obtained from SFL92-101, SFL92-102 and SFL92-103.

Sources:
Federal Register, Volume, 56, No. 20, January 30, 1991
40 CFR, Section 141.11 (July 1, 1987 Edition)
40 CFR, Section 141.62 (January 31, 1991 Edition)
40 CFR, Volume 56, No. 126, July 1, 1991.

All metals concentrations were below MCLs except antimony, aluminum, iron, and manganese. The antimony concentration in SFL92-703 (31 μg/L) exceeded the MCL of 6 μg/L. The concentration of aluminum, iron and manganese detected at the site exceeded the secondary MCLs which are used to define the aesthetic quality of drinking water, and KALs in both the upgradient and downgradient wells.

To further assess the metals results, a comparison between concentrations of metals detected at the SFL and metals from the Fort Riley and Ogden drinking water wells was performed (Table 4-9). With the exception of aluminum, iron, and manganese, metals concentrations in the Fort Riley and Ogden drinking water wells and the SFL background wells were similar. As shown in Table 4-9, elevated levels of arsenic, barium, iron, magnesium, manganese, sodium and potassium exist in many of the monitoring wells at the SFL. Aluminum and calcium had isolated positive results above the Fort Riley and Ogden drinking water wells.

In addition to the wet chemical inorganics (chloride, nitrate, sulfate, bicarbonate, sulfide, total organic carbon and total and amenable cyanide) collected during the baseline sampling event, several parameters were added in the first quarter sampling event to assist in defining possible treatment technologies. These additional parameters included alkalinity, ammonia, biochemical oxygen demand, chemical oxygen demand, hardness, total Kjeldahl nitrogen and total suspended solids. Total suspended solids and chloride results were higher than background concentrations in all downgradient wells. Nitrate was only detected slightly above background levels at 2.7 μg/L at well SFL92-301. Samples from 13 of the 17 monitoring wells at the SFL had concentrations of sulfate above background levels. Bicarbonate exceeded background concentrations in samples SFL92-201, SFL92-301, SFL92-501, SFL92-502 and SFL92-503.

In addition, ammonia exceeded background concentrations in each of the well clusters at SFL. Concentrations of total Kjeldahl nitrogen were detected in wells SFL92-201, SFL92-301, SFL92-401, SFL92-403 and SFL92-503 but were not detected in the background samples. The concentrations of total organic carbon exceeded the background levels in samples from six of the seven monitoring well clusters at the SFL (all except well cluster 8). Hardness values were elevated in samples SFL92-201, SFL92-301, SFL92-502, SFL92-503, SFL92-601 and SFL92-602. Elevated biological oxygen demand values were found in samples SFL92-201, SFL92-503, SFL92-601 and SFL92-602. Detectable values of chemical oxygen demand were present in samples from all seven monitoring well locations at the SFL but were not detected in the background wells. Concentrations of alkalinity exceeded background levels in samples SFL92-601 and SFL92-602. Concentrations of sulfide, total cyanide and amenable cyanide were not detected in any samples collected during this sampling event.

4.2.2.4 Second Quarter (February 1993) Groundwater Analysis Results - Detectable concentrations of organic and inorganic constituents were present in the groundwater samples collected during the second quarter (February 1993) sampling event at SFL. Table 4-10 presents positive analytical results of the second quarter groundwater analyses.

TABLE 4-9

COMPARISON OF FIRST QUARTER METALS RESULTS TO WATER SUPPLY WELLS
Southwest Funston Landfill
Fort Riley, Kansas

TOTAL METAL, µg/L	FORT RILEY DRINKING WELLS(a)	OGDEN WATER WELLS(b)	SOUTHWEST FUNSTON LANDFILL MONITORNG WELLS							
			CLUSTER 1	CLUSTER 2	CLUSTER 3	CLUSTER 4	CLUSTER 5	CLUSTER 6	CLUSTER 7	CLUSTER 8
Arsenic	2.0–3.0	1–10	2.9–9.3	13	2.3–45	2.8	2.0–42	6.6–20	6.2–14	13–14
Aluminum	60–70	ND	230	350	ND	ND	ND	ND	250	ND
Barium	181–321	80–170	290–370	230–400	170–230	700–930	240–340	270–1700	160–180	100–230
Calcium	85600–87300	14700–197000	120000–170000	140000–220000	110000–190000	190000–200000	170000–220000	150000–330000	97000–120000	120000–170000
Iron	32–114	14–380	260–500	5900–19000	63–7700	18000	11000–12000	7900–28000	1400–2200	160–2700
Magnesium	19800–20800	21600–37000	24000	25000–36000	18000–30000	35000–36000	32000–33000	29000–77000	19000–23000	23000–31000
Manganese	51–197	7–250	220–880	1500–2000	660–1300	2100–2400	1900–2100	1900–2100	500–1200	430–1400
Potassium	600–9140	3420–7200	3400–8400	8000–11000	7500–19000	9300–11000	9100–11000	9400–11000	7600–8800	4300–9800
Sodium	35700–36600	20000–66900	9800–22000	51000–140000	59000–100000	100000	71000–76000	61000–78000	34000–58000	29000–33000
Zinc	11–266	4–59	11–31	4–7	5	4	4–6	4–13	11	6–8

ND – Not Detected

(Bl) – Sample results are less than 5 times the amount detected in method blank. Result is estimated.

(a) – Concentration ranges from Fort Riley drinking water wells installed in the alluvium. This includes the Main Cantonment Area.

(b) = Concentration ranges from Ogden water wells installed in the alluvium.

Sources:
DOD, 1987
DOD, 1987b
KHEL, 1991
KHEL, 1991b

TABLE 4-10

POSITIVE RESULTS FOR SECOND QUARTER (FEB 1993) GROUND-WATER SAMPLES

Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	SFL92101	SFL92102	SFL92103	SFL92201	SFL92203	SFL92301	SFL92302	SFL92303	SFL92401	SFL92403	SFL92501	SFL92502
Date Collected:	2-2-93	2-3-93	2-2-93	2-2-93	2-2-93	2-2-93	2-2-93	2-2-93	2-2-93	2-2-93	2-1-93	2-2-93
VOLATILES ORGANICS (ug/L):												
Benzene	--	--	--	--	--	--	--	--	--	--	--	--
Methylene chloride	15	--	18	13	--	--	--	11	--	10	--	13
trans-1,2-Dichloroethene	--	--	--	--	--	--	--	--	--	--	5.3	4.0
DISSOLVED METALS (ug/L):												
Arsenic	9.1	3.3	--	--	15	3.9	27	20	--	4.4	3.1	20
Selenium	--	--	1.8	--	--	--	--	--	--	--	--	--
Aluminum	--	--	--	--	--	--	--	--	430	--	--	--
Antimony	--	--	--	--	--	--	--	26	--	23	--	--
Barium	350	250	240	290	210	210	260	170	880	710	200	310
Beryllium	3.0	2.0	2.0	3.0	2.0	3.0	2.0	2.0	2.0	3.0	3.0	3.0
Calcium	160000	130000	120000	210000	140000	180000	130000	130000	180000	190000	200000	170000
Cobalt	9.0	--	--	--	--	--	--	--	--	--	--	--
Iron	630	--	100	15000	5400	2100	8800	3700	17000	17000	11000	9900
Magnesium	23000	21000	23000	33000	24000	26000	20000	23000	33000	34000	30000	30000
Manganese	790	170	120	2600	1500	1200	1300	1400	2000	2200	1800	1900
Nickel	--	--	--	11	13	--	--	--	24	--	--	--
Potassium	8100	5900	3300	10000	8300	15000	8600	7900	10000	9400	11000	8400
Silver	--	3.0	--	3.0	7.0	--	--	--	--	--	3.0	5.0
Sodium	9500	15000	22000	42000	140000	51000	90000	100000	91000	96000	61000	67000
Vanadium	--	6.0	--	--	--	--	5.0	--	--	--	--	--
Zinc	8.0 B1	5.0 B1	6.0 B1	6.0 B1	4.0 B1	4.0 B1	4.0 B1	6.0 B1	--	--	4.0 B1	15 B1
TOTAL METALS (ug/L):												
Arsenic	7.6	3.2	2.3	2.1	13	2.8	21	19	<2.0	3.0	2.2	14
Selenium	--	--	2.1	--	--	--	--	--	--	--	--	--
Aluminum	--	--	--	--	--	--	--	--	--	--	--	--
Antimony	--	--	--	--	--	--	--	--	--	--	--	--
Barium	360	240	270	320	220	190	250	180	940	730	220	330
Beryllium	3.0	1.0	2.0	3.0	2.0	3.0	2.0	2.0	3.0	3.0	2.0	2.0
Calcium	160000	130000	130000	220000	140000	190000	140000	140000	200000	200000	200000	180000
Chromium	10 B1	--	11 B1	--	--	--	--	15 B1	--	--	--	--
Cobalt	10	--	8.0	--	--	9.0	12	9.0	8.0	8.0	--	--
Copper	--	4.0	--	--	--	--	--	--	--	--	--	--
Iron	590	--	90	16000	5300	2000	9300	3800	18000	18000	11000	9800
Magnesium	24000	21000	24000	35000	23000	27000	21000	24000	36000	35000	31000	31000
Manganese	810	170	120	2700	1400	1300	1400	1400	2200	2300	1800	2000
Nickel	--	--	--	21	14	--	20	13	--	20	--	16
Potassium	8500	6600	3800	11000	8400	16000	9200	8400	11000	10000	11000	8900
Silver	5.0	--	--	8.0	3.0	4.0	--	--	3.0	4.0	3.0	--
Sodium	9800	16000	23000	44000	130000	53000	94000	110000	99000	99000	63000	70000
Vanadium	--	9.0	--	--	--	--	--	--	--	--	--	--
Zinc	6.0	4.0	5.0	5.0	4.0	5.0	4.0	4.0	--	4.0	--	--
PESTICIDE/PCBs (μg/L):	--	--	--	--	--	--	--	--	--	--	--	--
EXPLOSIVES (μg/L):	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 4-10

POSITIVE RESULTS FOR SECOND QUARTER (FEB 1993) GROUND-WATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	SFL92101	SFL92102	SFL92103	SFL92201	SFL92203	SFL92301	SFL92302	SFL92303	SFL92401	SFL92403	SFL92501	SFL92502
Date Collected:	2-2-93	2-3-93	2-2-93	2-2-93	2-2-93	2-2-93	2-2-93	2-2-93	2-2-93	2-2-93	2-1-93	2-2-93
<u>TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (</u>	--	--	--	--	--	--	--	--	--	--	--	--
<u>ORGANOPHOSPHORUS PESTICIDES (µg/L):</u>	--	--	--	--	--	--	--	--	--	--	--	--
<u>HERBICIDES (µg/L):</u>	--	--	--	--	--	--	--	--	--	--	--	--
<u>SEMI-VOLATILE ORGANICS (µg/L):</u>	--	--	--	--	--	--	--	--	--	--	--	--
<u>WET CHEMICAL INORGANICS (mg/L):</u>												
TSS	NA	NA	NA	NA	NA	NA	NA	NA	43.00	37.00	19.00	20.00
INORGANIC CHLORIDE	4.80	7.60	9.90	67.70	281.00	89.50	150.00	194.00	140.00	146.00	90.40	103.00
NITRATE	--	1.60	3.80	--	--	1.50	--	--	--	--	--	--
SULFATE	89.00	40.70	25.10	175.00	206.00	177.00	162.00	178.00	91.40	102.00	162.00	95.80
AMMONIA (N)	NA	NA	NA	NA	NA	NA	NA	NA	1.76	0.72	0.53	0.27
ORGANIC CARBON	--	--	29.40	6.20	2.20	4.50	2.60	2.00	7.20	6.10	5.00	3.30
HARDNESS as CaCO3	NA	NA	NA	NA	NA	NA	NA	NA	684.00	684.00	660.00	576.00
BICARBONATE as CaCO3	468.00	403.00	433.00	582.00	211.00	456.00	302.00	291.00	646.00	608.00	560.00	519.00
ALKALINITY as CaCO3	NA	NA	NA	NA	NA	NA	NA	NA	646.00	608.00	563.00	519.00
TOTAL CYANIDE	--	--	--	--	--	--	--	--	--	--	--	--
AMENABLE CN	--	--	--	--	--	--	--	--	--	--	--	--
NITROGEN (TKN)	NA	NA	NA	NA	NA	NA	NA	NA	3.00	1.00	1.00	--
TOTAL SULFIDE	414.00	446.00	426.00	454.00	414.00	406.00	430.00	446.00	482.00	474.00	566.00	442.00
BOD (5 DAY)	NA	NA	NA	NA	NA	NA	NA	NA	--	--	6.00	--
COD	NA	NA	NA	NA	NA	NA	NA	NA	--	--	--	--

NOTES:
NA - Not Analyzed
--- - Not Detected
B1 - Sample Results are less than 5 times the amount detected in method blank. Result is estimated.

TABLE 4-10

POSITIVE RESULTS FOR SECOND QUARTER (FEB 1993) GROUND-WATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	Sample SFL92503	Duplicate SFL92504	SFL92601	SFL92602	SFL92603	SFL92701	SFL92703	Sample SFL92801	Duplicate SFL92802	SFL92803
Date Collected:	2-1-93	2-1-93	2-2-93	2-2-93	2-2-93	2-3-93	2-3-93	2-3-93	2-3-93	2-3-93
VOLATILES ORGANICS (ug/L):										
Benzene	--	--	1.6	1.5	--	--	--	--	--	--
Methylene chloride	10	10	--	--	13	11	--	13	13	11
trans-1,2-Dichloroethene	--	--	--	--	--	--	--	--	--	--
DISSOLVED METALS (ug/L):										
Arsenic	51	51	4.4	18	22	6.5	15	14	21	--
Selenium	--	--	--	--	--	--	--	--	--	--
Aluminum	--	--	--	--	--	--	--	--	--	--
Antimony	--	--	--	--	--	32	--	--	--	--
Barium	260	270	1600	950	290	240	200	240	230	140
Beryllium	2.0	2.0	3.0	3.0	2.0	1.0	1.0	--	2.0	2.0
Calcium	150000	160000	300000	220000	160000	95000	130000	160000	170000	120000
Cobalt	--	--	--	--	--	--	--	--	--	--
Iron	11000	11000	30000	25000	8200	2900	2200	2600	2700	--
Magnesium	28000	28000	65000	36000	28000	19000	26000	23000	24000	30000
Manganese	1700	1800	2000	2200	1900	580	1300	400	420	1300
Nickel	--	--	--	--	--	--	15	--	--	11
Potassium	8500	8600	14000	13000	9300	7300	10000	10000	11000	5000
Silver	--	--	--	--	--	7.0	5.0	--	4.0	4.0
Sodium	64000	66000	64000	61000	76000	61000	37000	30000	30000	32000
Vanadium	--	--	--	--	--	--	--	--	--	--
Zinc	4.0 B1	10 B1	--	--	4.0 B1	19	9.0	6.0	6.0	6.0
TOTAL METALS (ug/L):										
Arsenic	21	22	4.2	19	16	6.2	13	17	18	--
Selenium	--	--	--	--	--	--	--	--	--	--
Aluminum	--	--	--	--	--	--	170	--	--	--
Antimony	--	--	--	--	--	--	--	--	22	23
Barium	310	280	1800	1000	320	240	200	220	240	130
Beryllium	2.0	2.0	4.0	3.0	2.0	1.0	2.0	2.0	3.0	1.0
Calcium	160000	160000	320000	230000	160000	93000	130000	170000	170000	120000
Chromium	--	--	12 B1	--	13 B1	--	--	--	--	10
Cobalt	--	--	--	--	10	--	8.0	--	--	--
Copper	--	--	--	--	--	4.0	--	--	--	15
Iron	12000	12000	32000	27000	8500	3000	2300	2700	2700	55
Magnesium	30000	29000	70000	38000	30000	18000	26000	24000	23000	28000
Manganese	1900	1800	2100	2300	2000	560	1300	410	410	1200
Nickel	--	--	13	--	16	--	--	14	--	--
Potassium	9300	9200	15000	14000	9900	7400	10000	11000	11000	5700
Silver	--	3.0	--	--	4.0	3.0	8.0	6.0	7.0	--
Sodium	70000	68000	69000	64000	80000	58000	36000	30000	30000	30000
Vanadium	--	--	--	--	--	10	--	--	--	25
Zinc	--	--	13	--	6.0	8.0	10	9.0	5.0	5.0
PESTICIDE/PCBs (µg/L):	--	--	--	--	--	--	--	--	--	--
EXPLOSIVES (µg/L):	--	--	--	--	--	--	--	--	--	--

TABLE 4-10

POSITIVE RESULTS FOR SECOND QUARTER (FEB 1993) GROUND-WATER SAMPLES

Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Date Collected:	Sample SFL92503 2-1-93	Duplicate SFL92504 2-1-93	SFL92601 2-2-93	SFL92602 2-2-93	SFL92603 2-2-93	SFL92701 2-3-93	SFL92703 2-3-93	Sample SFL92801 2-3-93	Duplicate SFL92802 2-3-93	SFL92803 2-3-93
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (	--	--	--	--	--	--	--	--	--	--
ORGANOPHOSPHORUS PESTICIDES (μg/L):	--	--	--	--	--	--	--	--	--	--
HERBICIDES (μg/L):	--	--	--	--	--	--	--	--	--	--
SEMI-VOLATILE ORGANICS (μg/L):	--	--	--	--	--	--	--	--	--	--
WET CHEMICAL INORGANICS (mg/L):										
TSS	20.00	28.00	70.00	63.00	21.00	1.00	18.00	NA	NA	NA
INORGANIC CHLORIDE	105.00	104.00	135.00	92.00	133.00	48.80	42.00	30.20	30.20	27.30
NITRATE	--	--	--	--	--	--	0.20	--	--	1.90
SULFATE	85.10	84.50	4.90	33.90	162.00	71.20	148.00	132.00	128.00	114.00
AMMONIA (N)	0.50	0.44	0.23	0.47	0.36	0.78	0.37	NA	NA	NA
ORGANIC CARBON	4.20	4.40	12.20	7.30	2.70	2.80	--	2.10	2.10	--
HARDNESS as CaCO3	530.00	530.00	1100.00	772.00	588.00	352.00	456.00	NA	NA	NA
BICARBONATE as CaCO3	502.00	502.00	1090.00	775.00	428.00	319.00	352.00	464.00	460.00	359.00
ALKALINITY as CaCO3	510.00	498.00	1090.00	775.00	428.00	319.00	352.00	NA	NA	NA
TOTAL CYANIDE	--	--	--	--	--	--	--	--	--	--
AMENABLE CN	--	--	--	--	--	--	--	--	--	--
NITROGEN (TKN)	--	1.00	1.00	1.00	--	1.00	1.00	NA	NA	NA
TOTAL SULFIDE	406.00	5020.00	445.00	429.00	418.00	418.00	430.00	518.00	414.00	94.40
BOD (5 DAY)	4.00	4.00	3.00	4.00	--	5.00	2.00	NA	NA	NA
COD	--	--	30.50	23.30	--	--	--	NA	NA	NA

NOTES:
NA – Not Analyzed
-- – Not Detected
B1 – Sample Results are less than 5 times the amount detected in n

The groundwater gradient during this sampling event was east-southeast toward the Kansas River and Threemile Creek (Figure 3-16). The direction of groundwater flow indicates that Threemile Creek is acting as a discharge area for groundwater contaminant migration. Additional discussion of the direction of groundwater flow during this sampling event is presented in Section 3.6.2.2.3.

4.2.2.4.1 Volatile Organics - The only organic compounds detected during the second quarter sampling event at SFL were VOCs. The VOCs detected included methylene chloride, benzene, and trans-1,2-dichloroethene. Methylene chloride was detected in 11 samples from background and downgradient wells in concentrations ranging from 10 to 18 μg/L. The method blanks and trip blanks associated with all volatile organic samples were free of contaminants; therefore, the presence of methylene chloride in these samples cannot be attributed to laboratory contamination or contamination during sample handling. Methylene chloride was detected in all monitoring well locations, including the background wells SFL92-101 and SFL92-103. Concentrations of benzene were detected in samples SFL92-601 and SFL92-602 at 1.6 μg/L and 1.5 μg/L, respectively. Since these samples represent the shallow and intermediate wells at this location, the vertical extent of benzene is confined to the upper portion of the saturated zone. Concentrations of trans-1,2-dichloroethene were detected in samples SFL92-501 and SFL92-502 at 5.3 μg/L and 4.0 μg/L, respectively. Because these samples represent the shallow and intermediate wells at this location, the vertical extent of trans-1,2-dichloroethene seems to be limited to the upper portion of the saturated zone. Figure 4-8 provides well locations with corresponding positive organic analytical results.

4.2.2.4.2 Inorganics - Arsenic, selenium, aluminum, antimony, barium, beryllium, calcium, chromium, cobalt, copper, iron, magnesium, nickel, potassium, silver, sodium, vanadium, and zinc were detected in the groundwater samples collected at the SFL. Table 4-11 presents the metals results exceeding background concentrations at SFL. Concentrations of all metals except antimony, iron, and manganese were below all federal MCLs. The antimony concentrations in SFL92-803 (23 μg/L) exceeded the MCL of 6 μg/L. Iron and manganese concentrations detected at the site exceeded the secondary MCLs, which are used to define the aesthetic quality of drinking water, and the KALs in both the upgradient and downgradient wells.

A comparison between concentrations of metals detected during this sampling event and metals detected in samples collected from the Fort Riley and City of Ogden drinking water wells shows elevated concentrations of arsenic, iron, manganese and potassium in many of the monitoring wells at the SFL. Aluminum, barium, calcium, cobalt, manganese and sodium had isolated positive results above the concentrations found in these drinking water wells. This comparison of data is presented in Table 4-12.

FIGURE 4-8

GROUND-WATER ANALYTICAL RESULTS*
SECOND QUARTER (FEBRUARY 1993)
SOUTHWEST FUNSTON LANDFILL

FORT RILEY, KANSAS

VOLATILE ORGANICS (ug/L)	SFL92-101	SFL92-102	SFL92-103
METHYLENE CHLORIDE	15	ND	18
TOTAL METALS (ug/L)			
MANGANESE	810	170	120
IRON	590	ND	90

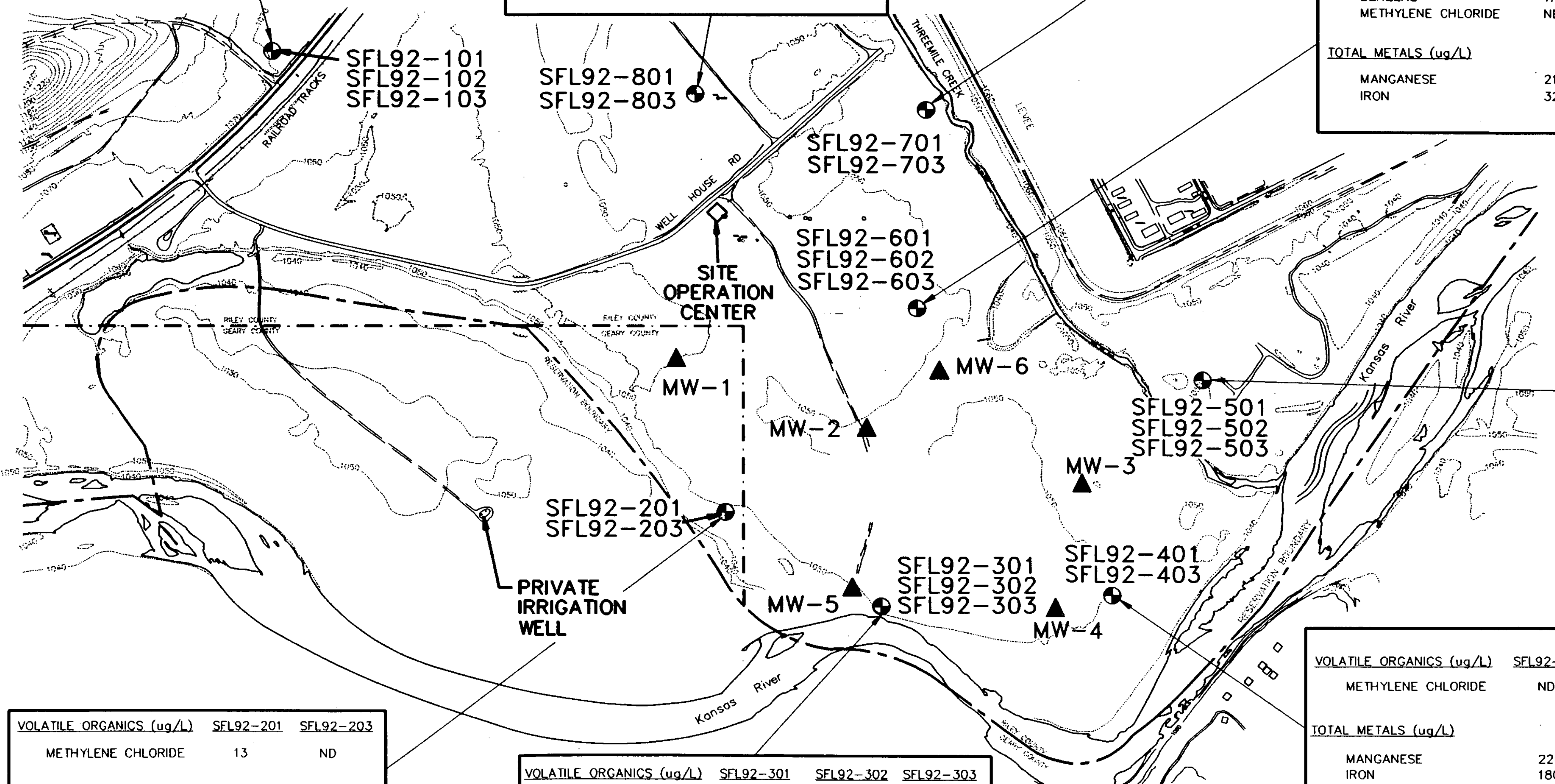
VOLATILE ORGANICS (ug/L)	SFL92-801	SFL92-803
METHYLENE CHLORIDE	13	11
TOTAL METALS (ug/L)		
ANTIMONY	ND	23
MANGANESE	410	1200
IRON	2700	55

VOLATILE ORGANICS (ug/L)	SFL92-701	SFL92-703
METHYLENE CHLORIDE	11	ND
TOTAL METALS (ug/L)		
MANGANESE	560	1300
IRON	3000	2300

NOTE

*THIS INCLUDES ALL POSITIVE ORGANIC RESULTS AND METALS RESULTS WHICH EXCEED FEDERAL MCLS.

VOLATILE ORGANICS (ug/L)	SFL92-601	SFL92-602	SFL92-603
BENZENE	1.6	1.5	ND
METHYLENE CHLORIDE	ND	ND	13
TOTAL METALS (ug/L)			
MANGANESE	2100	2300	2000
IRON	32000	27000	8500



VOLATILE ORGANICS (ug/L)	SFL92-501	SFL92-502	SFL92-503
METHLENE CHLORIDE	ND	13	10
TRANS-1,2-DICHLOROETHENE	5.3	4.0	ND
TOTAL METALS (ug/L)			
MANGANESE	1800	2000	1900
IRON	11000	9800	12000

VOLATILE ORGANICS (ug/L)	SFL92-201	SFL92-203
METHYLENE CHLORIDE	13	ND
TOTAL METALS (ug/L)		
MANGANESE	2700	1400
IRON	16000	5300

VOLATILE ORGANICS (ug/L)	SFL92-301	SFL92-302	SFL92-303
METHYLENE CHLORIDE	ND	ND	11
TOTAL METALS (ug/L)			
MANGANESE	1200	1300	1400
IRON	2000	9300	3800

VOLATILE ORGANICS (ug/L)	SFL92-401	SFL92-403
METHYLENE CHLORIDE	ND	10
TOTAL METALS (ug/L)		
MANGANESE	2200	2300
IRON	18000	18000

LEGEND

- ⊕ CLUSTERED WELL LOCATION
- ▲ EXISTING CLOSURE WELLS
- 1050 CONTOUR INTERVAL (10 ft)
- ++++++ RAILROAD TRACKS
- ND - NOT DETECTED

0 800 1600

APPROXIMATE SCALE IN FEET

LAW ENVIRONMENTAL INC.
GOVERNMENT SERVICES DIVISION

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TABLE 4-11

METALS RESULTS EXCEEDING BACKGROUND CONCENTRATIONS SECOND QUARTER (FEBRUARY 1993) GROUND-WATER SAMPLES

Southwest Funston Landfill
Fort Riley, Kansas

METAL	MAXIMUM BACKGROUND CONC'N*	SAMPLES EXCEEDING MAXIMUM BACKGROUND CONCENTRATIONS		MCL
Total Antimony	ND	SFL92-303	23 μg/L	6
Total Arsenic, μg,L	7.6	SFL92-203	13 μg/L	50
		SFL92-302	21 μg/L	
		SFL92-303	19 μg/L	
		SFL92-502	14 μg/L	
		SFL92-503	21 μg/L	
		SFL92-602	19 μg/L	
		SFL92-603	16 μg/L	
		SFL92-703	13 μg/L	
		SFL92-801	17 μg/L	
Total Selenium, μg/L	2.1	none		50
Total Aluminum, μg/l	ND	SFL92-703	170 μg/L	200 (s)
Total Barium, μg/L	360	SFL92-401	940 μg/L	2000
		SFL92-403	730 μg/L	
		SFL92-601	1800 μg/L	
		SFL92-602	1000 μg/L	
Total Beryllium, μg/L	3.0	SFL92-601	4 μg/L	4.0
Total Calcium, μg/L	160000	SFL92-201	220000 μg/L	NA
		SFL92-403	200000 μg/L	
		SFL92-501	200000 μg/L	
		SFL92-601	320000 μg/L	
Total Iron, μg/L	590	SFL92-201	16000 μg/L	300 (s)
		SFL92-203	5300 μg/L	
		SFL92-301	2000 μg/L	
		SFL92-302	9300 μg/L	
		SFL92-303	3800 μg/L	
		SFL92-401	18000 μg/L	
		SFL92-403	18000 μg/L	
		SFL92-501	11000 μg/L	
		SFL92-502	9800 μg/L	
		SFL92-503	12000 μg/L	
		SFL92-601	32000 μg/L	
		SFL92-602	27000 μg/L	
		SFL92-603	8500 μg/L	
		SFL92-701	3000 μg/L	
		SFL92-703	2300 μg/L	
		SFL92-801	2700 μg/L	

TABLE 4-11

METALS RESULTS EXCEEDING BACKGROUND CONCENTRATIONS SECOND QUARTER (FEBRUARY 1993) GROUND-WATER SAMPLES

Southwest Funston Landfill

Fort Riley, Kansas

METAL	MAXIMUM BACKGROUND CONC'N*	SAMPLES EXCEEDING MAXIMUM BACKGROUND CONCENTRATIONS		MCL
Total Magnesium, μg/L	24000	SFL92-201	35000 μg/L	NA
		SFL92-401	36000 μg/L	
		SFL92-403	35000 μg/L	
		SFL92-501	31000 μg/L	
		SFL92-502	31000 μg/L	
		SFL92-503	30000 μg/L	
		SFL92-601	70000 μg/L	
		SFL92-602	38000 μg/L	
		SFL92-603	30000 μg/L	
Total Manganese, μg/L	810	SFL92-201	2700 μg/L	50 (s)
		SFL92-203	1400 μg/L	
		SFL92-301	1300 μg/L	
		SFL92-302	1400 μg/L	
		SFL92-303	1400 μg/L	
		SFL92-401	2200 μg/L	
		SFL92-403	2300 μg/L	
		SFL92-501	1800 μg/L	
		SFL92-502	2000 μg/L	
		SFL92-503	1900 μg/L	
		SFL92-601	2100 μg/L	
		SFL92-602	2300 μg/L	
		SFL92-603	2000 μg/L	
		SFL92-703	1300 μg/L	
		SFL92-803	1200 μg/L	
Total Potassium, μg/L	8500	SFL92-201	11000 μg/L	NA
		SFL92-301	16000 μg/L	
		SFL92-302	9200 μg/L	
		SFL92-401	11000 μg/L	
		SFL92-501	11000 μg/L	
		SFL92-601	15000 μg/L	
		SFL92-602	14000 μg/L	
		SFL92-801	11000 μg/L	

TABLE 4-11

METALS RESULTS EXCEEDING BACKGROUND CONCENTRATIONS
SECOND QUARTER (FEBRUARY 1993) GROUND-WATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

METAL	MAXIMUM BACKGROUND CONC'N*	SAMPLES EXCEEDING MAXIMUM BACKGROUND CONCENTRATIONS		MCL
Total Sodium, μg/L	23000	SFL92-201	44000 μg/L	NA
		SFL92-203	130000 μg/L	
		SFL92-301	53000 μg/L	
		SFL92-302	94000 μg/L	
		SFL92-303	110000 μg/L	
		SFL92-401	99000 μg/L	
		SFL92-403	99000 μg/L	
		SFL92-501	63000 μg/L	
		SFL92-502	70000 μg/L	
		SFL92-503	70000 μg/L	
		SFL92-601	69000 μg/L	
		SFL92-602	64000 μg/L	
		SFL92-603	80000 μg/L	
		SFL92-701	58000 μg/L	
		SFL92-703	36000 μg/L	
		SFL92-801	30000 μg/L	
		SFL92-803	30000 μg/L	
Total Zinc, μg/L	6.0	SFL92-601	13 μg/L	5000 (s)
		SFL92-701	8 μg/L	
		SFL92-703	10 μg/L	
		SFL92-801	9 μg/L	

ND - not detected
NA - not available
MCL - Maximum Contaminant Level
(s) - secondary MCL
* Background concentrations were obtained from SFL92-101, SFL92-102 and SFL92-103.

Sources:
Federal Register, Volume, 56, No. 20, January 30, 1991
40 CFR, Section 141.11 (July 1, 1987 Edition)
40 CFR, Section 141.62 (January 31, 1991 Edition)
40 CFR, Volume 56, No. 126, July 1, 1991.

TABLE 4-12

COMPARISON OF SECOND QUARTER TOTAL METALS RESULTS TO WATER SUPPLY WELLS

Southwest Funston Landfill
Fort Riley, Kansas

TOTAL METAL, µg/L	FORT RILEY DRINKING WELLS(a)	OGDEN WATER WELLS(b)	SOUTHWEST FUNSTON LANDFILL MONITORNG WELLS							
			CLUSTER 1	CLUSTER 2	CLUSTER 3	CLUSTER 4	CLUSTER 5	CLUSTER 6	CLUSTER 7	CLUSTER 8
Arsenic	2.0-3.0	1-10	2.3-7.6	2.1-13	2.8-21	3.0	2.2-22	4.2-19	6.2-13	18
Aluminum	.60-70	ND	ND	ND	ND	ND	ND	ND	170	ND
Barium	181-321	80-170	240-360	220-320	180-250	730-940	220-730	320-1800	200-240	130-240
Calcium	85600-87300	14700-197000	130000-160000	140000-220000	140000-190000	200000	180000-200000	160000-320000	93000-130000	120000-170000
Cobalt	4.0	ND	8.0-10	ND	9.0-12	8.0	ND	10	8.0	ND
Iron	32-114	14-380	590	5300-16000	2000-9300	18000	9800-18000	8500-32000	2300-3000	55-2700
Magnesium	19800-20800	21600-37000	21000-24000	23000-35000	21000-27000	35000-36000	31000-35000	30000-70000	18000-26000	23000-28000
Manganese	51-197	7-250	120-810	1400-2700	1300-1400	2200-2300	1800-2300	2000-2300	560-1300	410-1200
Potassium	600-9140	3420-7200	3800-8500	8400-11000	8400-16000	11000	8900-11000	9900-15000	7400-10000	5700-11000
Sodium	35700-36600	20000-66900	9800-23000	44000-130000	53000-110000	99000	63000-99000	64000-80000	36000-58000	30000
Zinc	11-266	4-59	4.0-6.0	4.0-5.0	4.0-5.0	4.0	4.0	13	8.0-10	5.0-9.0

ND - Not Detected
(Bl) - Sample results are less than 5 times the amount detected in method blank. Result is estimated.
(a) - Concentration ranges from Fort Riley drinking water wells installed in the alluvium. This includes the Main Cantonment Area.
(b) = Concentration ranges from Ogden water wells installed in the alluvium.

Sources:
DOD, 1987
DOD, 1987b
KHEL, 1991
KHEL, 1991b

As with the first quarterly sampling event, several wet chemical inorganic parameters were added in the second quarter sampling event to assist in defining possible treatment technologies and to confirm results generated during the first quarterly sampling event. These additional parameters were alkalinity, ammonia, biological oxygen demand, chemical oxygen demand, hardness, total Kjeldahl nitrogen and total suspended solids. Because these parameters were not analyzed in the background wells during the second quarter sampling, results from the second quarter sampling for these constituents can not be compared to background levels. Concentrations of these constituents will instead be compared to concentrations in well clusters 4, 5, 6, and 7 during the first quarter sampling event.

In the second quarter, alkalinity increased slightly (less than 25 percent) in all wells except well SFL92-601, which remained consistent with first quarter results. Ammonia concentrations decreased slightly in wells SFL92-502 and SFL92-601, while increasing slightly in wells SFL92-401, SFL92-501, and SFL92-602 and significantly (greater than 25 percent) in wells SFL92-403, SFL92-503, SFL92-603, SFL92-701, and SFL92-703. Biological oxygen demand values were higher in wells SFL92-501 and SFL92-503, while concentrations decreased slightly in wells SFL92-502, SFL92-601, and SFL92-602. Concentrations of total Kjeldahl nitrogen increased slightly in all wells except SFL92-403, SFL92-502 and SFL92-503. Hardness increased slightly in wells SFL92-503 and SFL92-602, while concentrations in wells SFL92-502 and SFL92-601 decreased slightly. Levels of total suspended solids significantly decreased in wells SFL92-501, SFL92-701 and SFL92-703. Detectable concentrations of chemical oxygen demand were present only in samples SFL92-601 and SFL92-602, which represents a significant reduction in the number of samples with positive chemical oxygen demand results.

Chloride results were higher than background concentrations in all downgradient wells. Nitrate was detected below background levels in all downgradient wells. Sulfate was detected above background levels in all downgradient wells except SFL92-503, SFL92-601, SFL92-602, and SFL92-701. Total organic carbon was detected below background levels in all downgradient wells. Bicarbonate was detected below background levels in all downgradient wells except for wells SFL92-201, SFL92-401, SFL92-403, SFL92-501, SFL92-502, SFL92-503, SFL92-601, and SFL92-602. Sulfide exceeded background levels in wells SFL92-201, SFL92-401, SFL92-403, SFL92-501, and SFL92-801. Concentrations of total and amenable cyanide were not detected in any samples collected during this sampling event.

4.2.2.5 Third Quarter (May 1993) Groundwater Analysis Results - As with the previous sampling events, both organic and inorganic constituents were detected in the groundwater samples collected during the third quarter (May 1993) sampling event at the SFL. Table 4-13 presents positive analytical results of the third quarter groundwater analyses.

The groundwater gradient during this sampling event was directed to the center portion of the SFL, indicating Threemile Creek was acting as a recharge source (Figure 3-18). Additional

TABLE 4-13

POSITIVE ANALYTICAL RESULTS FOR THIRD QUARTER (MAY 1993) SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	SFL92101	SFL92102	SFL92103	SFL92201	SFL92203	SFL92301	SFL92302	SFL92303
Date Collected:	5-4-93	5-4-93	5-3-93	5-5-93	5-5-93	5-6-93	5-6-93	5-6-93
<u>VOLATILE ORGANICS (µg/L):</u>								
1,1-Dichloroethane	--	--	--	--	--	--	--	--
Benzene	--	--	--	--	--	--	--	--
Methylene chloride	10 (T)	--	10 (T)	--	--	--	14	--
Trichloroethene	--	--	--	--	--	--	--	--
Trichlorofluoromethane	--	--	--	--	--	--	--	--
trans-1,2-Dichloroethene	--	--	--	--	--	--	--	--
<u>TOTAL RECOVERABLE FURNANCE METALS ug/L):</u>								
Arsenic	9.1	3.8	--	2.3	17	2.4	16	21
Lead	7.9	4.2	1.0	1.3	--	--	1.1	--
Selenium	--	2.5	3.1	--	--	--	--	--
Thallium	--	--	--	--	--	--	1.7	1.7
<u>TOTAL RECOVERABLE ICP METALS (ug/L):</u>								
Aluminum	--	160	--	--	100	--	--	--
Barium	340	220	200	200	190	110	130	130
Beryllium	2.0	--	--	2.0	--	--	--	--
Cadmium	--	--	--	--	--	--	--	--
Calcium	160000	120000	120000	190000	130000	120000	71000	100000
Chromium	--	--	--	--	--	--	9.0	--
Copper	--	--	--	8.0	--	--	--	--
Iron	1800	190	--	11000	4700	1300	4200	3000
Magnesium	24000	21000	26000	29000	22000	19000	11000	18000
Manganese	810	58	38	1600	1400	650	670	1100
Nickel	--	--	--	--	--	--	--	--
Potassium	8000	3800	3500	10000	7700	11000	5000	6300
Sodium	9800	17000	26000	39000	140000	53000	55000	69000
<u>TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L):</u>								
TRPH	--	--	--	--	--	--	--	0.74
<u>WET CHEMICAL INORGANICS (mg/L):</u>								
INORGANIC CHLORIDE	5.20	8.00	11.60	58.4	257	67.10	60.90	67.30
NITRATE	--	2.20	2.30	--	--	1.80	--	--
SULFATE	85.40	22.90	32.70	167	204	161.00	107.00	109.00
ORGANIC CARBON	--	--	--	5.50	2.80	3.70	2.90	2.40
BICARBONATE as CaCO3	462.00	416.00	418.00	436	200	275.00	154.00	281.00
TOTAL SULFIDE	257.00	618.00	640.00	301	310	320.00	318.00	314.00
<u>Organophosphorus Pesticides (ug/L):</u>	--	--	--	--	--	--	--	--
<u>Herbicides (ug/L):</u>	--	--	--	--	--	--	--	--
<u>Semi-Volatiles (ug/L):</u>	--	--	--	--	--	--	--	--
<u>Explosives (ug/L):</u>	-- (H)	-- (H)	-- (H)	-- (H)	-- (H)	-- (H)	-- (H)	-- (H)
<u>PESTICIDES/PCBs (µg/L):</u>	--	--	--	--	--	--	--	--

T – Sample results are less than 10 times the amount detected
in the trip blank. Result is estimated.
H – Estimated result based on exceeded holdtime.
Results may be biased low.

TABLE 4-13

POSITIVE ANALYTICAL RESULTS FOR THIRD QUARTER (MAY 1993) SAMPLES

Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	SFL92401 5-4-93	SFL92403 5-4-93	SFL92501 5-4-93	SFL92502 5-4-93	SFL92503 5-4-93	SFL92504 5-4-93	SFL92601 5-5-93	SFL92602 5-5-93	SFL92603 5-5-93
VOLATILE ORGANICS (μg/L):									
1,1-Dichloroethane	--	--	--	--	--	--	3.0	--	--
Benzene	--	--	--	--	--	--	14	--	--
Methylene chloride	--	--	--	--	12 (T)	--	--	11 (T)	--
Trichloroethene	--	--	--	--	--	--	--	--	--
Trichlorofluoromethane	2.1	--	--	--	--	--	--	--	--
trans-1,2-Dichloroethene	--	--	3.5	--	--	--	6.2	--	--
TOTAL RECOVERABLE FURNANCE METALS ug/L):									
Arsenic	--	2.8	2.7	14	24	24	6.7	22	21
Lead	3.0	2.7	--	1.9	1.1	1.1	1.3	1.3	3.2
Selenium	--	--	--	--	--	--	--	--	--
Thallium	--	--	--	--	--	--	--	--	--
TOTAL RECOVERABLE ICP METALS (ug/L):									
Aluminum	--	--	--	--	--	--	--	--	--
Barium	860	730	200	310	310	300	1800	880	280
Beryllium	2.0	2.0	2.0	2.0	2.0	2.0	3.0	2.0	2.0
Cadmium	4.0	--	--	--	--	--	--	--	--
Calcium	190000	190000	180000	170000	170000	160000	300000	200000	150000
Chromium	--	--	--	--	--	--	--	--	--
Copper	--	--	--	--	--	--	8.0	9.0	--
Iron	17000	18000	9400	11000	14000	14000	36000	23000	8200
Magnesium	35000	34000	30000	30000	31000	30000	68000	33000	27000
Manganese	2100	2300	1700	1900	2000	1900	2200	2200	2000
Nickel	--	--	--	--	--	--	28	--	--
Potassium	11000	8900	9400	8400	8700	8500	14000	13000	8900
Sodium	98000	100000	70000	70000	73000	71000	74000	58000	97000
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L):									
TRPH	--	--	--	--	--	--	--	--	--
WET CHEMICAL INORGANICS (mg/L):									
INORGANIC CHLORIDE	173.00	148.00	102.00	103.00	105.00	107.00	130	92.7	145
NITRATE	--	--	--	--	--	--	--	--	--
SULFATE	95.30	105.00	102.00	82.60	77.40	77.10	4.20	71.7	172
ORGANIC CARBON	6.90	5.80	3.90	4.10	4.00	3.90	14.2	5.50	3.40
BICARBONATE as CaCO3	611.00	559.00	526.00	524.00	524.00	518.00	1040	588	388
TOTAL SULFIDE	603.00	293.00	301.00	282.00	286.00	306.00	306	310	301
Organophosphorus Pesticides (ug/L):	--	--	--	--	--	--	--	--	--
Herbicides (ug/L):	--	--	--	--	--	--	--	--	--
Semi-Volatiles:	--	--	--	--	--	--	--	--	--
Explosives (ug/L):	-- (H)	-- (H)	-- (H)	-- (H)	-- (H)	-- (H)	-- (H)	-- (H)	-- (H)
PESTICIDES/PCBs (μg/L):	--	--	--	--	--	--	--	--	--

T – Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.

H – Estimated result based on exceeded holdtime. Results may be biased low.

TABLE 4-13

POSITIVE ANALYTICAL RESULTS FOR THIRD QUARTER (MAY 1993) SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	SFL92701 5-5-93	SFL92703 5-5-93	SFL92801 5-4-93	SFL92802 5-4-93	SFL92803 5-4-93
VOLATILE ORGANICS (μg/L):					
1,1-Dichloroethane	--	--	--	--	--
Benzene	--	--	--	--	--
Methylene chloride	--	--	--	--	--
Trichloroethene	4.3	--	--	--	--
Trichlorofluoromethane	--	--	--	--	--
trans-1,2-Dichloroethene	--	--	--	--	--
TOTAL RECOVERABLE FURNANCE METALS ug/L):					
Arsenic	6.0	15	12	13	2.5
Lead	3.8	--	--	1.9	1.0
Selenium	--	--	--	--	--
Thallium	--	--	--	--	--
TOTAL RECOVERABLE ICP METALS (ug/L):					
Aluminum	100	--	--	--	--
Barium	300	210	220	220	140
Beryllium	--	--	2.0	2.0	--
Cadmium	--	--	--	--	4.0
Calcium	100000	130000	150000	150000	130000
Chromium	--	--	--	--	--
Copper	--	--	--	--	--
Iron	4600	2400	2500	2500	--
Magnesium	20000	26000	22000	22000	31000
Manganese	710	1400	340	340	1300
Nickel	--	--	--	--	--
Potassium	6700	8700	9600	9700	4400
Sodium	58000	37000	28000	29000	36000
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L):					
TRPH	--	--	--	--	--
WET CHEMICAL INORGANICS (mg/L):					
INORGANIC CHLORIDE	54.7	27.8	23.80	24.80	37.80
NITRATE	--	--	--	1.70	--
SULFATE	89.5	135	101.00	103.00	120.00
ORGANIC CARBON	3.40	--	2.50	2.20	--
BICARBONATE as CaCO3	303	--	410.00	422.00	375.00
TOTAL SULFIDE	290	310	289.00	302.00	301.00
Organophosphorus Pesticides (ug/L):	--	--	--	--	--
Herbicides (ug/L):	--	--	--	--	--
Semi-Volatiles:	--	--	--	--	--
Explosives (ug/L):	-- (H)	-- (H)	-- (H)	-- (H)	-- (H)
PESTICIDES/PCBs (μg/L):	--	--	--	--	--

T - Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.
H - Estimated result based on exceeded holdtime. Results may be biased low.

discussion of the direction of groundwater flow during this sampling event is presented in Section 3.6.2.2.4.

4.2.2.5.1 Organic Compounds - The only organic compounds detected during the third quarter sampling event at SFL were petroleum hydrocarbons detected through TRPH analysis and VOCs. Concentrations of TRPH were detected only in sample SFL92-303 at 0.74 mg/L. VOCs were not detected in samples collected at well clusters 2 and 8. Methylene chloride was detected in five of the samples at concentrations ranging from 10 to 14 μg/L. Three of the four trip blanks associated with the groundwater samples contained methylene chloride at concentrations just above the quantitation limit (10 μg/L). This may be attributed to possible contamination during sample handling and shipment or possible laboratory contamination, even though method blanks associated with these samples were free of contaminants. Only the methylene chloride in SFL92-302 (14 μg/L) is not associated with trip blank contamination.

Other VOCs detected in the groundwater samples included benzene, 1,1-dichloroethane, trichloroethene, trichlorofluoromethane, and trans-1,2-dichloroethene. The highest concentrations of VOCs were detected in sample SFL92-601. Figure 4-9 provides well locations with corresponding positive organic analytical results.

Four of the VOCs mentioned above were detected only once during the third quarterly sampling event. These compounds include benzene (SFL92-601), 1,1-dichloroethane (SFL92-601), trichloroethene (SFL92-701), and trichlorofluoromethane (SFL92-401). Because the detectable concentrations of these compounds were limited to shallow monitoring wells, the vertical extent of these constituents during this sampling event is limited to the uppermost portion of the saturated zone.

Detectable concentrations of trans-1,2-dichloroethene were present in two samples (SFL92-501 and SFL92-601). The vertical extent of trans-1,2-dichloroethene at these locations was confined to the uppermost portion of the saturated zone, as well.

4.2.2.5.2 Inorganics - The inorganic portion of the analytical program followed during this sampling event was similar to that of the baseline sampling event with two exceptions: samples for dissolved metals analyses were not collected and a change in the analytical method used for the analysis of total thallium was implemented. The collection of dissolved metals samples was discontinued because total metals concentrations are used for risk assessment, and during the baseline and two subsequent quarterly groundwater sampling events, total and dissolved metals concentrations were similar at the SFL. This may be attributed to the low levels of particulates in the samples demonstrated by the consistently low NTU values achieved during purging (usually < 10 NTUs at the completion of purging). The change in the method for total thallium

FIGURE 4-9

GROUND-WATER ANALYTICAL RESULTS*
THIRD QUARTER (MAY 1993)
SOUTHWEST FUNSTON LANDFILL

FORT RILEY, KANSAS

VOLATILE ORGANICS (ug/L)	SFL92-101	SFL92-102	SFL92-103
METHYLENE CHLORIDE	10 (T)	ND	10 (T)
TOTAL METALS (ug/L)			
MANGANESE	810	58	38
IRON	1800	190	ND

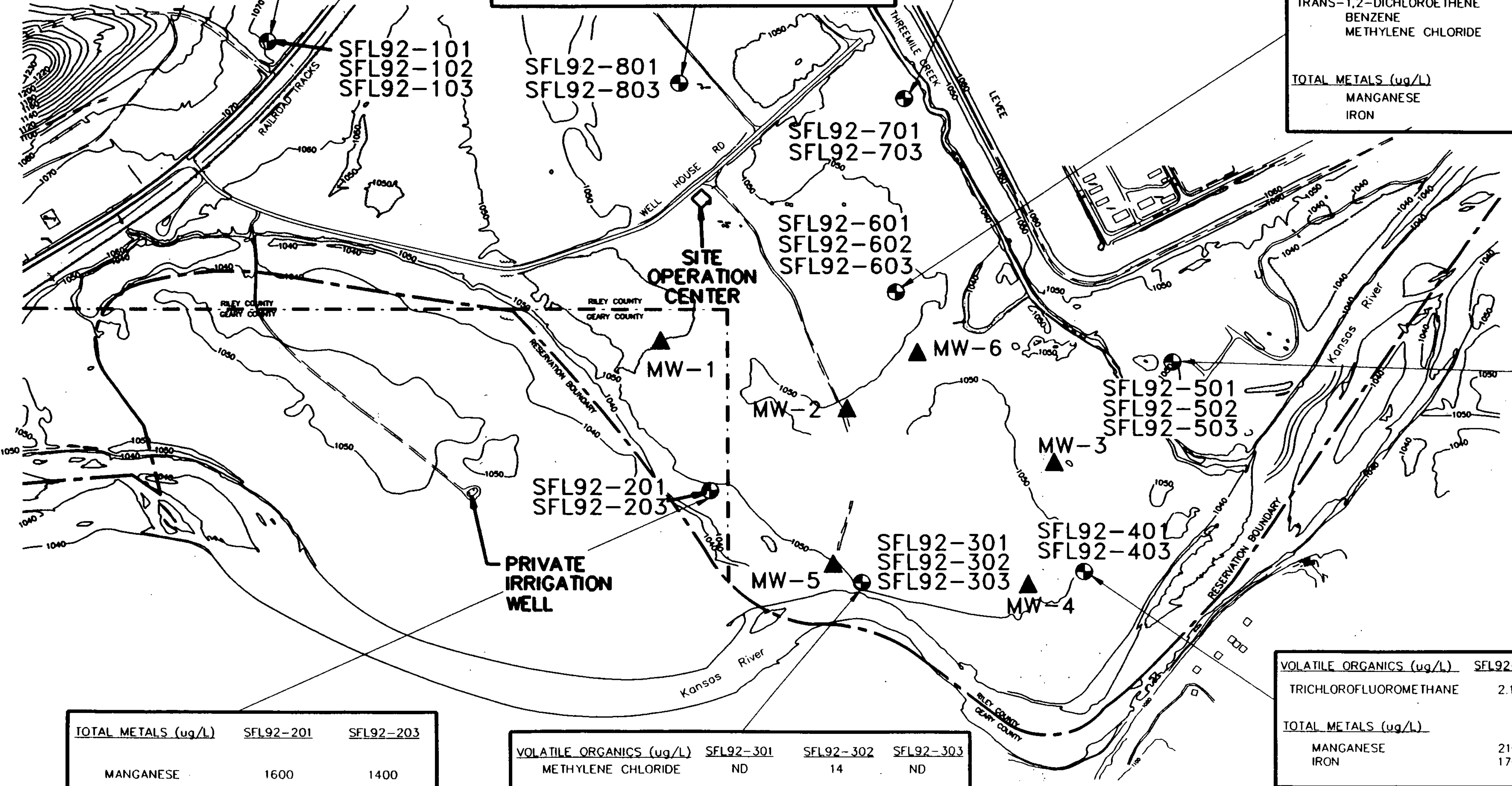
TOTAL METALS (ug/L)	SFL92-801	SFL92-803
MANGANESE	340	1300
IRON	2500	ND

VOLATILE ORGANICS (ug/L)	SFL92-701	SFL92-703
TRICHLOROETHENE	4.3	ND
TOTAL METALS (ug/L)		
MANGANESE	710	1400
IRON	4600	2400

NOTE

*THIS INCLUDES ALL POSITIVE ORGANIC RESULTS AND METALS RESULTS WHICH EXCEED FEDERAL MCLS.

VOLATILE ORGANICS (ug/L)	SFL92-601	SFL92-602	SFL92-603
1,1-DICHLOROETHANE	3.0	ND	ND
TRANS-1,2-DICHLOROETHENE	6.2	ND	ND
BENZENE	14	ND	ND
METHYLENE CHLORIDE	ND	11 (T)	ND
TOTAL METALS (ug/L)			
MANGANESE	2200	2200	2000
IRON	36000	23000	8200



VOLATILE ORGANICS (ug/L)	SFL92-501	SFL92-502	SFL92-503
TRANS-1,2- DICHLOROETHENE	3.5	ND	ND
METHYLENE CHLORIDE	ND	ND	12 (T)
TOTAL METALS (ug/L)			
MANGANESE	1700	1900	2000
IRON	9400	11000	14000

LEGEND

- ◐ CLUSTERED WELL LOCATION
- ▲ EXISTING CLOSURE WELLS
- —1050— CONTOUR INTERVAL (10 ft)
- +++++ RAILROAD TRACKS
- ND – NOT DETECTED
- T – SAMPLE RESULTS ARE LESS THAN 10 TIMES AMOUNT IN TRIP BLANK.

TOTAL METALS (ug/L)	SFL92-201	SFL92-203
MANGANESE	1600	1400
IRON	11000	4700

VOLATILE ORGANICS (ug/L)	SFL92-301	SFL92-302	SFL92-303
METHYLENE CHLORIDE	ND	14	ND
TRPH (mg/L)	ND	ND	0.74
TOTAL METALS (ug/L)			
MANGANESE	650	670	1100
IRON	1300	4200	3000

VOLATILE ORGANICS (ug/L)	SFL92-401	SFL92-403
TRICHLOROFLUOROMETHANE	2.1	ND
TOTAL METALS (ug/L)		
MANGANESE	2100	2300
IRON	17000	18000

0 800 1600

APPROXIMATE SCALE IN FEET

LAW ENVIRONMENTAL INC.
GOVERNMENT SERVICES DIVISION

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analysis was implemented so that the detection limit would be below the recently promulgated MCL of 2.0 μg/L for thallium which became effective in May 1992.

Aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, nickel, potassium, selenium, sodium and thallium were detected in the groundwater samples at the SFL. Table 4-14 presents the metals results exceeding background concentrations as detected in wells SFL92-101, SFL92-102, and SFL92-103. Concentrations of all metals except beryllium, iron and manganese were below all federal MCLs (USEPA, 1991) and KALs. The concentrations of iron and manganese detected in both background and downgradient wells exceeded secondary MCLs and KALs.

A comparison between concentrations of metals detected during this sampling event and metals detected in samples collected from the Fort Riley and City of Ogden drinking water wells shows elevated concentrations of arsenic, calcium, iron, manganese and potassium in many of the monitoring wells at the SFL. Aluminum, barium, calcium, magnesium and sodium had isolated positive results above the concentrations found in these drinking water wells. This comparison of data is presented in Table 4-15.

Of the wet chemical inorganic parameters (chloride, nitrate, sulfate, bicarbonate, sulfide, total organic carbon and total and amenable cyanide) analyzed, all parameters were detected at the SFL except total and amenable cyanide. Chloride results were higher than background concentrations in all downgradient wells. Sulfate results were higher than background concentrations all downgradient well clusters. Bicarbonate significantly exceeded background concentrations in samples SFL92-401, SFL92-403, SFL92-601 and SFL92-602. While concentrations of total organic carbon were not detected in the background monitoring wells, total organic carbon was found in all downgradient wells except SFL92-703 and SFL92-803. Concentrations of nitrate and sulfide did not exceed background levels in any downgradient wells. None of the wet chemical inorganic parameters were detected in concentrations exceeding MCLs or KALs.

4.2.2.6 Comparison of Baseline and Quarterly Sampling Results - Four groundwater sampling events have occurred at SFL, the baseline (July 1992), the first quarter (November 1992), the second quarter (February 1993), and the third quarter (May 1993). Results of the four rounds were compared to identify trends in the data. Table 4-16 presents the data comparison.

Volatile organic results from the quarterly sampling results do not indicate definite trends when compared to baseline results. The baseline study identified several volatile organic compounds at low concentrations in wells SFL92-501, SFL92-502, and SFL92-503. None of these compounds were detected in the following three quarters except trans-1,2-dichloroethene in the second and third quarters. An additional compound, 1,2-dichloroethane, was detected in samples SFL92-501 and SFL92-502 during the first quarter; however, the baseline, second and third

TABLE 4-14

METALS RESULTS EXCEEDING BACKGROUND CONCENTRATIONS THIRD QUARTER (MAY 1993) GROUND-WATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

METAL	MAXIMUM BACKGROUND CONC'N*	SAMPLES EXCEEDING MAXIMUM BACKGROUND CONCENTRATIONS		MCL
Total Arsenic, μg,L	9.1	SFL92-203	17 μg/L	50
		SFL92-302	16 μg/L	
		SFL92-303	21 μg/L	
		SFL92-502	14 μg/L	
		SFL92-503	24 μg/L	
		SFL92-602	22 μg/L	
		SFL92-603	21 μg/L	
		SFL92-703	15 μg/L	
		SFL92-801	13 μg/L	
Total Lead, μg/L	7.9	none		15
Total Selenium, μg/L	3.1	none		50 (s)
Total Aluminum, μg/l	160	none		200 (s)
Total Barium, μg/L	340	SFL92-401	860 μg/L	2000
		SFL92-403	730 μg/L	
		SFL92-601	1800 μg/L	
		SFL92-602	880 μg/L	
Total Beryllium, μg/L	2.0	SFL92-601	3 μg/L	4.0
Total Cadmium, μg/L	ND	SFL92-401	4 μg/L	5.0
		SFL92-803	4 μg/L	
Total Calcium, μg/L	160000	SFL92-601	300000 μg/L	NA
		SFL92-602	200000 μg/L	
Total Chromium, μg/L	ND	SFL92-302	9 μg/L	100
Total Cobalt, μg/L	ND	SFL92-603	10 μg/L	NA
Total Copper, μg/L	ND	SFL92-201	8 μg/L	1300
		SFL92-601	8 μg/L	
		SFL92-602	9 μg/L	

TABLE 4-14

METALS RESULTS EXCEEDING BACKGROUND CONCENTRATIONS THIRD QUARTER (MAY 1993) GROUND-WATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

METAL	MAXIMUM BACKGROUND CONC'N*	SAMPLES EXCEEDING MAXIMUM BACKGROUND CONCENTRATIONS		MCL
Total Iron, µg/L	1800	SFL92-201	11000 µg/L	300 (s)
		SFL92-203	4700 µg/L	
		SFL92-302	4200 µg/L	
		SFL92-303	3000 µg/L	
		SFL92-401	17000 µg/L	
		SFL92-403	18000 µg/L	
		SFL92-501	9400 µg/L	
		SFL92-502	11000 µg/L	
		SFL92-503	14000 µg/L	
		SFL92-601	36000 µg/L	
		SFL92-602	23000 µg/L	
		SFL92-603	8200 µg/L	
		SFL92-701	4600 µg/L	
		SFL92-703	2400 µg/L	
		SFL92-801	2500 µg/L	
Total Magnesium, µg/L	26000	SFL92-401	35000 µg/L	NA
		SFL92-403	34000 µg/L	
		SFL92-601	68000 µg/L	
		SFL92-602	33000 µg/L	
Total Manganese, µg/L	810	SFL92-201	1600 µg/L	50 (s)
		SFL92-203	1400 µg/L	
		SFL92-303	1100 µg/L	
		SFL92-401	2100 µg/L	
		SFL92-403	2300 µg/L	
		SFL92-501	1700 µg/L	
		SFL92-502	1900 µg/L	
		SFL92-503	2000 µg/L	
		SFL92-601	2200 µg/L	
		SFL92-602	2200 µg/L	
		SFL92-603	2000 µg/L	
		SFL92-703	1400 µg/L	
		SFL92-803	1300 µg/L	
Total Nickel, µg/L	ND	SFL92-601	28 µg/L	100
Total Potassium, µg/L	8000	SFL92-201	10000 µg/L	NA
		SFL92-301	11000 µg/L	
		SFL92-401	11000 µg/L	
		SFL92-601	14000 µg/L	
		SFL92-602	13000 µg/L	

TABLE 4-14

METALS RESULTS EXCEEDING BACKGROUND CONCENTRATIONS
THIRD QUARTER (MAY 1993) GROUND-WATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

METAL	MAXIMUM BACKGROUND CONC'N*	SAMPLES EXCEEDING MAXIMUM BACKGROUND CONCENTRATIONS		MCL
Total Sodium, μg/L	26000	SFL92-201	39000 μg/L	NA
		SFL92-203	140000 μg/L	
		SFL92-301	53000 μg/L	
		SFL92-302	55000 μg/L	
		SFL92-303	69000 μg/L	
		SFL92-401	98000 μg/L	
		SFL92-403	100000 μg/L	
		SFL92-501	70000 μg/L	
		SFL92-502	70000 μg/L	
		SFL92-503	73000 μg/L	
		SFL92-601	74000 μg/L	
		SFL92-602	58000 μg/L	
		SFL92-603	97000 μg/L	
		SFL92-701	58000 μg/L	
		SFL92-703	37000 μg/L	
		SFL92-803	36000 μg/L	
Total Thallium, μg/L	ND	SFL92-302	1.7 μg/L	2.0
		SFL92-303	1.7 μg/L	

ND - not detected
NA - not available
MCL - Maximum Contaminant Level
(s) - secondary MCL
* Background concentrations were obtained from SFL92-101, SFL92-102 and SFL92-103.

Sources:
Federal Register, Volume, 56, No. 20, January 30, 1991
40 CFR, Section 141.11 (July 1, 1987 Edition)
40 CFR, Section 141.62 (January 31, 1991 Edition)
40 CFR, Volume 56, No. 126, July 1, 1991.

TABLE 4-15

COMPARISON OF THIRD QUARTER METALS RESULTS TO WATER SUPPLY WELLS
Southwest Funston Landfill
Fort Riley, Kansas

TOTAL METAL, µg/L	FORT RILEY DRINKING WELLS(a)	OGDEN WATER WELLS(b)	SOUTHWEST FUNSTON LANDFILL MONITORNG WELLS							
			CLUSTER 1	CLUSTER 2	CLUSTER 3	CLUSTER 4	CLUSTER 5	CLUSTER 6	CLUSTER 7	CLUSTER 8
Arsenic	2.0-3.0	1-10	9.1	2.3-17	2.4-21	2.8	2.7-24	6.7-22	6.0-15	2.5-13
Aluminum	60-70	ND	160	100	ND	ND	ND	ND	100	ND
Barium	181-321	80-170	200-340	190-200	110-130	730-860	200-310	280-1800	210-300	140-220
Calcium	85600-87300	14700-197000	120000-160000	130000-190000	71000-120000	190000	160000-180000	150000-300000	100000-130000	130000-150000
Iron	32-114	14-380	1800	4700-11000	1300-4200	17000-18000	9400-14000	8200-36000	2400-4600	2500
Magnesium	19800-20800	21600-37000	21000-26000	22000-29000	11000-19000	34000-35000	30000-31000	27000-68000	20000-26000	22000-31000
Manganese	51-197	7-250	38-810	1400-1600	650-1100	2100-2300	1700-2000	2000-2200	710-1400	340-1300
Potassium	600-9140	3420-7200	3500-8000	77000-10000	5000-11000	8900-11000	8400-9400	8900-14000	6700-8700	4400-9700
Sodium	35700-36600	20000-66900	9800-26000	39000-140000	53000-69000	98000-100000	70000-73000	58000-74000	37000-58000	28000-36000

ND - Not Detected

(Bl) - Sample results are less than 5 times the amount detected in method blank. Result is estimated.

(a) - Concentration ranges from Fort Riley drinking water wells installed in the alluvium. This includes the Main Cantonment Area.

(b) = Concentration ranges from Ogden water wells installed in the alluvium.

Sources:
DOD, 1987
DOD, 1987b
KHEL, 1991
KHEL, 1991b

TABLE 4-16

COMPARISON OF BASELINE AND QUARTERLY GROUND-WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Date Collected	SFL92101 07-20-92	SFL92101 11-02-92	SFL92101 02-02-93	SFL92101 05-04-93	SFL92102 07-20-92	SFL92102 11-02-92	SFL92102 02-02-93	SFL92102 05-04-93	SFL92103 07-20-92	SFL92103 11-03-92	SFL92103 02-02-93	SFL92103 05-03-93
VOLATILE ORGANICS (µg/L):												
1,1,1,2-Tetrachloroethane	--	--	--	--	--	--	--	--	--	--	--	--
1,1,2,2-Tetrachloroethane	--	--	--	--	--	--	--	--	--	--	--	--
1,1,2-Trichloroethane	--	--	--	--	--	--	--	--	--	--	--	--
1,2,3-Trichloropropane	--	--	--	--	--	--	--	--	--	--	--	--
1,2-Dibromoethane	--	--	--	--	--	--	--	--	--	--	--	--
1,1-Dichloroethane	--	--	--	--	--	--	--	--	--	--	--	--
1,2-Dichloroethane	--	--	--	--	--	--	--	--	--	--	--	--
1,2-Dichloropropane	--	--	--	--	--	--	--	--	--	--	--	--
2-Hexanone	--	--	--	--	--	--	--	--	--	--	--	--
Benzene	--	--	--	--	--	--	--	--	--	--	--	--
Bromoform	--	--	--	--	--	--	--	--	--	--	--	--
Chlorodibromomethane	--	--	--	--	--	--	--	--	--	--	--	--
Ethyl methacrylate	--	--	--	--	--	--	--	--	--	--	--	--
Methacrylonitrile	--	--	--	--	--	--	--	--	--	--	--	--
Methyl chloride	--	--	--	--	--	--	--	--	--	--	--	--
Methyl isobutyl ketone	--	--	--	--	--	--	--	--	--	--	--	--
Methylene bromide	--	--	--	--	--	--	--	--	--	--	--	--
Methylene chloride	21 (T)	--	15	10 (T)	18 (T)	--	--	--	16 (T)	--	18	10 (T)
Pentachloroethane	--	--	--	--	--	--	--	--	--	--	--	--
Styrene	--	--	--	--	--	--	--	--	--	--	--	--
Trichlorofluoromethane	--	--	--	--	--	--	--	--	--	--	--	--
Vinyl chloride	--	--	--	--	--	--	--	--	--	--	--	--
Xylenes (total)	--	--	--	--	--	--	--	--	--	--	--	--
cis-1,3-Dichloropropene	--	--	--	--	--	--	--	--	--	--	--	--
trans-1,2-Dichloroethene	--	--	--	--	--	--	--	--	--	--	--	--
trans-1,4-Dichloro-2-butene	--	--	--	--	--	--	--	--	--	--	--	--
Trichloroethene	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L):	--	-- (E)	--	--	--	-- (E)	--	--	--	3.9 (E)	--	--
DISSOLVED FURNACE METALS (µg/L):												
Arsenic	7.0	8.1	9.1	NA	3.3	3.4	3.3	NA	--	--	--	NA
Lead	--	1.2	--	NA	--	1.2	--	NA	--	--	--	NA
Selenium	--	--	--	NA	--	--	--	NA	1.9	1.3	1.8	NA
DISSOLVED MERCURY (µg/L):	--	--	--	NA	--	--	--	NA	--	--	--	NA
DISSOLVED ICP METALS (µg/L):												
Aluminum	--	--	--	NA	--	--	--	NA	--	--	--	NA
Antimony	--	--	--	NA	--	--	--	NA	--	--	--	NA
Barium	340	390	350	NA	240	--	250	NA	210	280	240	NA
Beryllium	1.6	3.0	3.0	NA	1.5	2.0	2.0	NA	1.3	1.0	2.0	NA
Cadmium	--	--	--	NA	--	--	--	NA	--	--	--	NA
Calcium	160000	170000	160000	NA	140000	140000	130000	NA	120000	120000	120000	NA
Chromium	--	13	9.0	NA	--	--	--	NA	--		--	NA
Iron	1600	580	630	NA	55	--	--	NA	--	--	100	NA
Magnesium	23000	24000	23000	NA	22000	23000	21000	NA	26000	24000	23000	NA
Manganese	1000	890	790	NA	310	230	170	NA	270	220	120	NA
Nickel	--	--	--	NA	--	--	--	NA	--	--	--	NA
Potassium	8000	8300	8100	NA	4700	5400	5900	NA	3200	3500	3300	NA
Silver	--	--	--	NA	--	--	3.0	NA	--	--	--	NA
Sodium	12000	9900	9500	NA	15000	15000	15000	NA	20000	23000	22000	NA
Vanadium	--	--	--	NA	--	--	6.0	NA	--	--	--	NA
Zinc	16 (B1)	10 (B1)	8.0 (B1)	NA	91	6.0 (B1)	5.0 (B1)	NA	14 (B1)	27 (B1)	6.0 (B1)	NA

TABLE 4–16

COMPARISON OF BASELINE AND QUARTERLY GROUND–WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	SFL92101	SFL92101	SFL92101	SFL92101	SFL92102	SFL92102	SFL92102	SFL92102	SFL92103	SFL92103	SFL92103	SFL92103
Date Collected	07–20–92	11–02–92	02–02–93	05–04–93	07–20–92	11–02–92	02–02–93	05–04–93	07–20–92	11–03–92	02–02–93	05–03–93
TOTAL RECOVERABLE FURNACE METALS (µg/L):												
Arsenic	7.1	9.3	7.6	9.1	3.7	2.9	3.2	3.8	2.0	––	2.3	––
Lead	––	–– (M2)	––	7.9	––	1.1 (M2)	––	4.2	––	–– (M2)	––	1.0
Selenium	––	1.1 (M2)	––	––	––	1.4 (M2)	––	2.5	2.1	1.6 (M2)	2.1	3.1
Thallium	NA	NA	NA	––	NA	NA	NA	––	NA	NA	NA	––
TOTAL ICP METALS (µg/L):												
Aluminum	––	––	––	––	460	230	––	160	120	––	––	––
Antimony	––	––	––	––	––	––	––	––	––	––	––	––
Barium	350	370	360	340	250	290	240	220	220	290	270	200
Beryllium	1.8	2.0	3.0	2.0	1.5	2.0	1.0	––	1.8	1.0	2.0	––
Cadmium	––	––	––	––	––	––	––	––	––	––	––	––
Calcium	160000	170000	160000	160000	140000	140000	130000	120000	120000	120000	130000	120000
Chromium	––	––	10 (B1)	––	––	––	––	––	––	––	11 (B1)	––
Cobalt	––	––	10	––	––	––	––	––	––	––	8.0	––
Copper	––	––	––	––	––	––	4.0	––	––	––	––	––
Iron	1700	500	590	1800	550	320	––	190	110	260	90	––
Magnesium	23000	24000	24000	24000	23000	24000	21000	21000	26000	24000	24000	26000
Manganese	1000	880	810	810	320	250	170	58	290	220	120	38
Nickel	––	––	––	––	––	––	––	––	––	––	––	––
Potassium	8000	8400	8500	8000	4700	5700	6600	3800	3300	3400	3800	3500
Silver	––	––	5.0	––	––	––	––	––	––	––	––	––
Sodium	12000	9800	9800	9800	16000	15000	16000	17000	21000	22000	23000	26000
Vanadium	––	––	––	––	––	––	9.0	––	––	––	––	––
Zinc	18 (B1)	31	6.0	––	14 (B1)	11	4.0	––	16 (B1)	15	5.0	––
WET CHEMISTRY (mg/L):												
Total Suspended Solids	NA	2.0 (E)	NA	NA	NA	1.0	NA	NA	NA	2.0	NA	NA
Inorganic Chloride	7.5	5.2	4.8	5.2	11	7.4	NA	8.0	13	9.6	9.9	12
Nitrate	––	––	––	––	3.8	––	NA	2.2	4.4	2.5	3.8	2.3
Sulfate	69	88 (M2)	89	85	41	56 (M2)	NA	23	38	25 (M2)	25	33
Ammonia (N)	NA	0.12	NA	NA	––	––	NA	NA	NA	––	NA	NA
Organic Carbon	3.3 (M1)	2.5	––	––	––	––	NA	––	––	––	29	––
Hardness as $CaCO_3$	NA	520	NA	NA	NA	432	NA	NA	NA	420	NA	NA
Bicarbonate as $CaCO_3$	576	439	468	462	541	398	NA	416	523	402	433	418
Alkalinity as $CaCO_3$	NA	439	NA	NA	––	398	NA	NA	NA	402	NA	NA
Total Cyanide	––	––	––	––	––	––	NA	––	––	––	––	––
Amenable CN	–– (M2)	––	––	––	–– (M2)	––	NA	––	–– (M2)	––	––	––
Nitrogen (TKN)	NA	––	NA	NA	NA	––	NA	NA	NA	––	NA	NA
Total Sulfide	12 (E)	––	414	257	26 (E)	––	NA	618	28 (E)	––	426	640
BOD (5 day)	NA	1.0	NA	NA	NA	1.0	NA	NA	NA	1.1	NA	NA
COD	NA	––	NA	NA	NA	––	NA	NA	NA	––	NA	NA

NOTE: No positive results were obtained for semi–volatile organics, pesticides/PCBs, explosives, organophosphorous pesticides or herbicides.
–– Not detected. NA – Not analyzed.
B1 – Sample results are less than 5 times the amount detected in the method blank. Result is estimated.
B2 – Sample results are less than 10 times the amount detected in the method blank. Result is estimated.
E – Estimated result.
F – Field duplicate RPD exceeds control limit. Estimated due to poor precision.
M1 – Matrix spike recovery is high due to sample matrix effect. Sample result is biased high.
M2 – Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.
T – Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.
R – Result is rejected.

TABLE 4-16

COMPARISON OF BASELINE AND QUARTERLY GROUND-WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Date Collected	SAMPLE SFL92201 07-22-92	DUPLICATE SFL92202 07-22-92	SFL92201 11-03-92	SFL92201 02-02-93	SFL92201 05-05-93	SFL92203 07-22-92	SFL92203 11-03-92	SFL92203 02-02-93	SFL92203 05-05-93
VOLATILE ORGANICS (μg/L):									
1,1,1,2-Tetrachloroethane	--	--	--	--	--	--	--	--	--
1,1,2,2-Tetrachloroethane	--	--	--	--	--	--	--	--	--
1,1,2-Trichloroethane	--	--	--	--	--	--	--	--	--
1,2,3-Trichloropropane	--	--	--	--	--	--	--	--	--
1,2-Dibromoethane	--	--	--	--	--	--	--	--	--
1,1-Dichloroethane	--	--	--	--	--	--	--	--	--
1,2-Dichloroethane	--	--	--	--	--	--	--	--	--
1,2-Dichloropropane	--	--	--	--	--	--	--	--	--
2-Hexanone	--	--	--	--	--	--	--	--	--
Benzene	--	--	--	--	--	--	--	--	--
Bromoform	--	--	--	--	--	--	--	--	--
Chlorodibromomethane	--	--	--	--	--	--	--	--	--
Ethyl methacrylate	--	--	--	--	--	--	--	--	--
Methacrylonitrile	--	--	--	--	--	--	--	--	--
Methyl chloride	--	--	--	--	--	--	--	--	--
Methyl isobutyl ketone	--	--	--	--	--	--	--	--	--
Methylene bromide	--	--	--	--	--	--	--	--	--
Methylene chloride	--	15 (B2)(T)	7.2 (B2)	13	--	8.0 (B2)(T)	6.4 (B2)	--	--
Pentachloroethane	--	--	--	--	--	--	--	--	--
Styrene	--	--	--	--	--	--	--	--	--
Trichlorofluoromethane	--	--	--	--	--	--	--	--	--
Vinyl chloride	--	--	--	--	--	--	--	--	--
Xylenes (total)	--	--	--	--	--	--	--	--	--
cis-1,3-Dichloropropene	--	--	--	--	--	--	--	--	--
trans-1,2-Dichloroethene	--	--	--	--	--	--	--	--	--
trans-1,4-Dichloro-2-butene	--	--	--	--	--	--	--	--	--
Trichloroethene	--	--	--	--	--	--	--	--	--
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L):	--	--	-- (E)	--	--	--	3.5 (E)	--	--
DISSOLVED FURNACE METALS (μg/L									
Arsenic	--	--	--	--	NA	19	16	15	NA
Lead	--	--	--	--	NA	--	--	--	NA
Selenium	--	--	--	--	NA	--	--	--	NA
DISSOLVED MERCURY (μg/L):	0.6	--	--	--	NA	--	--	--	NA
DISSOLVED ICP METALS (μg/L):									
Aluminum	--	--	--	--	NA	140	--	--	NA
Antimony	--	--	--	--	NA	--	--	--	NA
Barium	300	290	380	290	NA	210	210	210	NA
Beryllium	1.6	1.7	3.0	3.0	NA	1.4	1.0	2.0	NA
Cadmium	--	--	--	--	NA	--	--	--	NA
Calcium	170000	170000	220000	210000	NA	140000	140000	140000	NA
Chromium	--	--	--	--	NA	--	--	--	NA
Iron	17000	17000	18000	15000	NA	4600	5300	5400	NA
Magnesium	27000	27000	35000	33000	NA	25000	24000	24000	NA
Manganese	1600	1600	1900	2600	NA	1500	1500	1500	NA
Nickel	--	--	--	11	NA	--	--	13	NA
Potassium	9000	8900	11000	10000	NA	8200	7900	8300	NA
Silver	--	--	--	3.0	NA	--	--	7.0	NA
Sodium	45000	44000	50000	42000	NA	150000	140000	140000	NA
Vanadium	--	--	--	--	NA	--	--	--	NA
Zinc	9.8 (B1)	11 (B1)	4.0 (B1)	6.1 (B1)	NA	19 (B1)	10 (B1)	4.0 (B1)	NA

TABLE 4-16

COMPARISON OF BASELINE AND QUARTERLY GROUND-WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Date Collected	SAMPLE SFL92201 07-22-92	DUPLICATE SFL92202 07-22-92	SFL92201 11-03-92	SFL92201 02-02-93	SFL92201 05-05-93	SFL92203 07-22-92	SFL92203 11-03-92	SFL92203 02-02-93	SFL92203 05-05-93
TOTAL RECOVERABLE FURNACE METALS (µg/L):									
Arsenic	--	--	--	2.1	2.3	19	13	13	17
Lead	--	--	-- (M2)	--	1.3	--	-- (M2)	--	--
Selenium	--	--	-- (M2)	--	--	1.0	-- (M2)	--	--
Thallium	NA	NA	NA	NA	--	NA	NA	NA	--
TOTAL ICP METALS (µg/L):									
Aluminum	--	--	--	--	--	110	350	--	100
Antimony	--	--	--	--	--	--	--	--	--
Barium	290	300	400	320	200	220	230	220	190
Beryllium	1.6	1.8	2.0	3.0	2.0	2.0	2.0	2.0	--
Cadmium	--	--	--	--	--	--	--	--	--
Calcium	170000	170000	220000	220000	190000	140000	140000	140000	130000
Chromium	--	--	--	--	--	--	--	--	--
Cobalt	--	--	--	--	--	--	--	--	--
Copper	--	--	--	--	8.0	--	--	--	--
Iron	17000	17000	19000	16000	11000	4400	5900	5300	4700
Magnesium	27000	27000	36000	35000	29000	25000	25000	23000	22000
Manganese	1600	1600	2000	2700	1600	1500	1500	1400	1400
Nickel	--	--	--	21	--	--	--	14	--
Potassium	8800	8900	11000	11000	10000	8000	8000	8400	7700
Silver	--	--	--	8.0	--	--	--	3.0	--
Sodium	44000	44000	51000	44000	39000	140000	140000	130000	140000
Vanadium	--	--	--	--	--	--	--	--	--
Zinc	7.8 (B1)	6.6 (B1)	4.0	5.0	--	14 (B1)	7.0	4.0	--
WET CHEMISTRY (mg/L):									
Total Suspended Solids	NA	NA	37	NA	NA	NA	30	NA	NA
Inorganic Chloride	60	61	83.4	68	58	279	275	281	257
Nitrate	--	--	--	--	--	--	--	--	--
Sulfate	78	78	152 (M2)	175	167	196	209 (M2)	206	204
Ammonia (N)	NA	NA	0.55	NA	NA	NA	0.23	NA	NA
Organic Carbon	3.0 (M1)	3.2 (M1)	5.0	6.2	5.5	--	2.2	2.2	2.8
Hardness as $CaCO_3$	NA	NA	692	NA	NA	NA	NA	NA	NA
Bicarbonate as $CaCO_3$	603	603	532	582	436	255	199	211	200
Alkalinity as $CaCO_3$	NA	NA	532	NA	NA	NA	199	NA	NA
Total Cyanide	--	--	--	--	--	--	--	--	--
Amenable CN	-- (M2)	-- (M2)	--	--	--	-- (M2)	--	--	--
Nitrogen (TKN)	NA	NA	1.1	NA	NA	NA	--	NA	NA
Total Sulfide	43 (E)	42 (E)	--	454	301	24 (E)	--	414	310
BOD (5 day)	NA	NA	1.2	NA	NA	NA	--	NA	NA
COD	NA	NA	21	NA	NA	NA	19	NA	NA

NOTE: No positive results were obtained for semi-volatile organics, pesticides/PCBs, explosives, organophosphorous pesticides or herbicides.

-- Not detected.

NA - Not analyzed.

B1 - Sample results are less than 5 times the amount detected in the method blank. Result is estimated.

B2 - Sample results are less than 10 times the amount detected in the method blank. Result is estimated.

E - Estimated result.

F - Field duplicate RPD exceeds control limit. Estimated due to poor precision.

M1 - Matrix spike recovery is high due to sample matrix effect. Sample result is biased high.

M2 - Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.

T - Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.

R - Result is rejected.

TABLE 4-16

COMPARISON OF BASELINE AND QUARTERLY GROUND-WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Date Collected	SFL92301 07-23-92	SFL92301 11-03-92	SFL92301 02-02-93	SFL92301 05-06-93	SFL92302 07-22-92	SFL92302 11-03-92	SFL92302 02-02-93	SFL92302 05-06-93	SFL92303 07-22-92	SFL92303 11-03-92	SFL92303 02-02-93	SFL92303 05-06-93
<u>VOLATILE ORGANICS (µg/L):</u>												
1,1,1,2-Tetrachloroethane	--	--	--	--	--	--	--	--	--	--	--	--
1,1,2,2-Tetrachloroethane	--	--	--	--	--	--	--	--	--	--	--	--
1,1,2-Trichloroethane	--	--	--	--	--	--	--	--	--	--	--	--
1,2,3-Trichloropropane	--	--	--	--	--	--	--	--	--	--	--	--
1,2-Dibromoethane	--	--	--	--	--	--	--	--	--	--	--	--
1,1-Dichloroethane	--	--	--	--	--	--	--	--	--	--	--	--
1,2-Dichloroethane	--	--	--	--	--	--	--	--	--	--	--	--
1,2-Dichloropropane	--	--	--	--	--	--	--	--	--	--	--	--
2-Hexanone	--	--	--	--	--	--	--	--	--	--	--	--
Benzene	--	--	--	--	--	--	--	--	--	--	--	--
Bromoform	--	--	--	--	--	--	--	--	--	--	--	--
Chlorodibromomethane	--	--	--	--	--	--	--	--	--	--	--	--
Ethyl methacrylate	--	--	--	--	--	--	--	--	--	--	--	--
Methacrylonitrile	--	--	--	--	--	--	--	--	--	--	--	--
Methyl chloride	--	--	--	--	--	--	--	--	--	--	--	--
Methyl isobutyl ketone	--	--	--	--	--	--	--	--	--	--	--	--
Methylene bromide	--	--	--	--	--	--	--	--	--	--	--	--
Methylene chloride	26 (B2)	7.0 (B2)	--	--	--	6.9 (B2)	--	14	--	--	11	--
Pentachloroethane	--	--	--	--	--	--	--	--	--	--	--	--
Styrene	--	--	--	--	--	--	--	--	--	--	--	--
Trichlorofluoromethane	--	--	--	--	--	--	--	--	--	--	--	--
Vinyl chloride	--	--	--	--	--	--	--	--	--	--	--	--
Xylenes (total)	--	--	--	--	--	--	--	--	--	--	--	--
cis-1,3-Dichloropropene	--	--	--	--	--	--	--	--	--	--	--	--
trans-1,2-Dichloroethene	--	--	--	--	--	--	--	--	--	--	--	--
trans-1,4-Dichloro-2-butene	--	--	--	--	--	--	--	--	--	--	--	--
Trichloroethene	--	--	--	--	--	--	--	--	--	--	--	--
<u>TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L):</u>	--	2.2 (E)	--	--	--	14 (E)	--	--	--	-- (E)	--	0.74
<u>DISSOLVED FURNACE METALS (µg/L):</u>												
Arsenic	2.6	--	3.9	NA	23	22	27	NA	21	22	20	NA
Lead	--	--	--	NA	--	--	--	NA	--	--	--	NA
Selenium	--	1.0	--	NA	--	--	--	NA	--	--	--	NA
<u>DISSOLVED MERCURY (µg/L):</u>	--	--	--	NA	--	--	--	NA	--	--	--	NA
<u>DISSOLVED ICP METALS (µg/L):</u>												
Aluminum	--	--	--	NA	--	--	--	NA	--	130	--	NA
Antimony	--	--	--	NA	--	--	--	NA	--	--	26	NA
Barium	89	200	210	NA	87	240	260	NA	160	190	170	NA
Beryllium	--	2.0	2.0	NA	--	1.0	2.0	NA	1.0	1.0	2.0	NA
Cadmium	--	--	--	NA	--	--	--	NA	--	--	--	NA
Calcium	62000	190000	180000	NA	46000	110000	130000	NA	110000	130000	130000	NA
Chromium	--	--	--	NA	--	--	--	NA	--	10	--	NA
Iron	2200	100	2100	NA	2800	7400	8800	NA	2800	3300	3700	NA
Magnesium	8400	28000	2600	NA	7000	17000	20000	NA	19000	22000	23000	NA
Manganese	420	660	1200	NA	470	1200	1300	NA	1100	1300	1400	NA
Nickel	--	--	--	NA	--	--	--	NA	--	--	--	NA
Potassium	9600	18000	15000	NA	5500	8200	8600	NA	7100	7400	7900	NA
Silver	--	--	--	NA	--	--	--	NA	--	--	--	NA
Sodium	59000	58000	51000	NA	86000	84000	90000	NA	110000	100000	100000	NA
Vanadium	--	--	--	NA	--	--	5.0	NA	--	--	--	NA
Zinc	10 (B1)	--	4.0 (B1)	NA	10 (B1)	12 (B1)	4.0 (B1)	NA	9.8 (B1)	11 (B1)	6.0 (B1)	NA

TABLE 4-16

COMPARISON OF BASELINE AND QUARTERLY GROUND-WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Date Collected	SFL92301 07-23-92	SFL92301 11-03-92	SFL92301 02-02-93	SFL92301 05-06-93	SFL92302 07-22-92	SFL92302 11-03-92	SFL92302 02-02-93	SFL92302 05-06-93	SFL92303 07-22-92	SFL92303 11-03-92	SFL92303 02-02-93	SFL92303 05-06-93
TOTAL RECOVERABLE FURNACE METALS ($\mu g/L$):												
Arsenic	2.6	2.3	2.8	2.4	25	45	21	16	24	21	19	21
Lead	--	-- (M2)	--	--	--	-- (M2)	--	1.1	--	-- (M2)	--	--
Selenium	--	1.1 (M2)	--	--	--	-- (M2)	--	--	--	-- (M2)	--	--
Thallium	NA	NA	NA	--	NA	NA	NA	1.7	NA	NA	NA	1.7
TOTAL ICP METALS ($\mu g/L$):												
Aluminum	--	--	--	--	110	--	--	--	--	--	--	--
Antimony	--	--	--	--	--	--	--	--	--	--	--	--
Barium	68	210	190	110	82	230	250	130	160	170	180	130
Beryllium	--	2.0	3.0	--	--	1.0	2.0	--	1.0	1.0	2.0	--
Cadmium	--	--	--	--	--	--	--	--	--	5.0	--	--
Calcium	60000	190000	190000	120000	44000	110000	140000	71000	110000	130000	140000	100000
Chromium	--	--	--	--	--	--	--	9.0	--	--	15 (B1)	--
Cobalt	--	--	9.0	--	--	--	12	--	--	--	9.0	--
Copper	--	--	--	--	--	--	--	--	--	--	--	--
Iron	2200	63	2000	1300	2700	7700	9300	4200	3000	3600	3800	3000
Magnesium	8200	30000	27000	19000	6800	18000	21000	11000	19000	22000	24000	18000
Manganese	410	660	1300	650	440	1200	1400	670	1100	1300	1400	1100
Nickel	--	--	--	--	--	--	20	--	--	--	13	--
Potassium	9500	19000	16000	11000	5300	8300	9200	5000	7200	7500	8400	6300
Silver	--	--	4.0	--	--	--	--	--	--	--	--	--
Sodium	58000	59000	53000	53000	85000	85000	94000	55000	110000	100000	110000	69000
Vanadium	--	--	--	--	--	--	--	--	--	--	--	--
Zinc	8.9 (B1)	--	5.0	--	14 (B1)	--	4.0	--	18 (B1)	5.0	4.0	--
WET CHEMISTRY (mg/L):												
Total Suspended Solids	NA	190 (M2)	NA	NA	NA	15	NA	NA	NA	11	NA	NA
Inorganic Chloride	59	0.44	90	67.1	73	113	150	61	149	141	194	67
Nitrate	--	5.2	1.5	1.8	--	--	--	--	--	--	--	--
Sulfate	73	580	177	161	73	132 (M2)	162	107	127	153 (M2)	178	109
Ammonia (N)	NA	453	NA	NA	NA	0.36	NA	NA	NA	0.19	NA	NA
Organic Carbon	3.9 (M1)	453	4.5	3.7	2.6 (M1)	3.3	2.6	2.9	--	--	2.0	2.4
Hardness as $CaCO_3$	NA	--	NA	NA	NA	348	NA	NA	NA	392	NA	NA
Bicarbonate as $CaCO_3$	209	--	456	275	193	278	302	154	322	284	291	281
Alkalinity as $CaCO_3$	NA	--	NA	NA	NA	278	NA	NA	NA	284	NA	NA
Total Cyanide	--	--	--	--	--	--	--	--	--	--	--	--
Amenable CN	-- (M2)	--	--	--	-- (M2)	--	--	--	-- (M2)	--	--	--
Nitrogen (TKN)	NA	1.1	--	NA	NA	--	NA	NA	NA	--	NA	NA
Total Sulfide	41 (E)	--	406	320	51 (E)	--	430	318	53 (E)	--	446	314
BOD (5 day)	NA	--	NA	NA	NA	--	NA	NA	NA	--	NA	NA
COD	NA	18.5	NA	NA	NA	--	NA	NA	NA	--	NA	NA

NOTE: No positive results were obtained for semi-volatile organics, pesticides/PCBs, explosives, organophosphorous pesticides or herbicides.
-- Not detected. NA – Not analyzed.
B1 – Sample results are less than 5 times the amount detected in the method blank. Result is estimated.
B2 – Sample results are less than 10 times the amount detected in the method blank. Result is estimated.
E – Estimated result.
F – Field duplicate RPD exceeds control limit. Estimated due to poor precision.
M1 – Matrix spike recovery is high due to sample matrix effect. Sample result is biased high.
M2 – Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.
T – Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.
R – Result is rejected.

TABLE 4–16

COMPARISON OF BASELINE AND QUARTERLY GROUND–WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Date Collected	SFL92401 07–22–92	SFL92401 11–04–92	SFL92401 02–02–93	SFL92401 05–04–93	SFL92403 07–22–92	SFL92403 11–04–92	SFL92403 02–02–93	SFL92403 05–04–93
VOLATILE ORGANICS (µg/L):								
1,1,1,2–Tetrachloroethane	--	--	--	--	--	--	--	--
1,1,2,2–Tetrachloroethane	--	--	--	--	--	--	--	--
1,1,2–Trichloroethane	--	--	--	--	--	--	--	--
1,2,3–Trichloropropane	--	--	--	--	--	--	--	--
1,2–Dibromoethane	--	--	--	--	--	--	--	--
1,1–Dichloroethane	--	--	--	--	--	--	--	--
1,2–Dichloroethane	--	--	--	--	--	--	--	--
1,2–Dichloropropane	--	--	--	--	--	--	--	--
2–Hexanone	--	--	--	--	--	--	--	--
Benzene	--	--	--	--	--	--	--	--
Bromoform	--	--	--	--	--	--	--	--
Chlorodibromomethane	--	--	--	--	--	--	--	--
Ethyl methacrylate	--	--	--	--	--	--	--	--
Methacrylonitrile	--	--	--	--	--	--	--	--
Methyl chloride	--	--	--	--	--	--	--	--
Methyl isobutyl ketone	--	--	--	--	--	--	--	--
Methylene bromide	--	--	--	--	--	--	--	--
Methylene chloride	6.8 (B2)(T)	12 (B2)	--	--	8.1 (B2)(T)	13 (B2)	10	--
Pentachloroethane	--	--	--	--	--	--	--	--
Styrene	--	--	--	--	--	--	--	--
Trichlorofluoromethane	--	--	--	2.1	--	--	--	--
Vinyl chloride	--	--	--	--	--	--	--	--
Xylenes (total)	--	--	--	--	--	--	--	--
cis–1,3–Dichloropropene	--	--	--	--	--	--	--	--
trans–1,2–Dichloroethene	--	--	--	--	--	--	--	--
trans–1,4–Dichloro–2–butene	--	--	--	--	--	--	--	--
Trichloroethene	--	--	--	--	--	--	--	--
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L):	--	-- (E)	--	--	--	-- (E)	--	--
DISSOLVED FURNACE METALS (µg/L):								
Arsenic	--	--	--	NA	2.7	2.5	4.4	NA
Lead	--	--	--	NA	--	--	--	NA
Selenium	--	--	--	NA	--	--	--	NA
DISSOLVED MERCURY (µg/L):	--	--	--	NA	--	--	--	NA
DISSOLVED ICP METALS (µg/L):								
Aluminum	--	--	430	NA	170	--	--	NA
Antimony	--	--	--	NA	--	--	23	NA
Barium	1000	930	880	NA	800	720	710	NA
Beryllium	1.9	2.0	2.0	NA	2.2	2.0	3.0	NA
Cadmium	--	--	--	NA	--	--	--	NA
Calcium	200000	200000	180000	NA	200000	200000	190000	NA
Chromium	--	--	--	NA	--	--	--	NA
Iron	18000	18000	17000	NA	17000	18000	17000	NA
Magnesium	37000	36000	33000	NA	36000	36000	34000	NA
Manganese	2200	2200	2000	NA	2400	2400	2200	NA
Nickel	--	--	24	NA	--	--	--	NA
Potassium	12000	11000	10000	NA	9700	9500	9400	NA
Silver	--	--	--	NA	--	--	--	NA
Sodium	100000	99000	91000	NA	100000	100000	96000	NA
Vanadium	--	--	--	NA	--	--	--	NA
Zinc	13 (B1)	6.0	--	NA	22 (B1)	4.0	--	NA

TABLE 4-16

COMPARISON OF BASELINE AND QUARTERLY GROUND-WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Date Collected	SFL92401 07-22-92	SFL92401 11-04-92	SFL92401 02-02-93	SFL92401 05-04-93	SFL92403 07-22-92	SFL92403 11-04-92	SFL92403 02-02-93	SFL92403 05-04-93
TOTAL RECOVERABLE FURNACE METALS (µg/L):								
Arsenic	--	--	--	--	2.6	2.8	3.0	2.8
Lead	--	-- (M2)	--	3.0	--	-- (M2)	--	2.7
Selenium	--	-- (M2)	--	--	--	-- (M2)	--	--
Thallium	NA	NA	NA	--	NA	NA	NA	--
TOTAL ICP METALS (µg/L):								
Aluminum	--	--	--	--	--	--	--	--
Antimony	--	--	--	--	--	--	--	--
Barium	1000	930	940	860	830	700	730	730
Beryllium	1.9	2.0	3.0	2.0	1.9	3.0	3.0	2.0
Cadmium	--	--	--	4.0	--	--	--	--
Calcium	200000	190000	200000	190000	210000	200000	200000	190000
Chromium	--	--	--	--	--	--	--	--
Cobalt	--	--	8.0	--	--	--	8.0	--
Copper	--	--	--	--	--	--	--	--
Iron	18000	18000	18000	17000	17000	18000	18000	18000
Magnesium	36000	36000	36000	35000	37000	35000	35000	34000
Manganese	2200	2100	2200	2100	2400	2400	2300	2300
Nickel	--	--	--	--	--	--	20	--
Potassium	11000	11000	11000	11000	9900	9300	10000	8900
Silver	--	--	3.0	--	--	--	4.0	--
Sodium	100000	100000	99000	98000	100000	100000	99000	100000
Vanadium	--	--	--	--	--	--	--	--
Zinc	11 (B1)	4.0	--	--	11 (B1)	--	4.0	--
WET CHEMISTRY (mg/L):								
Total Suspended Solids	NA	40	43	NA	NA	36	37	NA
Inorganic Chloride	139	149	140	173	139	150	146	148
Nitrate	--	--	--	--	--	--	--	--
Sulfate	77	90 (M2)	91	95	75	97 (M2)	102	105
Ammonia (N)	NA	1.52	1.76	NA	NA	0.39	0.72	NA
Organic Carbon	7.5 (M1)	8.5	7.2	6.9	6.7 (M1)	6.7	6.1	5.8
Hardness as $CaCO_3$	NA	NA	684	NA	NA	NA	684	NA
Bicarbonate as $CaCO_3$	831	NA	646	611	793	NA	608	559
Alkalinity as $CaCO_3$	NA	NA	NA	NA	NA	NA	NA	NA
Total Cyanide	--	--	--	--	--	--	--	--
Amenable CN	-- (M2)	--	--	--	-- (M2)	--	--	--
Nitrogen (TKN)	NA	2.5	3.0	NA	NA	1.1	1.0	NA
Total Sulfide	25 (E)	--	482	603	28 (E)	--	474	293
BOD (5 day)	NA	--	--	NA	NA	--	NA	NA
COD	NA	47	--	NA	NA	26	NA	NA

NOTE: No positive results were obtained for semi-volatile organics, pesticides/PCBs, explosives, organophosphorous pesticides or herbicides.

-- Not detected.
NA - Not analyzed.
B1 - Sample results are less than 5 times the amount detected in the method blank. Result is estimated.
B2 - Sample results are less than 10 times the amount detected in the method blank. Result is estimated.
E - Estimated result.
F - Field duplicate RPD exceeds control limit. Estimated due to poor precision.
M1 - Matrix spike recovery is high due to sample matrix effect. Sample result is biased high.
M2 - Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.
T - Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.
R - Result is rejected.

TABLE 4-16

COMPARISON OF BASELINE AND QUARTERLY GROUND-WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Date Collected	SFL92501 07-21-92	SFL92501 11-03-92	SFL92501 02-02-93	SFL92501 05-04-93	SFL92502 07-21-92	SFL92502 11-03-92	SFL92502 02-02-93	SFL92502 05-04-93
VOLATILE ORGANICS (µg/L):								
1,1,1,2-Tetrachloroethane	5.2	--	--	--	--	--	--	--
1,1,2,2-Tetrachloroethane	--	--	--	--	--	--	--	--
1,1,2-Trichloroethane	--	--	--	--	--	--	--	--
1,2,3-Trichloropropane	30	--	--	--	--	--	--	--
1,2-Dibromoethane	21	--	--	--	--	--	--	--
1,1-Dichloroethane	--	--	--	--	--	--	--	--
1,2-Dichloroethane	--	6.8	--	--	--	8.1	--	--
1,2-Dichloropropane	--	--	--	--	--	--	--	--
2-Hexanone	--	--	--	--	--	--	--	--
Benzene	--	--	--	--	--	--	--	--
Bromoform	--	--	--	--	--	--	--	--
Chlorodibromomethane	--	--	--	--	--	--	--	--
Ethyl methacrylate	22	--	--	--	--	--	--	--
Methacrylonitrile	29	--	--	--	--	--	--	--
Methyl chloride	11	--	--	--	--	--	--	--
Methyl isobutyl ketone	--	--	--	--	--	--	--	--
Methylene bromide	19	--	--	--	--	--	--	--
Methylene chloride	--	--	--	--	6.2 (T)	6.9 (B2)	13	--
Pentachloroethane	12	--	--	--	--	--	--	--
Styrene	--	--	--	--	--	--	--	--
Trichlorofluoromethane	5.2	--	--	--	--	--	--	--
Vinyl chloride	14	--	--	--	--	--	--	--
Xylenes (total)	8.4	--	--	--	--	--	--	--
cis-1,3-Dichloropropene	--	--	--	--	--	--	--	--
trans-1,2-Dichloroethene	8.7	--	5.3	3.5	7.9	--	4.0	--
trans-1,4-Dichloro-2-butene	18	--	--	--	--	--	--	--
Trichloroethene	--	--	--	--	--	--	--	--
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L):	--	2.3 (E)	--	--	--	3.1 (E)	--	--
DISSOLVED FURNACE METALS (µg/L								
Arsenic	2.5	--	3.1	NA	15	12	20	NA
Lead	--	2.1	--	NA	--	--	--	NA
Selenium	--	--	--	NA	--	--	--	NA
DISSOLVED MERCURY (µg/L):	--	--	--	NA	--	--	--	NA
DISSOLVED ICP METALS (µg/L):								
Aluminum	--	--	--	NA	--	--	--	NA
Antimony	--	--	--	NA	--	--	--	NA
Barium	240	220	200	NA	360	320	310	NA
Beryllium	2.0	2.0	3.0	NA	1.8	2.0	3.0	NA
Cadmium	--	--	--	NA	--	--	--	NA
Calcium	210000	210000	200000	NA	180000	190000	170000	NA
Chromium	--	20	--	NA	--	--	--	NA
Iron	11000	11000	11000	NA	10000	11000	9900	NA
Magnesium	32000	32000	30000	NA	33000	31000	30000	NA
Manganese	1900	1800	1800	NA	2100	2000	1900	NA
Nickel	--	22	--	NA	--	--	--	NA
Potassium	9600	11000	11000	NA	8700	8900	8400	NA
Silver	--	--	3.0	NA	--	--	5.0	NA
Sodium	68000	69000	61000	NA	73000	69000	67000	NA
Vanadium	--	--	--	NA	--	--	--	NA
Zinc	10 (B1)	7.0 (B1)	4.0 (B1)	NA	15	--	15 (B1)	NA

TABLE 4-16

COMPARISON OF BASELINE AND QUARTERLY GROUND-WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Date Collected	SFL92501 07-21-92	SFL92501 11-03-92	SFL92501 02-02-93	SFL92501 05-04-93	SFL92502 07-21-92	SFL92502 11-03-92	SFL92502 02-02-93	SFL92502 05-04-93
TOTAL RECOVERABLE FURNACE METALS (μg/L):								
Arsenic	--	2.0	2.2	2.7	14	20	14	14
Lead	--	-- (M2)	--	--	--	-- (M2)	--	1.9
Selenium	1.0	1.0 (M2)	--	--	--	-- (M2)	--	--
Thallium	NA	NA	NA	--	NA	NA	NA	--
TOTAL ICP METALS (μg/L):								
Aluminum	--	--	--	--	NA	--	--	--
Antimony	--	--	--	--	NA	--	--	--
Barium	220	240	220	200	NA	340	330	310
Beryllium	2.0	2.0	2.0	2.0	NA	2.0	2.0	2.0
Cadmium	--	--	--	--	NA	--	--	--
Calcium	210000	220000	200000	180000	NA	200000	180000	170000
Chromium	--	--	--	--	NA	--	--	--
Cobalt	--	--	--	--	NA	--	--	--
Copper	--	--	--	--	NA	--	--	--
Iron	12000	11000	11000	9400	NA	11000	9800	11000
Magnesium	32000	33000	31000	30000	NA	32000	31000	30000
Manganese	1900	1900	1800	1700	NA	2100	2000	1900
Nickel	--	18	--	--	NA	--	16	--
Potassium	9800	11000	11000	9400	NA	9400	8900	8400
Silver	--	--	3.0	--	NA	--	--	--
Sodium	69000	71000	63000	70000	NA	72000	70000	70000
Vanadium	--	--	--	--	NA	--	--	--
Zinc	17 (B1)	4.0	--	--	NA	--	--	--
WET CHEMISTRY (mg/L):								
Total Suspended Solids	NA	26	NA	NA	NA	24	20	NA
Inorganic Chloride	91	91	NA	102	102	100	103	103
Nitrate	--	--	NA	--	--	--	--	--
Sulfate	152	168 (M2)	NA	102	91	144 (M2)	96	83
Ammonia (N)	NA	0.43	NA	NA	NA	0.3	0.27	NA
Organic Carbon	5.4 (M1)	4.2	NA	3.9	6.2 (M1)	3.6	3.3	4.1
Hardness as CaCO$_3$	NA	NA	NA	NA	NA	608	576	NA
Bicarbonate as CaCO$_3$	683	530	NA	526	407	508	519	524
Alkalinity as CaCO$_3$	NA	530	NA	NA	NA	508	NA	NA
Total Cyanide	--	--	NA	--	--	--	--	--
Amenable CN	-- (M2)	--	NA	--	-- (M2)	--	--	--
Nitrogen (TKN)	NA	--	NA	NA	--	--	--	NA
Total Sulfide	77 (E)	--	NA	301	26 (E)	--	442	282
BOD (5 day)	NA	--	NA	NA	NA	1.0	--	NA
COD	NA	16	NA	NA	NA	19	--	NA

NOTE: No positive results were obtained for semi-volatile organics, pesticides/PCBs, explosives, organophosphorous pesticides or herbicides.

-- Not detected. NA - Not analyzed.

B1 - Sample results are less than 5 times the amount detected in the method blank. Result is estimated.

B2 - Sample results are less than 10 times the amount detected in the method blank. Result is estimated.

E - Estimated result.

F - Field duplicate RPD exceeds control limit. Estimated due to poor precision.

M1 - Matrix spike recovery is high due to sample matrix effect. Sample result is biased high.

M2 - Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.

T - Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.

R - Result is rejected.

TABLE 4-16

COMPARISON OF BASELINE AND QUARTERLY GROUND-WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Date Collected	SAMPLE SFL92503 07-23-92	DUPLICATE SFL92504 07-23-92	SAMPLE SFL92503 11-03-92	DUPLICATE SFL92504 11-03-92	SAMPLE SFL92503 02-02-93	DUPLICATE SFL92504 02-02-93	SAMPLE SFL92503 05-04-93	DUPLICATE SFL92504 05-04-93
<u>VOLATILE ORGANICS (µg/L):</u>								
1,1,1,2-Tetrachloroethane	6.0	--	--	--	--	--	--	--
1,1,2,2-Tetrachloroethane	6.3	--	--	--	--	--	--	--
1,1,2-Trichloroethane	--	--	--	--	--	--	--	--
1,2,3-Trichloropropane	34	--	--	--	--	--	--	--
1,2-Dibromoethane	24	--	--	--	--	--	--	--
1,1-Dichloroethane	--	--	--	--	--	--	--	--
1,2-Dichloroethane	--	--	--	--	--	--	--	--
1,2-Dichloropropane	--	--	--	--	--	--	--	--
2-Hexanone	--	--	--	--	--	--	--	--
Benzene	--	--	--	--	--	--	--	--
Bromoform	--	--	--	--	--	--	--	--
Chlorodibromomethane	--	--	--	--	--	--	--	--
Ethyl methacrylate	24	--	--	--	--	--	--	--
Methacrylonitrile	30	--	--	--	--	--	--	--
Methyl chloride	11	--	--	--	--	--	--	--
Methyl isobutyl ketone	--	--	--	--	--	--	--	--
Methylene bromide	22	--	--	--	--	--	--	--
Methylene chloride	--	--	--	--	10	10	12 (T)	--
Pentachloroethane	13	--	--	--	--	--	--	--
Styrene	--	--	--	--	--	--	--	--
Trichlorofluoromethane	5.2	--	--	--	--	--	--	--
Vinyl chloride	--	--	--	--	--	--	--	--
Xylenes (total)	9.1	--	--	--	--	--	--	--
cis-1,3-Dichloropropene	--	--	--	--	--	--	--	--
trans-1,2-Dichloroethene	--	--	--	--	--	--	--	--
trans-1,4-Dichloro-2-butene	20	--	--	--	--	--	--	--
Trichloroethene	--	--	--	--	--	--	--	--
<u>TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L):</u>	--	--	-- (E)	2.0 (E)	--	--	--	--
<u>DISSOLVED FURNACE METALS (µg/L</u>								
Arsenic	23	22	22	21	51	51	NA	NA
Lead	--	--	--	--	--	--	NA	NA
Selenium	--	--	--	--	--	--	NA	NA
<u>DISSOLVED MERCURY (µg/L):</u>	--	--	--	--	--	--	NA	NA
<u>DISSOLVED ICP METALS (µg/L):</u>								
Aluminum	--	--	--	--	--	--	NA	NA
Antimony	--	--	--	--	--	--	NA	NA
Barium	300	290	290	310	260	270	NA	NA
Beryllium	1.5	1.6	2.0	2.0	2.0	2.0	NA	NA
Cadmium	5.1	--	--	--	--	--	NA	NA
Calcium	160000	160000	160000	170000	150000	160000	NA	NA
Chromium	--	--	--	--	--	--	NA	NA
Iron	9500	9500	11000	11000	11000	11000	NA	NA
Magnesium	31000	31000	31000	31000	28000	28000	NA	NA
Manganese	1700	1700	1900	1900	1700	1800	NA	NA
Nickel	--	--	26	21	--	--	NA	NA
Potassium	10000	10000	8900	9100	8500	8600	NA	NA
Silver	--	--	--	--	--	--	NA	NA
Sodium	73000	74000	73000	75000	64000	66000	NA	NA
Vanadium	--	--	--	--	--	--	NA	NA
Zinc	22 (B1)	8.7 (B1)	28 (B1)	8.0 (B1)	4.0 (B1)	10 (B1)	NA	NA

TABLE 4-16

COMPARISON OF BASELINE AND QUARTERLY GROUND-WATER RESULTS

Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Date Collected	SAMPLE SFL92503 07-23-92	DUPLICATE SFL92504 07-23-92	SAMPLE SFL92503 11-03-92	DUPLICATE SFL92504 11-03-92	SAMPLE SFL92503 02-02-93	DUPLICATE SFL92504 02-02-93	SAMPLE SFL92503 05-04-93	DUPLICATE SFL92504 05-04-93
TOTAL RECOVERABLE FURNACE METALS (μg/L):								
Arsenic	24	24	22	42	21	22	24	24
Lead	--	--	-- (M2)	-- (M2)	--	--	1.1	1.1
Selenium	1.0	--	-- (M2)	-- (M2)	--	--	--	--
Thallium	NA	NA	NA	NA	NA	NA	--	--
TOTAL ICP METALS (μg/L):								
Aluminum	--	--	--	--	--	--	--	--
Antimony	--	--	--	--	--	--	--	--
Barium	310	300	310	300	310	280	310	300
Beryllium	1.7	1.7	2.0	2.0	2.0	2.0	2.0	2.0
Cadmium	--	--	--	--	--	--	--	--
Calcium	160000	160000	170000	170000	160000	160000	170000	160000
Chromium	--	--	--	--	--	--	--	--
Cobalt	--	--	--	--	--	--	--	--
Copper	--	--	--	--	--	--	--	--
Iron	10000	10000	12000	12000	12000	12000	14000	14000
Magnesium	31000	31000	32000	32000	30000	29000	31000	30000
Manganese	1800	1700	1900	1900	1900	1800	2000	1900
Nickel	--	--	--	--	--	--	--	--
Potassium	10000	10000	9100	9100	9300	9200	8700	8500
Silver	--	--	--	--	--	3.0	--	--
Sodium	75000	74000	76000	76000	70000	68000	73000	71000
Vanadium	--	--	--	--	--	--	--	--
Zinc	12 (B1)	8.2 (B1)	6.0	4.0	--	--	--	--
WET CHEMISTRY (mg/L):								
Total Suspended Solids	NA	NA	25	28	NA	NA	NA	NA
Inorganic Chloride	100	99	110	117	NA	NA	105	107
Nitrate	--	--	--	--	NA	NA	--	--
Sulfate	81	81	86	84 (M2)	NA	NA	77	77
Ammonia (N)	NA	NA	0.26	0.28	NA	NA	NA	NA
Organic Carbon	3.4 (M1)	3.3 (M1)	3.6	3.5	NA	NA	4.0	3.9
Hardness as $CaCO_3$	NA	NA	520	540	NA	NA	NA	NA
Bicarbonate as $CaCO_3$	598	619	467	465	NA	NA	524	518
Alkalinity as $CaCO_3$	NA	NA	467	465	NA	NA	NA	NA
Total Cyanide	--	--	--	--	NA	NA	--	--
Amenable CN	-- (M2)	-- (M2)	--	--	NA	NA	--	--
Nitrogen (TKN)	NA	NA	--	1.1 (E)	NA	NA	NA	NA
Total Sulfide	13 (E)(F)	27 (E)	--	--	NA	NA	286	306
BOD (5 day)	NA	NA	1.0	2.0	NA	NA	NA	NA
COD	NA	NA	23	--	NA	NA	NA	NA

NOTE: No positive results were obtained for semi-volatile organics, pesticides/PCBs, explosives, organophosphorous pesticides or herbicides.

-- Not detected. NA - Not analyzed.

B1 - Sample results are less than 5 times the amount detected in the method blank. Result is estimated.

B2 - Sample results are less than 10 times the amount detected in the method blank. Result is estimated.

E - Estimated result.

F - Field duplicate RPD exceeds control limit. Estimated due to poor precision.

M1 - Matrix spike recovery is high due to sample matrix effect. Sample result is biased high.

M2 - Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.

T - Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.

R - Result is rejected.

TABLE 4-16

COMPARISON OF BASELINE AND QUARTERLY GROUND-WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Date Collected	SFL92601 07-23-92	SFL92601 11-05-92	SFL92601 02-02-93	SFL92601 05-05-93	SFL92602 07-21-92	SFL92602 11-05-92	SFL92602 02-02-93	SFL92602 05-05-93	SFL92603 07-21-92	SFL92603 11-04-92	SFL92603 02-02-93	SFL92603 05-05-93
VOLATILE ORGANICS (µg/L):												
1,1,1,2-Tetrachloroethane	--	--	--	--	--	--	--	--	--	--	--	--
1,1,2,2-Tetrachloroethane	--	--	--	--	--	--	--	--	--	--	--	--
1,1,2-Trichloroethane	--	--	--	--	--	--	--	--	--	--	--	--
1,2,3-Trichloropropane	--	--	--	--	--	--	--	--	--	--	--	--
1,2-Dibromoethane	--	--	--	--	--	--	--	--	--	--	--	--
1,1-Dichloroethane	--	--	--	3.0	--	--	--	--	--	--	--	--
1,2-Dichloroethane	--	16	--	--	--	--	--	--	--	--	--	--
1,2-Dichloropropane	--	--	--	--	--	--	--	--	--	--	--	--
2-Hexanone	--	--	--	--	--	--	--	--	--	--	--	--
Benzene	8.9	5.0	1.6	14	--	4.9	1.5	--	--	--	--	--
Bromoform	--	--	--	--	--	--	--	--	--	--	--	--
Chlorodibromomethane	--	--	--	--	--	--	--	--	--	--	--	--
Ethyl methacrylate	--	--	--	--	--	--	--	--	--	--	--	--
Methacrylonitrile	--	--	--	--	--	--	--	--	--	--	--	--
Methyl chloride	--	--	--	--	--	--	--	--	--	--	--	--
Methyl isobutyl ketone	--	--	--	--	--	--	--	--	--	--	--	--
Methylene bromide	--	--	--	--	--	--	--	--	--	--	--	--
Methylene chloride	--	7.6 (B2)	--	--	--	32 (B2)	--	11 (T)	--	10 (B2)	13	--
Pentachloroethane	--	--	--	--	--	--	--	--	--	--	--	--
Styrene	--	--	--	--	--	--	--	--	--	--	--	--
Trichlorofluoromethane	--	--	--	--	--	--	--	--	--	--	--	--
Vinyl chloride	18	--	--	--	--	--	--	--	--	--	--	--
Xylenes (total)	--	--	--	--	--	--	--	--	--	--	--	--
cis-1,3-Dichloropropene	--	--	--	--	--	--	--	--	--	--	--	--
trans-1,2-Dichloroethene	--	--	--	6.2	--	--	--	--	--	--	--	--
trans-1,4-Dichloro-2-butene	--	--	--	--	--	--	--	--	--	--	--	--
Trichloroethene	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L):	--	-- (E)	--	--	--	-- (E)	--	--	--	-- (E)	--	--
DISSOLVED FURNACE METALS (µg/L												
Arsenic	4.0	6.0	4.4	NA	15	18	18	NA	18	19	22	NA
Lead	--	--	--	NA	--	--	--	NA	--	--	--	NA
Selenium	--	--	--	NA	--	--	--	NA	--	--	--	NA
DISSOLVED MERCURY (µg/L):	--	--	--	NA	--	--	--	NA	--	--	--	NA
DISSOLVED ICP METALS (µg/L):												
Aluminum	--	--	--	NA	--	--	--	NA	--	--	--	NA
Antimony	--	--	--	NA	--	--	--	NA	--	--	--	NA
Barium	2000	1700	1600	NA	620	900	950	NA	260	270	290	NA
Beryllium	3.0	3.0	3.0	NA	1.4	2.0	3.0	NA	1.4	2.0	2.0	NA
Cadmium	--	--	--	NA	--	--	--	NA	--	--	--	NA
Calcium	330000	310000	300000	NA	150000	210000	220000	NA	140000	160000	160000	NA
Chromium	--	--	--	NA	--	--	--	NA	--	--	--	NA
Iron	35000	28000	30000	NA	18000	23000	25000	NA	5700	8100	8200	NA
Magnesium	67000	74000	65000	NA	22000	34000	36000	NA	26000	30000	28000	NA
Manganese	2500	2100	2000	NA	1600	2100	2200	NA	1500	1900	1900	NA
Nickel	--	34	--	NA	--	--	--	NA	--	--	--	NA
Potassium	15000	14000	14000	NA	12000	12000	13000	NA	9900	9600	9300	NA
Silver	--	--	--	NA	--	--	--	NA	--	--	--	NA
Sodium	64000	59000	64000	NA	43000	58000	61000	NA	71000	80000	76000	NA
Vanadium	--	8.0	--	NA	--	9.0	--	NA	--	--	--	NA
Zinc	11 (B1)	12	--	NA	11 (B1)	7.0	--	NA	18 (B1)	--	4.0 (B1)	NA

TABLE 4-16

COMPARISON OF BASELINE AND QUARTERLY GROUND-WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Date Collected	SFL92601 07-23-92	SFL92601 11-05-92	SFL92601 02-02-93	SFL92601 05-05-93	SFL92602 07-21-92	SFL92602 11-05-92	SFL92602 02-02-93	SFL92602 05-05-93	SFL92603 07-21-92	SFL92603 11-04-92	SFL92603 02-02-93	SFL92603 05-05-93
TOTAL RECOVERABLE FURNACE METALS (µg/L):												
Arsenic	3.9	6.6	4.2	6.7	16	20	19	22	18	20	16	21
Lead	--	-- (M2)	--	1.3	--	-- (M2)	--	1.3	--	-- (M2)	--	3.2
Selenium	--	-- (M2)	--	--	1.0	-- (M2)	--	--	2.2	-- (M2)	--	--
Thallium	NA	NA	NA	--	NA	NA	NA	--	NA	NA	NA	--
TOTAL ICP METALS (µg/L):												
Aluminum	--	--	--	--	110	--	--	--	--	--	--	--
Antimony	--	--	--	--	--	--	--	--	--	--	--	--
Barium	2000	1700	1800	1800	650	940	1000	880	300	270	320	280
Beryllium	3.2	4.0	4.0	3.0	1.6	2.0	3.0	2.0	2.3	2.0	2.0	2.0
Cadmium	--	--	--	--	--	--	--	--	--	--	--	--
Calcium	330000	330000	320000	300000	160000	210000	230000	200000	140000	150000	160000	150000
Chromium	--	--	12 (B1)	--	--	--	--	--	--	--	13 (B1)	--
Cobalt	--	--	--	--	--	--	--	--	10	--	10	--
Copper	--	--	--	8.0	--	--	--	9.0	--	--	--	--
Iron	35000	28000	32000	36000	20000	24000	27000	23000	5800	7900	8500	8200
Magnesium	68000	77000	70000	68000	24000	36000	38000	33000	27000	29000	30000	27000
Manganese	2500	2100	2100	2200	1700	2100	2300	2200	1500	1900	2000	2000
Nickel	--	29	13	28	--	20	--	--	--	--	16	--
Potassium	15000	14000	15000	14000	12000	12000	14000	13000	10000	9400	9900	8900
Silver	--	--	--	--	--	--	--	--	--	--	4.0	--
Sodium	63000	61000	69000	74000	46000	61000	64000	58000	73000	78000	80000	97000
Vanadium	--	9.0	--	--	--	--	--	--	--	--	--	--
Zinc	8.6 (B1)	13	13	--	14 (B1)	12	--	--	20 (B1)	4.0	6.0	--
WET CHEMISTRY (mg/L):												
Total Suspended Solids	NA	60	70	NA	NA	60	63	NA	NA	20	21	NA
Inorganic Chloride	110	144	135	130	55	88	92	93	78	123	133	145
Nitrate	--	--	--	--	--	--	--	--	--	--	--	--
Sulfate	--	12 (M2)	4.9	4.2	62	48 (M2)	34	72	99	153 (M2)	162	172
Ammonia (N)	NA	0.25	0.23	NA	NA	0.44	0.47	NA	NA	0.26	0.36	NA
Organic Carbon	11 (M1)	14	12	14	3.5 (M1)	7.0	7.3	5.5	4.6 (M1)	3.1	2.7	3.4
Hardness as $CaCO_3$	NA	1120	1100	NA	NA	684	772	NA	NA	NA	588	NA
Bicarbonate as $CaCO_3$	1360	NA	1090	1040	574	NA	775	588	531	NA	428	388
Alkalinity as $CaCO_3$	NA	1090	NA	NA	NA	654	NA	NA	NA	NA	NA	NA
Total Cyanide	--	--	--	--	--	--	--	--	--	--	--	--
Amenable CN	-- (M2)	--	--	--	-- (M2)	--	--	--	-- (M2)	--	--	--
Nitrogen (TKN)	NA	--	1.0	NA	--	--	1.0	NA	NA	--	--	NA
Total Sulfide	12 (E)	--	445	306	27 (E)	--	429	310	38 (E)	--	418	301
BOD (5 day)	NA	19	3.0	NA	NA	10	4.0	NA	NA	--	--	NA
COD	NA	55	31	NA	NA	23	23	NA	NA	21	--	NA

NOTE: No positive results were obtained for semi-volatile organics, pesticides/PCBs, explosives, organophosphorous pesticides or herbicides.
-- Not detected. NA - Not analyzed.
B1 - Sample results are less than 5 times the amount detected in the method blank. Result is estimated.
B2 - Sample results are less than 10 times the amount detected in the method blank. Result is estimated.
E - Estimated result.
F - Field duplicate RPD exceeds control limit. Estimated due to poor precision.
M1 - Matrix spike recovery is high due to sample matrix effect. Sample result is biased high.
M2 - Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.
T - Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.
R - Result is rejected.

TABLE 4-16

COMPARISON OF BASELINE AND QUARTERLY GROUND-WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Date Collected	SFL92701 07-21-92	SFL92701 11-04-92	SFL92701 02-02-93	SFL92701 05-05-93	SFL92703 07-21-92	SFL92703 11-04-92	SFL92703 02-02-93	SFL92703 05-05-93
VOLATILE ORGANICS (µg/L):								
1,1,1,2-Tetrachloroethane	--	--	--	--	--	--	--	--
1,1,2,2-Tetrachloroethane	--	--	--	--	--	--	--	--
1,1,2-Trichloroethane	--	--	--	--	--	--	--	--
1,2,3-Trichloropropane	--	--	--	--	--	--	--	--
1,2-Dibromoethane	--	--	--	--	--	--	--	--
1,1-Dichloroethane	--	--	--	--	--	--	--	--
1,2-Dichloroethane	--	--	--	--	--	--	--	--
1,2-Dichloropropane	--	--	--	--	--	--	--	--
2-Hexanone	--	--	--	--	--	--	--	--
Benzene	--	--	--	--	--	--	--	--
Bromoform	--	--	--	--	--	--	--	--
Chlorodibromomethane	--	--	--	--	--	--	--	--
Ethyl methacrylate	--	--	--	--	--	--	--	--
Methacrylonitrile	--	--	--	--	--	--	--	--
Methyl chloride	--	--	--	--	--	--	--	--
Methyl isobutyl ketone	--	--	--	--	--	--	--	--
Methylene bromide	--	--	--	--	--	--	--	--
Methylene chloride	6.3	12 (B2)	11	--	--	12 (B2)	--	--
Pentachloroethane	--	--	--	--	--	--	--	--
Styrene	--	--	--	--	--	--	--	--
Trichlorofluoromethane	--	--	--	--	--	--	--	--
Vinyl chloride	--	--	--	--	--	--	--	--
Xylenes (total)	--	--	--	--	--	--	--	--
cis-1,3-Dichloropropene	--	--	--	--	--	--	--	--
trans-1,2-Dichloroethene	--	--	--	--	--	--	--	--
trans-1,4-Dichloro-2-butene	--	--	--	--	--	--	--	--
Trichloroethene	--	--	--	4.3	--	--	--	--
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L):	--	-- (E)	--	--	--	-- (E)	--	--
DISSOLVED FURNACE METALS (µg/L):								
Arsenic	5.4	6.5	6.5	NA	11	13	15	NA
Lead	--	--	--	NA	--	--	--	NA
Selenium	--	1.5	--	NA	--	--	--	NA
DISSOLVED MERCURY (µg/L):	--	--	--	NA	--	--	--	NA
DISSOLVED ICP METALS (µg/L):								
Aluminum	--	--	--	NA	--	--	--	NA
Antimony	--	--	--	NA	--	--	--	NA
Barium	260	200	240	NA	210	200	200	NA
Beryllium	--	1.0	1.0	NA	1.2	1.0	1.0	NA
Cadmium	--	--	--	NA	--	--	--	NA
Calcium	97000	94000	95000	NA	120000	130000	130000	NA
Chromium	--	--	--	NA	--	--	--	NA
Iron	3300	1400	2900	NA	1600	2100	2200	NA
Magnesium	19000	19000	19000	NA	24000	26000	26000	NA
Manganese	600	500	580	NA	970	1300	1300	NA
Nickel	--	--	--	NA	--	--	15	NA
Potassium	7100	7500	7300	NA	10000	9800	10000	NA
Silver	--	--	7.0	NA	--	--	5.0	NA
Sodium	67000	58000	61000	NA	42000	38000	37000	NA
Vanadium	--	--	--	NA	--	--	--	NA
Zinc	10 (B1)	--	19	NA	10 (B1)	--	9.0	NA

TABLE 4-16

COMPARISON OF BASELINE AND QUARTERLY GROUND-WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	SFL92701	SFL92701	SFL92701	SFL92701	SFL92703	SFL92703	SFL92703	SFL92703
Date Collected	07-21-92	11-04-92	02-02-93	05-05-93	07-21-92	11-04-92	02-02-93	05-05-93
TOTAL RECOVERABLE FURNACE METALS (µg/L):								
Arsenic	4.5	6.2	6.2	6.0	12	14	13	15
Lead	--	-- (M2)	--	3.8	--	-- (M2)	--	--
Selenium	1.6	1.5 (M2)	--	--	1.1	-- (M2)	--	--
Thallium	NA	NA	NA	--	NA	NA	NA	--
TOTAL ICP METALS (µg/L):								
Aluminum	--	--	--	100	150	250	170	--
Antimony	--	--	--	--	--	31	--	--
Barium	260	180	240	300	220	160	200	210
Beryllium	1.0	1.0	1.0	--	1.2	1.0	2.0	--
Cadmium	--	--	--	--	--	--	--	--
Calcium	91000	97000	93000	100000	120000	120000	130000	130000
Chromium	--	--	--	--	--	--	--	--
Cobalt	--	--	--	--	--	--	8.0	--
Copper	--	--	4.0	--	--	--	--	--
Iron	3100	1400	3000	4600	1600	2200	2300	2400
Magnesium	18000	19000	18000	20000	24000	23000	26000	26000
Manganese	560	500	560	710	960	1200	1300	1400
Nickel	--	--	--	--	--	--	--	--
Potassium	6700	7600	7400	6700	10000	8800	10000	8700
Silver	--	--	3.0	--	--	--	8.0	--
Sodium	63000	58000	58000	58000	43000	34000	36000	37000
Vanadium	--	--	10	--	--	--	--	--
Zinc	6.8 (B1)	--	8.0	--	18 (B1)	11	10	--
WET CHEMISTRY (mg/L):								
Total Suspended Solids	NA	6.0	NA	NA	NA	46	NA	NA
Inorganic Chloride	58	52	NA	54.7	39	42	NA	27.8
Nitrate	--	--	NA	--	--	--	NA	--
Sulfate	64	60 (M2)	NA	89.5	122	153 (M2)	NA	135
Ammonia (N)	NA	0.42	NA	NA	NA	0.21	NA	NA
Organic Carbon	4.6 (M1)	2.9	NA	3.4	--	--	NA	--
Hardness as $CaCO_3$	NA	NA	NA	NA	NA	NA	NA	NA
Bicarbonate as $CaCO_3$	407	NA	NA	303	657	NA	NA	--
Alkalinity as $CaCO_3$	NA	NA	NA	NA	NA	NA	NA	NA
Total Cyanide	--	--	NA	--	--	--	NA	--
Amenable CN	-- (M2)	--	NA	--	-- (M2)	--	NA	--
Nitrogen (TKN)	NA	--	NA	NA	NA	--	NA	NA
Total Sulfide	26 (E)	--	NA	290	25 (E)	--	NA	310
BOD (5 day)	NA	--	NA	NA	NA	--	NA	NA
COD	NA	11	NA	NA	NA	--	NA	NA

NOTE: No positive results were obtained for semi-volatile organics, pesticides/PCBs, explosives, organophosphorous pesticides or herbicides.

-- Not detected. NA - Not analyzed.

B1 - Sample results are less than 5 times the amount detected in the method blank. Result is estimated.

B2 - Sample results are less than 10 times the amount detected in the method blank. Result is estimated.

E - Estimated result.

F - Field duplicate RPD exceeds control limit. Estimated due to poor precision.

M1 - Matrix spike recovery is high due to sample matrix effect. Sample result is biased high.

M2 - Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.

T - Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.

R - Result is rejected.

TABLE 4-16

COMPARISON OF BASELINE AND QUARTERLY GROUND-WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

		SAMPLE	DUPLICATE	SAMPLE	DUPLICATE	SAMPLE	DUPLICATE				
PARAMETER	SFL92801	SFL92801	SFL92802	SFL92801	SFL92802	SFL92801	SFL92802	SFL92803	SFL92803	SFL92803	SFL92803
Date Collected	07-20-92	11-04-92	11-04-92	02-02-93	02-02-93	05-04-93	05-04-93	07-20-92	11-04-92	02-02-93	05-04-93
VOLATILE ORGANICS (µg/L):											
1,1,1,2-Tetrachloroethane	--	--	--	--	--	--	--	--	--	--	--
1,1,2,2-Tetrachloroethane	15	--	--	--	--	--	--	12	--	--	--
1,1,2-Trichloroethane	8.8	--	--	--	--	--	--	--	--	--	--
1,2,3-Trichloropropane	--	--	--	--	--	--	--	--	--	--	--
1,2-Dibromoethane	--	--	--	--	--	--	--	--	--	--	--
1,1-Dichloroethane	--	--	--	--	--	--	--	--	--	--	--
1,2-Dichloroethane	--	--	--	--	--	--	--	--	--	--	--
1,2-Dichloropropane	4.1	--	--	--	--	--	--	3.6	--	--	--
2-Hexanone	22	--	--	--	--	--	--	18	--	--	--
Benzene	2.4	--	--	--	--	--	--	--	--	--	--
Bromoform	8.0	--	--	--	--	--	--	6.4	--	--	--
Chlorodibromomethane	5.2	--	--	--	--	--	--	--	--	--	--
Ethyl methacrylate	--	--	--	--	--	--	--	--	--	--	--
Methacrylonitrile	--	--	--	--	--	--	--	--	--	--	--
Methyl chloride	--	--	--	--	--	--	--	--	--	--	--
Methyl isobutyl ketone	22	--	--	--	--	--	--	19	--	--	--
Methylene bromide	--	--	--	--	--	--	--	--	--	--	--
Methylene chloride	8.4 (T)	12 (B2)	13 (B2)	13	13	--	--	12 (T)	13 (B2)	11	--
Pentachloroethane	--	--	--	--	--	--	--	--	--	--	--
Styrene	3.1	--	--	--	--	--	--	--	--	--	--
Trichlorofluoromethane	--	--	--	--	--	--	--	--	--	--	--
Vinyl chloride	--	--	--	--	--	--	--	--	--	--	--
Xylenes (total)	--	--	--	--	--	--	--	6.3	--	--	--
cis-1,3-Dichloropropene	5.9	--	--	--	--	--	--	5.4	--	--	--
trans-1,2-Dichloroethene	--	--	--	--	--	--	--	--	--	--	--
trans-1,4-Dichloro-2-butene	--	--	--	--	--	--	--	--	--	--	--
Trichloroethene	--	--	--	--	--	--	--	--	--	--	--
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L):	--	-- (E)	-- (E)	--	--	--	--	--	-- (E)	--	--
DISSOLVED FURNACE METALS (µg/L											
Arsenic	14	14	12	14	21	NA	NA	--	--	--	NA
Lead	--	--	--	--	--	NA	NA	--	--	--	NA
Selenium	--	--	--	--	--	NA	NA	1.2	--	--	NA
DISSOLVED MERCURY (µg/L):	--	--	--	--	--	NA	NA	--	--	--	NA
DISSOLVED ICP METALS (µg/L):											
Aluminum	--	--	--	--	--	NA	NA	--	--	--	NA
Antimony	--	47 (R)	--	--	--	NA	NA	--	31	--	NA
Barium	240	210	210	240	230	NA	NA	120	98	140	NA
Beryllium	1.7	2.0	2.0	--	2.0	NA	NA	1.4	1.0	2.0	NA
Cadmium	--	--	--	--	--	NA	NA	--	--	--	NA
Calcium	150000	160000	160000	160000	170000	NA	NA	120000	120000	120000	NA
Chromium	--	--	--	--	--	NA	NA	--	--	--	NA
Iron	2800	2700	2700	2600	2700	NA	NA	51	--	--	NA
Magnesium	22000	23000	23000	23000	24000	NA	NA	30000	30000	30000	NA
Manganese	440	440	440	400	420	NA	NA	1200	1400	1300	NA
Nickel	--	--	--	--	--	NA	NA	--	--	11	NA
Potassium	9200	9600	9600	10000	11000	NA	NA	4700	4300	5000	NA
Silver				--	4.0	NA	NA	--	--	4.0	NA
Sodium	27000	29000	29000	30000	30000	NA	NA	39000	32000	32000	NA
Vanadium	--	--	--	--	--	NA	NA	--	--	--	NA
Zinc	10 (B1)	7.0	6.0	6.0	6.0	NA	NA	16 (B1)	8.0	6.0	NA

TABLE 4-16

COMPARISON OF BASELINE AND QUARTERLY GROUND-WATER RESULTS
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER		SAMPLE	DUPLICATE	SAMPLE	DUPLICATE	SAMPLE	DUPLICATE				
	SFL92801	SFL92801	SFL92802	SFL92801	SFL92802	SFL92801	SFL92802	SFL92803	SFL92803	SFL92803	SFL92803
Date Collected	07-20-92	11-04-92	11-04-92	02-02-93	02-02-93	05-04-93	05-04-93	07-20-92	11-04-92	02-02-93	05-04-93
TOTAL RECOVERABLE FURNACE METALS (µg/L):											
Arsenic	14	13	14	17	18	12	13	--	--	--	2.5
Lead	--	-- (M2)	-- (M2)	--	--	--	1.9	--	-- (M2)	--	1.0
Selenium	--	1.4 (M2)	-- (M2)	--	--	--	--	1.2	-- (M2)	--	--
Thallium	NA	NA	NA	NA	NA	--	--	NA	NA	NA	--
TOTAL ICP METALS (µg/L):											
Aluminum	--	--	--	--	22	--	--	170	--	--	--
Antimony	--	--	--	--	--	--	--	--	--	23	--
Barium	260	230	210	220	240	220	220	120	100	130	140
Beryllium	1.6	3.0	2.0	2.0	3.0	2.0	2.0	1.4	1.0	1.0	--
Cadmium	--	--	--	--	--	--	--	--	--	--	4.0
Calcium	150000	170000	160000	170000	170000	150000	150000	120000	120000	120000	130000
Chromium	--	--	--	--	--	--	--	--	--	10	--
Cobalt	--	--	--	--	--	--	--	--	--	--	--
Copper	--	--	--	--	--	--	--	--	--	15	--
Iron	2700	2700	2700	2700	2700	2500	2500	230	160 (B1)	55	--
Magnesium	22000	23000	23000	24000	23000	22000	22000	30000	31000	28000	31000
Manganese	430	450	430	410	410	340	340	1200	1400	1200	1300
Nickel	--	--	--	14	--	--	--	--	--	--	--
Potassium	9400	9800	9700	11000	11000	9600	9700	4800	4300	5700	4400
Silver	--	--	--	6.0	7.0	--	--	--	--	--	--
Sodium	28000	30000	29000	30000	30000	28000	29000	39000	33000	30000	36000
Vanadium	--	--	--	--	--	--	--	--	--	25	--
Zinc	14 (B1)	8.0	6.0	9.0	5.0	--	--	19 (B1)	6.0	5.0	--
WET CHEMISTRY (mg/L):											
Total Suspended Solids	NA	--	NA	NA	NA	NA	NA	NA	2.0	NA	NA
Inorganic Chloride	25	5.2	NA	NA	NA	23.8	24.8	34	29	NA	37.8
Nitrate	--	--	--	NA	NA	--	1.7	4.0	2.2	NA	--
Sulfate	95	NA	95	NA	NA	101	103	104	131 (M2)	NA	120
Ammonia (N)	NA	0.1	NA	NA	NA	NA	NA	NA	-- (E)	NA	NA
Organic Carbon	3.6 (M1)	3.6	NA	NA	NA	2.5	2.2	2.8 (M1)	2.8	NA	--
Hardness as $CaCO_3$	NA	NA	NA	NA	NA	NA	NA	NA	452	NA	NA
Bicarbonate as $CaCO_3$	523	NA	NA	NA	NA	410	422	450	NA	NA	375
Alkalinity as $CaCO_3$	NA	NA	NA	NA	NA	NA	NA	NA	347	NA	NA
Total Cyanide	--	NA	--	NA	NA	--	--	--	--	NA	--
Amenable CN	-- (M2)	--	NA	NA	NA	--	--	-- (M2)	--	NA	--
Nitrogen (TKN)	NA	--	--	NA	NA	NA	NA	NA	--	NA	NA
Total Sulfide	39 (E)	2.2	39	NA	NA	289	302	38 (E)	38	NA	301
BOD (5 day)	NA	--	NA	NA	NA	NA	NA	NA	--	NA	NA
COD	NA	--	NA	NA	NA	NA	NA	NA	--	NA	NA

NOTE: No positive results were obtained for semi-volatile organics, pesticides/PCBs, explosives, organophosphorous pesticides or herbicides.

-- Not detected. NA – Not analyzed.

B1 – Sample results are less than 5 times the amount detected in the method blank. Result is estimated.

B2 – Sample results are less than 10 times the amount detected in the method blank. Result is estimated.

E – Estimated result.

F – Field duplicate RPD exceeds control limit. Estimated due to poor precision.

M1 – Matrix spike recovery is high due to sample matrix effect. Sample result is biased high.

M2 – Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.

T – Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.

R – Result is rejected.

quarter results were non-detect. Several volatile organic compounds were detected in wells SFL92-801 and SFL92-802 during the baseline study but were not identified in subsequent sampling rounds. Benzene was detected in the samples from SFL92-601 collected during baseline and all quarterly studies. During the first and second quarters, benzene was also detected in sample SFL92-602. Vinyl chloride was detected once in sample SFL92-602 during the baseline sampling event only. In addition, 1,2-dichloroethane was detected in sample SFL92-601 in the first quarter only. Compounds 1,1-dichloroethane and trans-1,2-dichloroethene were detected in SFL92-601 during the third quarter study only. Additionally, trichlorofluoromethane was measured in sample SFL92-401 and trichloroethylene in SFL92-701 during the third quarter only.

The baseline analysis and second quarter analysis did not yield any positive results for TRPH. However, TRPH was detected in low concentrations in several samples during the first and third quarters. Groundwater samples from monitoring wells SFL92-103, SFL92-203, SFL92-301, SFL92-302, SFL92-501, SFL92-502, and SFL92-503 produced positive TRPH results in the first quarterly sampling event when groundwater flow was towards the river (Figure 3-15). TRPH was detected in sample SFL92-303 in the third quarter analysis when groundwater flow was influenced by river infiltration (Figure 3-18).

Metal results were generally consistent from baseline to the quarterly data. However, arsenic, calcium, iron, magnesium, manganese, and potassium concentrations increased significantly in samples from wells SFL92-301 and SFL92-302 during the first quarter, remained consistent during the second quarter and decreased in the third quarter. These differences may be related to the different groundwater/surface water conditions present during the sampling events. In addition, lead was not detected in the baseline study or the second quarter study, but was detected once in sample SFL92-102 during first quarter, and in all well clusters during the third quarter. Nickel was not detected in the baseline results but was detected in samples SFL92-401, SFL92-501, SFL92-601, and SFL92-602 during the first quarter and in samples from all well clusters except well cluster 1 during the second quarter. Vanadium was detected in sample SFL92-601 during the first quarter and in samples SFL92-102, SFL92-701, and SFL92-803 during the second quarter.

The major ions tested at SFL during the baseline, first quarter and second quarter showed fairly consistent results with the exception of sulfate which increased in the samples from cluster 3 during the first quarter and the second quarter studies. Bicarbonate was detected in all of the samples from the baseline and quarterly sampling events. Results increased significantly in samples from well cluster 3 during the first quarter sampling event and remained consistent through the second quarter sampling event. Total sulfide concentrations tended to increase in samples collected for the second and third quarters.

In summary, organic constituents were detected in all wells at each of the eight well clusters. The only organic detected in well SFL92-102 was methylene chloride in the trip blank. Methylene chloride (not associated with method blank contamination) was detected sporadically in all well clusters. Organics were detected at the landfill in monitoring well cluster 6 for the baseline sampling event and were detected again in samples collected in the following quarterly sampling events. Other organics were detected in baseline samples at monitoring well clusters 5 and 8, but were not found during the subsequent quarterly sampling events. Additionally, trichlorofluoromethane was measured in sample SFL92-401 and trichloroethene in SFL92-701 during the third quarter only. Results of the sampling events indicate that contamination of these areas is intermittent.

4.2.2.7 Comparison of Historical Groundwater Data - Six monitoring wells were installed around the landfill as part of the approved closure plan in 1984. Section 1.2.3 provides a detailed discussion. Each well was screened at three 4-foot intervals:

- The water table
- The top of bedrock
- An intermediate zone

Between the gravel packs at each screened interval, the well annulus was grouted with neat cement. The screens were slotted and constructed with glued joints.

According to groundwater data obtained in 1984 (McMaster, 1984), low levels of arsenic, cadmium, copper, lead, nickel, and zinc, with high levels of iron had been detected in the monitoring wells. Petroleum hydrocarbons were found in all wells in 1984 in the range of 2.62 to 11.9 mg/L . Since 1984, these monitoring wells have been sampled 11 times; the data are presented in Appendix B. Specific VOCs have been detected on several sampling occasions. Vinyl chloride was detected at 53 μg/L in 1986. Trichloroethene, dichloroethene, vinyl chloride, benzene, and ethylbenzene were detected as recently as 1987 in concentrations up to 20 μg/L. In 1988, the samples were not tested for total organic halides or VOC content. Iron and manganese levels were exceptionally high in all of the wells.

Table 4-17 presents a comparison of the 1992/93 data (includes baseline and quarterly data) to historical data. During the 1987 analyses, several VOCs were detected including benzene, vinyl chloride, trans-1,2-dichloroethene, trichloroethene, and ethylbenzene. All of these compounds were detected again in 1992 at comparable concentrations except ethylbenzene which was not detected. Several additional volatile constituents were detected in the 1992/93 study as well. The concentrations of barium, cadmium, magnesium, manganese, potassium, sodium, nitrate, sulfate, bicarbonate, total organic carbon and chemical oxygen demand were comparable between the historical and current data. Concentrations of iron, zinc, arsenic, and lead were lower in the current study. This may be due to the location of the monitoring wells. Historical data (i.e., 1987 data from closure wells) are from within the boundaries of the landfill, and data from the current study (i.e., 1992/93 data from Law wells) are from monitoring wells located at the periphery of the landfill.

TABLE 4-17

COMPARISON OF HISTORICAL DATA TO CURRENT GROUND-WATER DATA
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Year Collected/Laboratory	1992-93 LAW	1990 Wilson	1989 QWAL	1988 QAS	1987 USAEHA	1986 USAEHA	1985 USAEHA	1984 USAEHA
STATIC WATER ELEVATION (a)	1031.84 - 1033.38	1031.64 - 1034.95	na	1031.40 - 1033.10	923.2 - 1034.8	1031.9 - 1034.1	na	1035.89 - 1037.01
VOLATILE ORGANICS (µg/L):								
1,1,1,2-Tetrachloroethane	< 5 - 6	na	na	na	na	na	na	na
1,1,2,2-Tetrachloroethane	< 5 - 15	< 5.0	< 3.0	na	na	na	na	< 3.0
1,1,2-Trichloroethane	< 5 - 8.8	< 5.0	< 3.0	na	na	na	na	< 3.0
1,2,3-Trichloropropane	< 10 - 34	na	na	na	na	na	na	na
1,2-Dibromomethane	< 5 - 24	na	na	na	na	na	na	na
1,2-Dichloroethane	< 5 - 16	< 5.0	< 3.0	na	na	na	na	< 1.0
1,2-Dichloropropane	< 3 - 4.1	< 5.0	< 3.0	na	na	na	na	< 1.0
2-Hexanone	< 10 - 22	na	na	na	na	na	na	na
Benzene	< 1.5 - 14	< 5.0	< 3.0	na	ND- 10	na	na	< 1.0
Bromoform	< 5 - 8	< 5.0	< 3.0	na	na	na	na	< 1.0
Chlorodibromomethane	< 5.0 - 5.2	< 5.0	< 3.0	na	na	na	na	na
Ethyl methacrylate	< 5.0 - 24	na	na	na	na	na	na	na
Methacrylonitrile	< 10 - 30	na	na	na	na	na	na	na
Methyl chloride	< 5.0 - 11	< 5.0	< 3.0	na	na	na	na	na
Methyl isobutyl ketone	< 19 - 30	< 5.0	na	na	na	na	na	na
Methylene bromide	< 5.0 - 22	< 5.0	< 3.0	na	na	na	na	na
Methylene chloride	< 5.0 - 32	< 5.0	< 3.0	na	na	na	na	< DL - 3.0
Pentachloroethane	< 10 - 13	< 5.0	na	na	na	na	na	na
Styrene	< 3.0 - 3.1	na	na	na	na	na	na	na
Trichlorofluoromethane	< 2.0 - 5.2	< 5.0	< 3.0	na	na	na	na	na
Vinyl chloride	< 10 - 18	< 5.0	< 3.0	na	ND - 20	na	na	< 1.0 - 5.0
Xylenes (total)	< 5.0 - 9.1	na	na	na	na	na	na	na
cis-1,3-Dichloropropene	< 3.0 - 5.9	na	na	na	na	na	na	< 1.0
trans-1,2-Dichloroethene	< 3.5 - 8.7	< 5.0	< 3.0	na	ND - 7.0	na	na	< 1.0 - 2
trans-1,4-Dichloro-2-butene	< 10.0 - 20	na	na	na	na	na	na	na
trichloroethene	< 3.0 - 4.3	<5.0	<3.0	na	ND - 7.0	na	na	<1.0
Ethylbenzene	<2.0	<5.0	<3.0	na	ND - 8.0	na	na	<3.0
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L):	< 0.74 - 14	na	na	na	na	na	na	2.62 - 11.9
TOTAL RECOVERABLE ICP METALS (µg/L):								
Aluminum	< 100 - 460	na	na	na	na	na	na	na
Antimony	< 23 - 31	na	na	na	na	na	na	na
Barium	< 20 - 2000	180 - 1750	365 - 1850	na	260 - 2310	300 - 1620	na	na
Beryllium	< 1.0 - 4	na	na	na	na	na	na	na
Cadmium	< 4.0 - 5	< 5.0	4.0 - 18	na	< 0.5	< 1.0	na	< 2.9 - 3.4
Calcium	91 - 330000	142000 - 241000	123600 - 335100	108170 - 309000	120000 - 335000	120000 - 287000	na	na
Cobalt	< 8 - 12	na	na	na	na	na	na	na
Iron	< 55 - 36000	8140 - 38500	9700 - 53050	960 - 31413	4690 - 43100	3550 - 4310	1950 - 162000	< 30 - 14900
Magnesium	< 1100 - 77000	23000 - 40300	17000 - 57200	16620 - 58830	na	na	na	na
Manganese	< 38 - 2700	1640 - 2680	2580 - 4435	1277 - 4530	1470 - 4890	1220 - 3830	1200 - 2660	na
Nickel	< 13 - 29	na	na	na	na	na	na	< 7.0 - 13
Potassium	3300 - 19000	7900 - 14700	12500 - 21100	7400 - 33000	3530 - 2350	4520 - 17100	na	na
Sodium	9800 - 140000	33700 - 81600	20400 - 75100	25130 - 83550	13000 - 127000	19000 - 98000	30000 - 92000	na
Vanadium	< 7 - 25	na	na	na	na	na	na	< 100
Zinc	< 4 - 31	25 - 213	21-45	na	< 20	< 20	na	< 15.0 - 69.0

TABLE 4-17

COMPARISON OF HISTORICAL DATA TO CURRENT GROUND-WATER DATA
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER Year Collected/Laboratory	1992-93 LAW	1990 Wilson	1989 QWAL	1988 QAS	1987 USAEHA	1986 USAEHA	1985 USAEHA	1984 USAEHA
TOTAL RECOVERABLE FURNACE METALS (µg/L):								
Arsenic	< 2.0 - 45	< 10.0 - 57.5	9 - 100	na	5 - 100	10 -75	na	< 4.0 - 17
Lead	< 1.0 - 4.2	< 3.0 - 18.9	39 - 105	na	<1 - 24	5.0	na	<13.7 - 25.1
Selenium	< 1.0 - 3.1	< 5.0	<1.0 - 1.1	na	<1.0 -26	7.0 - 14	na	< 5.0
TOTAL MERCURY (µg/L):	< 0.2	< 0.2	< 1.0	na	< 0.5 - 0.5	<0.2	na	< 0.6
HERBICIDES (µg/L):	<QL	na	na	na	na	na	na	na
ORGANOPHOSPHORUS PESTICIDES (µg/L):	<QL	na	na	na	na	na	na	na
EXPLOSIVES (µg/L):	< QL	na	na	na	na	na	na	na
WET CHEMICAL INORGANICS (mg/L):								
Total Suspended Solids	1.0 - 190	na	na	na	na	na	na	na
Inorganic Chloride	0.44 - 281	42 - 143	36.10 - 133.5	28 - 47	na	na	56 - 162	74 - 131
Nitrate	0 - 5.2	0.6 - 1.0	<0.008 - 6.48	<0.1	na	na	.04 - .45	<.03 - .03
Sulfate	4.2 - 580	23 - 175	23.53 - 141.18	<0.5 - 158	39.0 - 245	20.0 - 175	28.0 - 165	10 - 191
Sulfide	11.7 - 76.6	na	na	na	na	na	na	na
Bicarbonate as CaCO3	0 - 1360	402 - 672	291.70 - 1121.6	na	na	na	na	na
Ammonia (N)	0.1 - 453	na	na	na	na	na	na	na
Total Kjeldahl Nitrogen	0 - 3	na	na	na	na	na	na	na
Organic Carbon	2.2 - 45.3	4.98 - 20.3	3.920 - 11.45	29.3 - 232.5	2.7 - 19	3.3 - 13.1	3.7 - 6.6	4.3 - 13
Chemical Oxygen Demand	<25 - 54.5	0.4 - 62.7	1.88 - 30.1	12.0 - 23.0	< 25 - 53	na	23 - 44	23 - 102

na - Not available
QL - Represents the limit of quantitation no regulatory limit established.
ND - Not Detected
Note: When lower limits were at zero, no detection limit was found.
QAS - Quality Analytical Services
QWAL - Law was unable to obtain acronym definition.
Current data includes baseline and the quarterly sampling data.
a - reference point used for static water elevation calculation is the top of casing.

4.2.3 Soil Investigation

Subsurface soil samples were collected from the deep monitoring well borings at the SFL in April and May of 1992. The samples were analyzed for an abbreviated RCRA Appendix IX list. This list was selected to encompass those analytes suspected or known to exist at the SFL. The parameters are provided in Table 4-2. Also, a survey of the soil cover at SFL was performed by PRC Environmental Management, Inc. (PRC). Surface soil samples were collected throughout the landfill and analyzed on site for lead, copper, and zinc by an X-Ray Fluorescence (XRF) analysis.

4.2.3.1 Historical Soil Data - A background search of historical data was conducted as part of this investigation. This search did not produce any soil analytical data.

4.2.3.2 Soil Sampling - Subsurface soil samples were collected from the eight deep monitoring well boring locations. The samples characterize subsurface soils at the periphery of the site to determine if there have been releases from the landfill. These borings were advanced using a mud rotary technique with samples for chemical analysis being collected with a stainless steel split-spoon. Three soil samples were selected from each boring for laboratory analysis. One sample was collected at the water table, and one was collected just above the soil/bedrock interface. The remaining soil samples were selected from the intermediate zone. Soil sampling procedures are provided in Section 2.1.5.3.

The surface soils were collected at a depth of 0 to 6 inches and analyzed on site by PRC in July of 1992. The sample locations were selected using a randomly based grid. The sampling points were approximately 100 feet apart.

4.2.3.3 Soil Sample Analysis - A summary of results for both the PRC surface soil investigation and the subsurface soil analyses is provided below. Surface soil sampling procedures are provided in Section 2.1.5.4.

4.2.3.3.1 Surface Soil Sample Analysis - This investigation was focused on the cover material of the landfill because of the suspected contaminants (lead, copper, and zinc) from small arms bullets. Approximately 60 percent of the cover material was excavated from the berm of a rifle range just north of SFL. Due to partial loss of soil cover material on some areas of the landfill as a result of surface erosion, burrowing and settlement, there is a potential for exposure to landfill wastes other than metal contamination. Surface soils were analyzed for lead, copper, and zinc by XRF. These results were obtained by a field screening technique and as such are considered EPA level II data (USEPA, 1987a). This indicates the results are only semi-quantitative in nature because of the limited quality control imposed. In addition, these results were estimated due to the initial calibration procedures which required the results to be recalculated. However, the results of the investigation should be sufficient to determine the presence or absence of lead, copper, and zinc in the surface soils. The XRF results were verified by splitting field samples and analyzing by a Contract Laboratory Program (CLP) laboratory. Results of the CLP analysis indicate lead values produced by XRF were biased high which means lead concentrations were over estimated. Lead concentrations were then recalculated as described in the PRC Revised Report (Appendix G). Copper and zinc XRF results correlated well with the CLP data.

Three background samples were collected for XRF analysis. Lead was detected at 230 mg/kg in background sample OLF-13. Lead was not detected in any other background sample (OLF-11 and OLF-12). Copper and zinc were not detected in any background sample.

There were 114 locations sampled at the SFL for XRF analysis. Fifty-two samples produced lead results above the method detection limit (MDL) of 100 mg/kg or parts per million (ppm) using the recalculated PRC results (Figure 2-6). Concentrations of lead ranged from 26 to 440 mg/kg with five sample results exceeding background concentrations. The highest concentrations of lead were detected in the eastern portion of the landfill. Only three samples produced results greater than the MDL of 100 mg/kg for zinc, and two samples contained detectable copper. Appendix G contains the original and revised PRC reports which provide figures with XRF data and a detailed discussion of the sampling and analysis of the cover material at SFL.

4.2.3.3.2 Subsurface Soil Sample Analysis - The analytical results of the subsurface soil investigation are discussed below. The discussions are separated into organic and inorganic analytical results.

Subsurface soil samples were analyzed for the following organic analytical parameters:

- Volatile organics
- Semi-volatile organics
- Chlorinated pesticides/PCBs
- Organophosphorus pesticides
- Acid herbicides
- TRPH

Positive results of the subsurface soil with corresponding depths are provided in Table 4-18. There were no positive results for acid herbicides or organophosphorus pesticides.

TABLE 4-18

POSITIVE RESULTS FOR SOIL BORING SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	Pilot Hole SFL92SB01C	SB101	SB102	SB103	Sample SB201	Duplicate SB2011	SB202
Sample Depth		(34-36')	(48-50')	(56-60')	(16-20')	(16-20')	(32-36')
Date Collected	01-30-92	04-03-92	04-03-92	04-03-92	05-05-92	05-05-92	05-05-92
VOLATILE ORGANICS (µg/kg):							
Carbon disulfide	--	--	--	--	4.2	--	--
Methyl chloride	--	--	--	--	--	--	--
Methylene chloride	34 (T)	65 (B2)	65 (B2)	19 (B2)	12	12	7.9 (T)
PESTICIDES/PCBs (µg/kg):							
4,4'-DDE	NS	--	--	--	9.6	55	--
Aroclor-1248	NS	--	--	--	250 (F)	-- (F)	--
SEMI-VOLATILE ORGANICS (µg/kg):							
Bis(2-ethylhexyl)phthalate	NS	430	--	--	-- (F)	9700 (F)	--
Butyl benzyl phthalate	NS	--	--	--	--	1000	--
TOTAL MERCURY (µg/kg):	NS	--	--	--	--	--	--
TOTAL FURNACE METALS (mg/kg):							
Arsenic	NS	--	3.4	2.4	3.2	3.6	1.3
Lead	NS	3.0	13	2.4	9.4	10	16
Selenium	NS	--	--	--	--	0.2	--
TOTAL ICP METALS (mg/kg):							
Aluminum	NS	1600	9200	1100	15000	21000	1300
Barium	NS	69	200	31	160	200	84
Beryllium	NS	--	0.5	--	0.7	1.0	--
Cadmium	NS	--	--	--	--	--	--
Calcium	NS	8800	5800	1600	14000	18000	7400
Chromium	NS	7.7	11	3.2	12	20	8.7
Cobalt	NS	2.8	9.2	3.0	7.8	5.6	--
Copper	NS	1.1	8.6	1.4	11	13	1.0
Iron	NS	3400	12000	6100	15000	21000	4400
Magnesium	NS	610	3000	360	3700	5100	420
Manganese	NS	36	110	100	280	470	48
Nickel	NS	4.1	14	9.6	15 (B1)	28 (B1)	7.5 (B1)

TABLE 4–18

POSITIVE RESULTS FOR SOIL BORING SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	Pilot Hole SFL92SB01C	SB101	SB102	SB103	Sample SB201	Duplicate SB2011	SB202
Sample Depth		(34–36')	(48–50')	(56–60')	(16–20')	(16–20')	(32–36')
Date Collected	01–30–92	04–03–92	04–03–92	04–03–92	05–05–92	05–05–92	05–05–92
TOTAL ICP METALS (mg/Kg)(cont'd):							
Potassium	NS	520	2000	280	2900	3800	310
Silver	NS	––	––	1.0	0.8	1.5	––
Sodium	NS	120	170	60	66	––	––
Thallium	NS	15	––	––	––	––	––
Vanadium	NS	7.6	21	10	32	41	9.6
Zinc	NS	8.0	39	11	53	73	18
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/Kg):	NS	78	63	34 (M1)(E)	380	470	43
WET CHEMICAL INORGANICS (mg/Kg):							
Total organic carbon	NS	900.00	2230.00	480	13100.00 (F)	9030.00 (F)	1300.00
Total cyanide	NS	––	––	––	––	––	––
ORGANOPHOSPHORUS PESTICIDE (ug/Kg):	NS	––	–– (H)	––	––	––	––
ACID HERBICIDES (ug/Kg):	NS	––	––	––	––	––	––

B1 – Sample results are less than 5 times the amount detected in the method blank. Result is estimated.
B2 – Sample results are less than 10 times the amount detected in the method blank. Result is estimated.
E – MS/MSD RPD exceeds control limit. Estimated result due to poor precision.
F – Field duplicate RPD exceeds control limit. Estimated result due to poor precision.
H – Estimated result based on exceeded holding time. Results may be biased low.
M1 – Matrix spike recovery is high due to sample matrix effect. Sample result may be biased low.
M2 – Matrix spike recovery is low due to sample matrix effect. Sample result may be biased low.
T – Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.
NS – Not sampled.
–– Not detected
Note: All sample results were reported using dry weight.

TABLE 4-18

POSITIVE RESULTS FOR SOIL BORING SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	Sample SB203	Duplicate SB2031	SB301	SB302	SB303	SB401	SB403
Sample Depth	(48-52')	(48-52')	(20-26')	(40-45')	(56-59')	(18-26')	(26-32')
Date Collected	05-05-92	05-05-92	04-07-92	04-08-92	04-08-92	04-15-92	04-18-92
VOLATILE ORGANICS (µg/kg):							
Carbon disulfide	--	--	--	--	--	--	--
Methyl chloride	--	--	--	--	--	--	--
Methylene chloride	14 (T)	12 (T)	21 (T)	17 (T)	13 (T)	37 (B2)	40 (B2)
PESTICIDES/PCBs (µg/kg):							
4,4'-DDE	--	--	--	--	--	--	--
Aroclor-1248	--	--	--	--	--	--	--
SEMI-VOLATILE ORGANICS (µg/kg):							
Bis(2-ethylhexyl)phthalate	--	--	--	490	460	--	660
Butyl benzyl phthalate	--	--	--	--	--	--	--
TOTAL MERCURY (µg/kg):	--	--	--	--	--	--	--
TOTAL FURNACE METALS (mg/kg):							
Arsenic	1.1	1.9	--	3.9	7.2	0.5	0.6
Lead	3.0	2.5	1.6	2.1	2.6	2.0	2.7
Selenium	--	--	--	--	--	--	--
TOTAL ICP METALS (mg/kg):							
Aluminum	5100 (F)	1200 (F)	570	390	930	560	1200
Barium	760 (F)	86 (F)	26	130	76	21	37
Beryllium	0.6	0.3	--	--	1.6	--	0.5
Cadmium	--	--	--	0.6	--	--	--
Calcium	20000	9700	4800	13000	120000	2500	36000
Chromium	9.4	3.2	5.2 (B1)	4.8 (B1)	8.4 (B1)	4.6	1.9
Cobalt	5.3	--	--	1.7	4.6	--	--
Copper	3.3	1.6	--	1.2	4.4	--	2.5
Iron	9000	4300	1300	4400	12000	1500	2300
Magnesium	1900 (F)	420 (F)	230	270	1600	230	700
Manganese	140 (F)	47 (F)	18	50	190	20	86
Nickel	15 (B1)	7.6 (B1)	--	4.3	11	--	5.8

TABLE 4-18

POSITIVE RESULTS FOR SOIL BORING SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	Sample SB203	Duplicate SB2031	SB301	SB302	SB303	SB401	SB403
Sample Depth	(48-52')	(48-52')	(20-26')	(40-45')	(56-59')	(18-26')	(26-32')
Date Collected	05-05-92	05-05-92	04-07-92	04-08-92	04-08-92	04-15-92	04-18-92
TOTAL ICP METALS (mg/Kg)(cont'd):							
Potassium	1400 (F)	240 (F)	240	160	340	230	390
Silver	1.1	1.3	--	--	--	--	--
Sodium	120	--	140	180	220	140	200
Thallium	17	21	--	--	--	--	--
Vanadium	16	9.0	3.0	10	20	2.3	6.4
Zinc	20	9.5	3.5	8.5	19	4.6	8.0
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/Kg):	61	40	27	--	23	83	10
WET CHEMICAL INORGANICS (mg/Kg):							
Total organic carbon	580.00	530.00	1090.00	220.00	340.00	160.00	280.00
Total cyanide	--	--	--	--	--	--	--
ORGANOPHOSPHORUS PESTICIDE (ug/Kg):	--	--	--	--	--	--	--
ACID HERBICIDES (ug/Kg):	--	--	--	--	--	--	--

B1 – Sample results are less than 5 times the amount detected in the method blank. Result is estimated.
B2 – Sample results are less than 10 times the amount detected in the method blank. Result is estimated.
F – Field duplicate RPD exceeds control limit. Estimated result due to poor precision.
M2 – Matrix spike recovery is low due to sample matrix effect. Sample result may be biased low.
T – Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.
NS – Not sampled.
-- Not detected
Note: All sample results were reported using dry weight.

TABLE 4-18

POSITIVE RESULTS FOR SOIL BORING SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER		SB501	SB502	SB503	SB601	SB602	SB603	SB701
	Sample Depth	(18–22')	(25–29')	(32–36')	(18–24')	(34–38')	(48–54')	(14–22')
	Date Collected	05–04–92	05–06–92	05–04–92	04–30–92	04–30–92	04–30–92	04–21–92
<u>VOLATILE ORGANICS (µg/kg):</u>								
Carbon disulfide		--	--	--	--	--	--	--
Methyl chloride		--	--	--	--	--	--	41
Methylene chloride		10 (T)	13 (T)	11 (T)	20 (B2)	22 (B2)	24 (B2)	--
<u>PESTICIDES/PCBs (µg/kg):</u>								
4,4'-DDE		--	--	--	--	--	--	--
Aroclor-1248		--	--	--	--	--	--	--
<u>SEMI-VOLATILE ORGANICS (µg/kg):</u>								
Bis(2-ethylhexyl)phthalate		--	--	--	--	--	--	--
Butyl benzyl phthalate		--	--	--	--	--	--	--
<u>TOTAL MERCURY (µg/kg):</u>		--	--	--	--	--	--	--
<u>TOTAL FURNACE METALS (mg/kg):</u>								
Arsenic		0.5	1.1	1.8	1.2	1.5	3.4	--
Lead		1.5	1.4	1.9	3.2	2.5	2.6	1.0
Selenium		--	--	--	--	--	--	--
<u>TOTAL ICP METALS (mg/kg):</u>								
Aluminum		910	1200	540	1100	840	370	470
Barium		46	98	100	36	46	210	39
Beryllium		--	0.4	0.3	--	0.2	0.2	--
Cadmium		--	--	--	--	--	--	--
Calcium		5600	15000	18000	6800	12000	17000	2100
Chromium		4.9	5.9	6.0	6.3	2.8	8.7	4.5
Cobalt		--	3.1	2.8	--	--	--	--
Copper		--	1.9	1.2	--	1.1	1.0	0.8
Iron		2100	3200	6200	2400	4100	4300	2100
Magnesium		300	740	380	420	350	340	200
Manganese		36	140	82	28	60	80	29
Nickel		--	10 (B1)	6.0	--	4.0	4.0	--

TABLE 4-18

POSITIVE RESULTS FOR SOIL BORING SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER		SB501	SB502	SB503	SB601	SB602	SB603	SB701
	Sample Depth	(18-22')	(25-29')	(32-36')	(18-24')	(34-38')	(48-54')	(14-22')
	Date Collected	05-04-92	05-06-92	05-04-92	04-30-92	04-30-92	04-30-92	04-21-92
TOTAL ICP METALS (mg/Kg)(cont'd):								
Potassium		260	250	160	340	240	130	200
Silver		--	--	--	--	--	--	--
Sodium		140 (R2)	--	140	88	96	88	140
Thallium		--	--	--	--	17	--	--
Vanadium		9.0	9.6	12	5.9	12	8.8	4.6
Zinc		5.8	9.7	12	6.1	9.1	6.4	4.0
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/Kg):		26	34	26	25	26	39	--
WET CHEMICAL INORGANICS (mg/Kg):								
Total organic carbon		670.00	960.00	6550.00	410.00	1520.00	300.00	120.00
Total cyanide		--	--	--	--	--	--	--
ORGANOPHOSPHORUS PESTICIDE (ug/Kg):		--	--	--	--	--	-- (H)	--
ACID HERBICIDES (ug/Kg):		--	--	--	--	--	--	--

B1 – Sample results are less than 5 times the amount detected in the method blank. Result is estimated.
B2 – Sample results are less than 10 times the amount detected in the method blank. Result is estimated.
H – Estimated result based on exceeded holding time. Results may be biased low.
M2 – Matrix spike recovery is low due to sample matrix effect. Sample result may be biased low.
R2 – Sample results are less than 5 times the amount detected in the rinsate.
T – Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.
-- Not detected
Note: All sample results were reported using dry weight.

TABLE 4-18

POSITIVE RESULTS FOR SOIL BORING SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER		SB702	SB703	SB801	Sample SB802	Duplicate SB8021	SB803
	Sample Depth	(32-38')	(52-60')	(22-30')	(44-54')	(44-54')	(60-64')
	Date Collected	04-21-92	04-21-92	04-06-92	04-06-92	04-06-92	04-06-92
VOLATILE ORGANICS (μg/kg):							
Carbon disulfide		--	--	--	--	--	--
Methyl chloride		--	--	--	--	--	--
Methylene chloride		38 (B2)	34 (B2)	28 (B2)	24 (B2)	26 (B2)	25 (B2)
PESTICIDES/PCBs (μg/kg):							
4,4'-DDE		--	--	--	--	--	--
Aroclor-1248		--	--	--	--	--	--
SEMI-VOLATILE ORGANICS (μg/kg):							
Bis(2-ethylhexyl)phthalate		--	--	800	--	37	590
Butyl benzyl phthalate		--	--	--	--	--	--
TOTAL MERCURY (μg/kg):		--	--	--	--	--	--
TOTAL FURNACE METALS (mg/kg):							
Arsenic		1.2	4.6 (C)	1.3	2.2	5.1	4.0
Lead		2.2	4.3	1.4	2.1	2.3	2.0
Selenium		--	0.2	--	--	--	--
TOTAL ICP METALS (mg/kg):							
Aluminum		540	4400	520	560	670	600
Barium		97	150	17	80 (F)	220 (F)	280
Beryllium		--	2.3	--	--	--	0.5
Cadmium		--	--	--	--	--	--
Calcium		3000	170000	3100	2600	2100	28000
Chromium		3.4	--	2.7 (B1)	6.4 (B1)	7.1 (B1)	7.1 (B1)
Cobalt		--	--	1.6	1.9	1.7	3.3
Copper		1.3	12	1.0	1.2	1.1	1.1
Iron		5400	8400	1400	5800	5700	9200
Magnesium		230	4100	220	240	320	620
Manganese		45	740	15	47	50	110
Nickel		6.8	30	--	5.3	5.5	7.9

TABLE 4–18

POSITIVE RESULTS FOR SOIL BORING SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER		SB702	SB703	SB801	Sample SB802	Duplicate SB8021	SB803
	Sample Depth	(32–38')	(52–60')	(22–30')	(44–54')	(44–54')	(60–64')
	Date Collected	04–21–92	04–21–92	04–06–92	04–06–92	04–06–92	04–06–92
TOTAL ICP METALS (mg/Kg)(cont'd):							
Potassium		230	1900	210	180	230	180
Silver		--	--	--	--	--	--
Sodium		130	700	130	130	140	200
Thallium		--	--	--	--	--	--
Vanadium		11	19	4.5	11	13	16
Zinc		9.0	16	4.3	8.8	11	13
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/Kg):		--	--	10	21	25	19
WET CHEMICAL INORGANICS (mg/Kg):							
Total organic carbon		350.00	780.00	700.00	500.00	540.00	2240.00
Total cyanide		--	--	--	--	--	--
ORGANOPHOSPHORUS PESTICIDE (ug/Kg):		--	--	--	--	--	--
ACID HERBICIDES (ug/Kg):		--	--	--	--	--	--

B1 – Sample results are less than 5 times the amount detected in the method blank. Result is estimated.
B2 – Sample results are less than 10 times the amount detected in the method blank. Result is estimated.
C – MSA correlation coefficient is below 0.995. Result is estimated.
M2 – Matrix spike recovery is low due to sample matrix effect. Sample result may be biased low.
-- Not detected
Note: All sample results were reported using dry weight.

Several VOCs were detected in subsurface soils. Methylene chloride was detected in 22 of the 23 subsurface soil samples at concentrations ranging from 7.9 to 65 μg/kg and in samples from both upgradient and downgradient locations. Methylene chloride was also detected in trip blanks associated with 8 of the 23 samples and in five of the eight laboratory method blanks associated with the samples. The method blank concentrations ranged from 6.7 to 20 μg/kg indicating laboratory contamination of samples associated with these blanks. Methylene chloride (not associated with trip blank or method blank contamination) was only detected in one sample (SB 201 at a depth of 16 to 20 feet). Carbon disulfide was detected once in sample SFLSB201, collected at a depth of 16 to 20 feet, at a concentration near the detection limit. Methyl chloride was detected once in sample SFLSB701 at a depth of 14 to 22 feet. Because these compounds were detected only once, at concentrations below the RCRA Corrective Action Levels (CALs), and were not detected in the corresponding groundwater samples, the presence of these compounds is probably not significant.

Pesticide and PCB compounds detected included 4,4'-DDE (a metabolite of DDT) and Aroclor-1248 (a PCB mixture). The 4,4'-DDE was detected at a concentration of 55 μg/kg and Aroclor-1248 at 250 μg/kg. Both were detected in soil sample SFLSB201, which was collected from a depth of 16 to 20 feet. Plastic and metal debris were encountered in this sample. The Aroclor-1248 was detected in the sample but not in the duplicate of this sample. This is most likely due to the heterogeneous nature of the soil.

Semi-volatile organic compounds detected include bis(2-ethylhexyl) phthalate and butyl benzyl phthalate. Bis(2-ethylhexyl)phthalate was detected in several soil samples including SFLSB101, SFLSB2011, SFLSB302, SFLSB303, SFLSB403, SFLSB801, SFLSB8021, and SFLSB803. It was detected in both upgradient and downgradient soil samples. Bis(2-ethylhexyl)phthalate is a common contaminant associated with latex gloves which are used both in the field and laboratory. However, the presence of this compound may also be associated with landfill activities, such as the disposal of plastics. Butyl benzyl phthalate was detected once in the duplicate sample SFLSB2011.

A TRPH analysis was performed on each soil sample. Positive interferences have been noted using the TRPH method that are theorized to be associated with naturally occurring soil organics and/or soil type. The background samples analyzed had positive results of TRPH indicating the possibility of false positives due to the sample matrix. Therefore, a comparison of upgradient and downgradient TRPH has been performed. Hydrocarbons were detected in most of the soils; however, the only soils exceeding background levels of TRPH were SFLSB201 and its duplicate SFLSB2011. In addition, the presence of appreciable concentrations of petroleum-related volatile and semi-volatile analytes or tentatively identified compounds (TICs) was not confirmed (TICs are found in Appendix F of the QCSR).

The only RCRA Corrective Action Level (CAL) exceeded for organic results was the Aroclor-1248, which was detected at 250 μg/kg in SFLSB-201. The CAL for Aroclor-1248 is 90 μg/kg.

Figures 4-10 and 4-11 provide the positive results of the analyses for organic parameters at each boring. Two areas were identified as being contaminated with bis(2-ethylhexyl)phthalate, the area north of Well House Road in well borings SFL92-103 and SFL92-803 and the area adjacent to the Kansas River in well borings SFL92-203, SFL92-303, and SFL92-403. Two positive bis(2-ethylhexyl)phthalate results occurred at shallow depths, two at intermediate, and three at deeper depths. Because the most data points available for contouring would be the three deeper results and the distance between sampling points, any contours developed would be highly speculative and therefore are not included. Figures 4-10 and 4-11, however, provide an interpretation of the vertical extent of bis(2-ethylhexyl)phthalate and other positive organic parameters. The contaminant appears to be at intermediate depths to bedrock in the subsurface soil samples from well borings SFL92-203, SFL92-303, and SFL92-403. Its occurrence at the localized dumping area north of Well House Road is throughout the soil column at SFL92-803; in the background boring, it is limited to a more shallow depth.

Many metals are naturally occurring in soil. To evaluate the impact of the SFL to the soil, a comparison must be made between metal concentrations upgradient and downgradient of the site. Small variances (less than 25 percent) in concentrations may be the result of the analytical uncertainty inherent in the analytical methodology; therefore, these will not be discussed. The analytical uncertainty value is derived from the accuracy data quality objective and control limits established for this project.

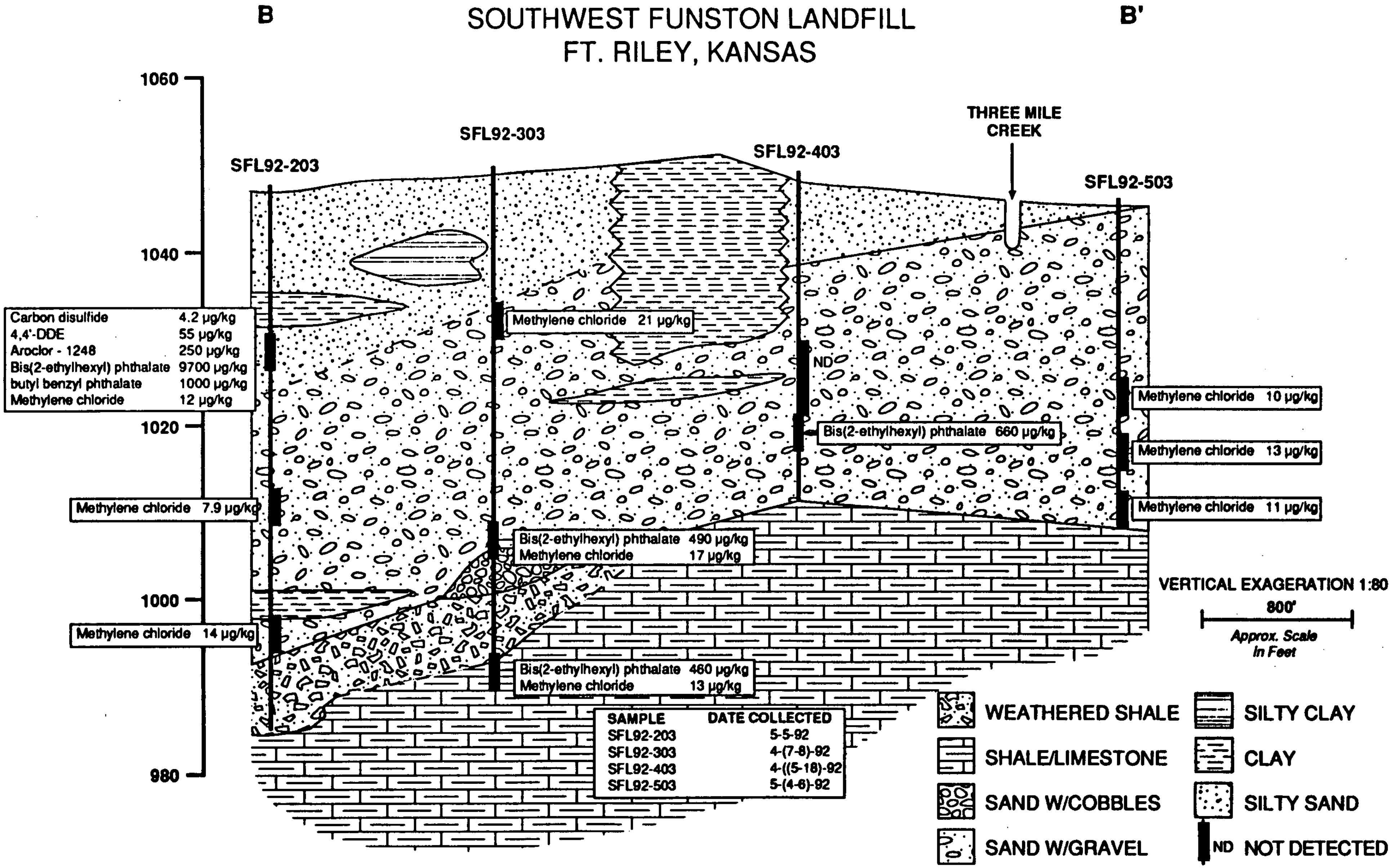
Arsenic, lead, selenium, aluminum, barium, beryllium, cadmium, calcium, chromium, copper, iron, magnesium, manganese, nickel, potassium, silver, sodium, thallium, vanadium and zinc were detected in the soil samples collected from the SFL. Generally, the highest concentrations of metals detected in the soil occurred at the shallowest sample collected from monitoring well boring SFL92-203 and the deeper samples in borings SFL92-303 and SFL92-703. Table 4-19 presents the metals results which exceed background concentrations. Lead, chromium, and cobalt were not detected in any downgradient samples at concentrations greater than background. Aluminum, iron, potassium, silver, thallium, vanadium, and zinc were detected at concentrations greater than the upgradient samples from the monitoring well boring for SFL92-203. All but thallium, detected in the deeper sample, were detected in SFLSB-201. Arsenic was detected in both upgradient and downgradient samples; samples exceeding background concentrations include SFLSB-303, SFLSB-703, and SFLSB-802. Selenium was detected at detection limit levels within SFLSB-201 and SFLSB-703, but not detected in any upgradient sample. Barium was detected at concentrations exceeding the upgradient concentration in samples SFLSB-203 and SFLSB-803.

Beryllium was detected above background concentration in samples SFLSB-201, SFLSB-303, and SFLSB-703. Cadmium was detected once in sample SFLSB-302. Calcium was detected above background concentrations in all downgradient borings. Copper, magnesium and nickel were detected above background in samples SFLSB-201 and SFLSB-703. Manganese was detected above background in samples SFLSB-201, SFLSB-303, SFLSB-502, and SFLSB-703. Finally, sodium was detected above background in samples SFLSB-303 and SFLSB-703.

FIGURE 4-10

SOIL ORGANIC ANALYTICAL RESULTS VERTICAL DISTRIBUTION CROSS SECTION B-B'

SOUTHWEST FUNSTON LANDFILL
FT. RILEY, KANSAS

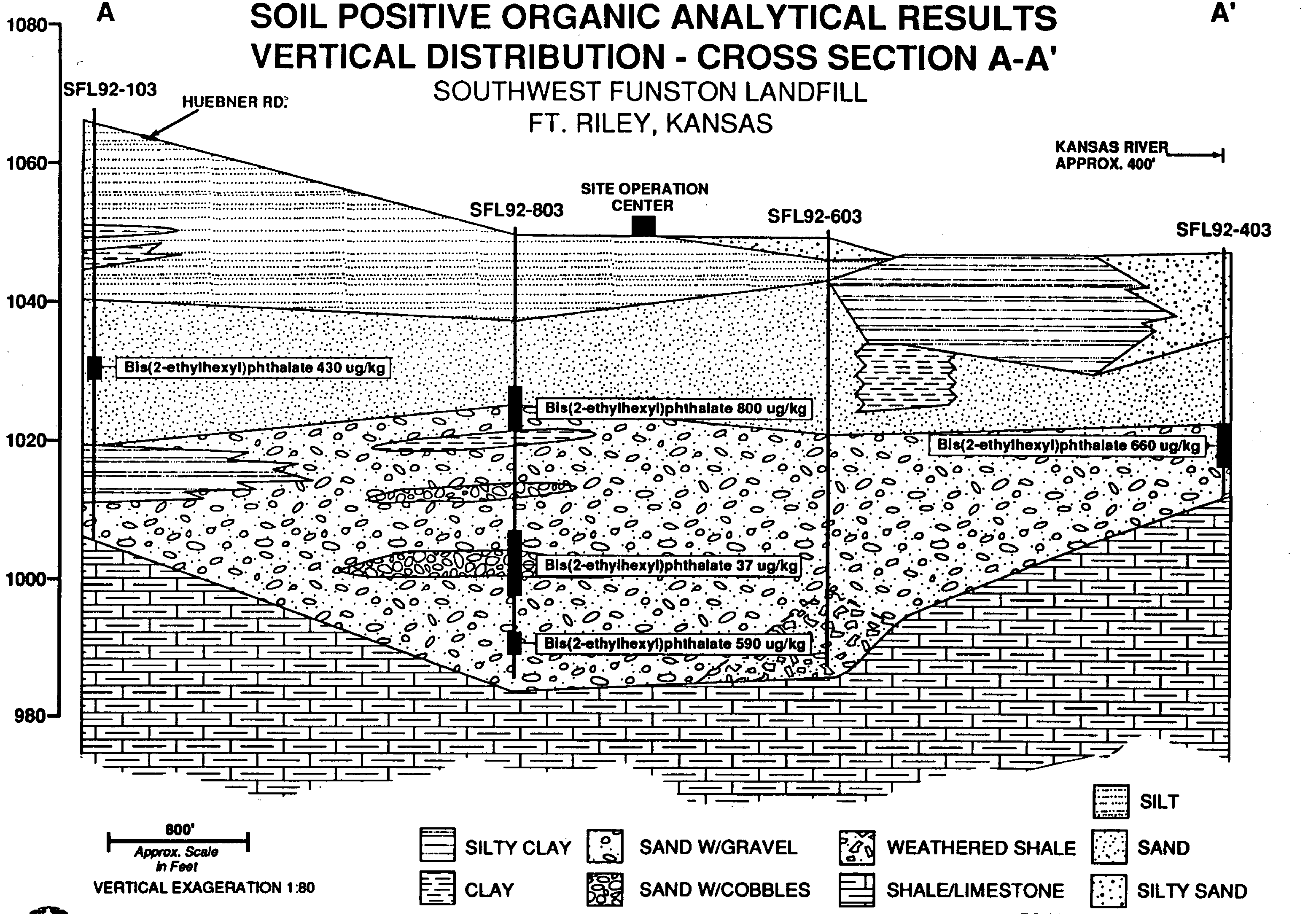


SAMPLE	DATE COLLECTED
SFL92-203	5-5-92
SFL92-303	4-(7-8)-92
SFL92-403	4-((5-18)-92
SFL92-503	5-(4-6)-92

FIGURE 4-11

SOIL POSITIVE ORGANIC ANALYTICAL RESULTS VERTICAL DISTRIBUTION - CROSS SECTION A-A'

SOUTHWEST FUNSTON LANDFILL
FT. RILEY, KANSAS



LAW ENVIRONMENTAL, INC.
GOVERNMENT SERVICES DIVISION

DRAFT FINAL RI, OCT. 1993 1530.74

TABLE 4-19

METALS RESULTS EXCEEDING BACKGROUND CONCENTRATIONS
SOIL SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

METAL	MAXIMUM BACKGROUND CONC'N*	SAMPLES EXCEEDING MAXIMUM BACKGROUND CONCENTRATIONS	DEPTH		CAL **
Arsenic, mg/kg	3.4	SFLSB-303	(56-59')	7.2 mg/kg	80
		SFLSB-703	(52-60')	4.6 mg/kg	
		SFLSB-802	(44-54')	5.1 mg/kg	
Lead, mg/kg	13	none			500***
Selenium, mg/kg	ND	SFLSB-201	(16-20')	0.2 mg/kg	NA
		SFLSB-703	(52-60')	0.2 mg/kg	
Aluminum, mg/kg	9200	SFLSB-201	(16-20')	21000 mg/kg	NA
Barium, mg/kg	200	SFLSB-203	(48-52')	760 mg/kg	4000
		SFLSB-803	(60-64')	280 mg/kg	
Beryllium, mg/kg	0.5	SFLSB-201	(16-20')	1 mg/kg	0.2
		SFLSB-303	(56-59')	1.6 mg/kg	
		SFLSB-703	(52-60')	2.3 mg/kg	
Cadmium, mg/kg	ND	SFLSB-302	(40-45')	0.6 mg/kg	40
Calcium, mg/kg	8800	SFLSB-201	(16-20')	18000 mg/kg	NA
		SFLSB-203	(48-52')	20000 mg/kg	
		SFLSB-302	(40-45')	13000 mg/kg	
		SFLSB-303	(56-59')	120000 mg/kg	
		SFLSB-403	(26-32')	36000 mg/kg	
		SFLSB-502	(25-29')	15000 mg/kg	
		SFLSB-503	(32-36')	18000 mg/kg	
		SFLSB-602	(34-38')	12000 mg/kg	
		SFLSB-603	(48-54')	17000 mg/kg	
		SFLSB-703	(52-60')	170000 mg/kg	
		SFLSB-803	(60-64')	28000 mg/kg	
Chromium, mg/kg	11	none			400
Cobalt, mg/kg	9.2	none			NA
Copper, mg/kg	8.6	SFLSB-201	(16-20')	13 mg/kg	NA
		SFLSB-703	(52-60')	12 mg/kg	
Iron, mg/kg	12000	SFLSB-201	(16-20')	21000 mg/kg	NA

TABLE 4–19

METALS RESULTS EXCEEDING BACKGROUND CONCENTRATIONS
SOIL SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

METAL	MAXIMUM BACKGROUND CONC'N*	SAMPLES EXCEEDING MAXIMUM BACKGROUND CONCENTRATIONS	DEPTH		CAL **
Magnesium, mg/kg	3000	SFLSB–201	(16–20')	5100 mg/kg	NA
		SFLSB–703	(52–60')	4100 mg/kg	
Manganese, mg/kg	110	SFLSB–201	(16–20')	470 mg/kg	NA
		SFLSB–303	(56–59')	190 mg/kg	
		SFLSB–502	(25–29')	140 mg/kg	
		SFLSB–703	(52–60')	740 mg/kg	
Nickel, mg/kg	14	SFLSB–201	(16–20')	28 mg/kg	2000
		SFLSB–703	(52–60')	30 mg/kg	
Potassium, mg/kg	2000	SFLSB–201	(16–20')	3800 mg/kg	NA
Silver, mg/kg	1.0	SFLSB–201	(16–20')	1.5 mg/kg	200
Sodium, mg/kg	170	SFLSB–303	(56–59')	220 mg/kg	NA
		SFLSB–703	(52–60')	700 mg/kg	
Thallium, mg/kg	15	SFLSB–203	(48–52')	21 mg/kg	7
Vanadium, mg/kg	21	SFLSB–201	(16–20')	41 mg/kg	NA
Zinc, mg/kg	39	SFLSB–201	(16–20')	73 mg/kg	NA

ND – not detected
NA – not available
* Maximum background concentrations were obtained from SFL92–101, SFL92–102, and SFL92–103.
** CAL – RCRA Corrective Action Levels
*** Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites (USEPA, 1989)

Source: Federal Register, Vol.55, No. 145, July 27, 1990. Pages 30798–30884. Corrective Action for Solid Waste Management Facilities, Proposed Rule.
Note: All sample results were calculated using dry weight.

Beryllium and thallium concentrations in the soil samples analyzed exceeded CALs in both upgradient and downgradient soils. No other metal CALs were exceeded. Table 4-19 also presents the RCRA CALs for soil.

4.2.4 Surface Water Investigation

Surface water samples were collected in May of 1992 and analyzed for the parameters provided in Table 4-20.

4.2.4.1 Surface Water Sampling - The objective of this task was to determine if contamination from the SFL has impacted the water quality of the Kansas River and Threemile Creek. A total of seven locations were selected. To assess possible contamination adjacent to the SFL, three sampling locations were chosen. In addition, three sampling locations were selected to provide background or ambient conditions along the Kansas River and Threemile Creek. Also, an additional sampling location was selected to provide downstream "recovery" conditions. Sample locations are provided on Figure 2-2. Surface water samples were collected off the bank of the river/creek in higher-flow areas to represent dynamic conditions. Sampling procedures are provided in Section 2.1.3.

Two Kansas River sampling locations were upstream of the river's contact with the suspected landfill boundaries. Sample location KRSW-01 is upstream of the discharge point from the Main Post wastewater treatment plant. This location was chosen to represent conditions prior to influences from waste-water effluents. Sampling location KRSW-02 represents conditions with the influence of waste-water effluents but upstream to any landfill leachate. Sample location KRSW-03 was selected to represent the condition of the surface water at the SFL's downgradient boundary contact with the Kansas River.

Threemile Creek flows into the Kansas River downstream of the inferred landfill boundaries. Sample locations KRSW-04 and KRSW-05 were selected to represent conditions influenced by both the landfill and Threemile Creeks discharge. In order to determine Threemile Creek's influence, two sampling locations were selected. The upstream sample location, TMSW-01, was chosen to represent conditions upstream of any leachate influence from the SFL. The downstream location, TMSW-02, was selected to monitor influences from landfill leachates into Threemile Creek prior to its confluence with the Kansas River.

4.2.4.2 Surface Water Analysis Results - Analytical results indicate metals and inorganic constituents present in the surface water collected. Table 4-21 provides the positive analytical

TABLE 4-20

SURFACE WATER/SEDIMENT ANALYTICAL PARAMETERS
Southwest Funston Landfill
Fort Riley, Kansas

ANALYSIS	EPA METHOD
LENL:	
Volatile Organics	8260
Semi-Volatile Organics	3550/8270 (Sediment) 3510/8270 (Surface water)
Chlorinated Pesticides/PCBs	3550/8080 (Sediment) 3510/8080 (Surface water)
ICP Metals[a]	3050/6010 (Sediment) 3005/6010 (Surface water)
GFAA Metals:	
Arsenic	3050/7060 (Sediment) 7060 (Surface water)
Lead	3020/7421 (Surface water)
Selenium	3050/7740 (Sediment) 7740 (Surface water)
Mercury	7471 (Sediment) 7470 (Surface water)
Total Recoverable Petroleum Hydrocarbons (TRPH)	3550/418.1 (Sediment) 418.1 (Surface water)
SWLO:	
Acid Herbicides	8150
Organophosphorus Pesticides	3550/8140 (Sediment) 3510/8140 (Surface water)
Wet Chemical Inorganics:	
Chloride	300 (Surface water only)
Sulfate	300 (Surface water only)
Nitrate	300 (Surface water only)
Bicarbonate	SM403 (Surface water only)
Cyanide, total	412D
Cyanide, amenable	412F (Surface water only)
Total Organic Carbon (TOC)	415.1

[a] = ICP metals include: aluminum, antimony, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, potassium, silver, sodium, thallium, vanadium, zinc.

LENL = Law Environmental National Laboratories

SWLO = Southwest Laboratory of Oklahoma

References: USEPA, 1986; USEPA, 1983; SM, 1985.

TABLE 4-21

POSITIVE RESULTS FOR SURFACE WATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	Upstream		Downstream				Upstream	Downstream
			Sample	Duplicate				
	KRSW01	KRSW02	KRSW03	KRSW06	KRSW04	KRSW05	TCSW01	TCSW02
Date Collected	05-27-92	05-27-92	05-27-92	05-27-92	05-26-92	05-26-92	05-28-92	05-28-92
VOLATILE ORGANICS (μg/L):								
Methylene chloride	16 (T)	16 (T)	16 (T)	16 (T)	12	--	11 (T)	13 (T)(R1)
PESTICIDES/PCBs (μg/L):	--	--	--	--	--	--	--	--
SEMI-VOLATILE ORGANICS (μg/L):	--	--	--	--	--	--	--	--
TOTAL FURNACE METALS (μg/L):								
Arsenic	3.5 (M2)(E)	4.3 (M2)(E)	4.5 (M2)(E)	4.3 (M2)(E)	4.4 (M2)(E)	4.6 (M2)(E)	2.5 (M2)(E)	4.4 (M2)(E)
Lead	-- (M2)	-- (M2)	-- (M2)	-- (M2)	-- (M2)	-- (M2)	-- (M2)	-- (M2)
Selenium	1.5	1.1	--	1.1	--	--	--	--
TOTAL ICP METALS (μg/L):								
Aluminum	620	1200	980	1100	1400	890	1300	1100
Barium	220	170	170	170	170	160	160	170
Beryllium	1.0	--	--	--	--	--	--	--
Calcium	74000	88000	88000	88000	80000	78000	94000	97000
Iron	660	1400	1300	1400	1600	1200	970	1200
Magnesium	22000	28000	26000	26000	25000	25000	23000	23000
Manganese	120	280	310	320	350	350	92	150
Potassium	11000	11000	11000	11000	11000	11000	12000	9700
Sodium	120000	280000	240000	240000	210000	210000	65000	60000
Vanadium	--	7.1	--	--	--	--	--	--
Zinc	27	26	21	23	22	22	35	26 (R2)
TOTAL MERCURY (μg/L):	--	--	--	--	--	--	--	--

TABLE 4-21

POSITIVE RESULTS FOR SURFACE WATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	Upstream		Downstream				Upstream	Downstream
			Sample	Duplicate				
	KRSW01	KRSW02	KRSW03	KRSW06	KRSW04	KRSW05	TCSW01	TCSW02
Date Collected	05-27-92	05-27-92	05-27-92	05-27-92	05-26-92	05-26-92	05-28-92	05-28-92
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (μg/L):	--	--	--	--	--	--	--	--
WET CHEMICAL INORGANICS:								
Inorganic chloride, (mg/L)	158.00	419.00	354.00	344.00	289.00	316.00	62.20	57.70
Nitrate, (mg/L)	2.20	--	--	--	--	--	5.80	4.50
Sulfate, (mg/L)	129.00	209.00	190.00	185.00	171.00	186.00	94.60	93.00
Total organic carbon, (mg/L)	11.20	12.30	10.70	11.00	14.90	13.80	6.40	6.50
Total cyanide, (μg/L)	--	--	--	--	--	--	--	--
Amenable cyanide, (μg/L)	--	--	--	--	--	--	--	--
Bicarbonate, (mg/L)	180.00	164.00	176.00	176.00	166.00	154.00	280.00	280.00
ORGANOPHOSPHORUS PESTICIDES (μg/L):								
ACID HERBICIDES (μg/L):	--	--	--	--	--	--	--	--

E – MS/MSD exceeds control limit. Estimated result due to poor precision.
M2 – Matrix spike recovery is low due to sample matrix effect. Sample result may be biased low.
R1 – Sample results are less than 10 times the amount detected in the rinsate. Result is estimated.
R2 – Sample results are less than 5 times the amount detected in the rinsate. Result is estimated.
T – Sample results are less than 10 times the amount detected in trip blank. Result is estimated.
-- Not detected

results of the surface water analyses. Results of the organic analyses performed indicated no measurable level of contamination of the surface waters sampled in the vicinity of the SFL except methylene chloride. Methylene chloride was detected at consistent concentrations in upstream and downstream samples indicating that the landfill did not contribute to the concentration of this compound. Although methylene chloride is a common laboratory contaminant, its presence cannot be attributed to laboratory contamination because the associated laboratory method blank did not contain this compound.

Many metals are naturally occurring in surface water. To evaluate the impact of the SFL to the surface water, a comparison must be made between metal concentrations upstream and downstream of the site. Small variances (less than 25 percent) in concentrations may be the result of the analytical uncertainty inherent in the analytical methodology; therefore, a variance less than 25 percent is not deemed significant and these will not be discussed. The analytical uncertainty value is derived from the accuracy data quality objective and control limits established for this project. Arsenic, aluminum, barium, calcium, iron, magnesium, manganese, potassium, and sodium were detected in all surface water samples. The samples downstream from SFL were not significantly (greater than 25 percent) higher than the upstream samples indicating that the landfill is not measurably impacting the surface water. One zinc result was slightly higher than the Kansas River upstream samples; however, this sample (TCSW-01) was located upstream of the landfill in Threemile Creek.

Several additional parameters were analyzed by the laboratories, including chloride, nitrate, sulfate, TOC, total cyanide, amenable cyanide, and bicarbonate. All of these parameters, except total and amenable cyanide, are naturally occurring in surface waters. These chemicals were assessed in the same manner as the metals. The concentrations of nitrate and bicarbonate are significantly higher in the samples from Threemile Creek than the concentrations in samples from the Kansas River. However, the concentrations in both Threemile Creek samples, upstream and downstream of the SFL, are close (less than 25 percent difference), indicating the landfill is not impacting the water in this creek.

4.2.4.3 <u>Historical Surface Water Data</u> - Surface water samples are routinely collected and analyzed from the Republican and Smokey Hill Rivers upstream of the SFL by KDHE. The historical data were accessed through the EPA STORET database. Results of arsenic, aluminum, and manganese are provided in Table 4-22. Arsenic and manganese values are consistent from the historical to the 1992 data. Current (Law, 1992) aluminum values are slightly higher than those detected historically. The STORET retrievals for the Kansas River are provided in Appendix C.

TABLE 4-22

COMPARISON OF HISTORICAL DATA TO CURRENT KANSAS RIVER SURFACE WATER DATA
Southwest Funston Landfill
Fort Riley, Kansas

Constituent	KDHE (1974-1993)	Law 1992
Aluminum, µg/L	220 - 1147	620 - 1400
Arsenic, µg/L	1 - 23	3.5 - 4.6
Manganese, µg/L	10 - 1217	120 - 350

4.2.5 Sediment Investigation

Sediment samples were collected in May of 1992 and analyzed for the parameters provided in Table 4-20.

4.2.5.1 Sediment Sampling - Seven sediment samples were collected immediately after the associated surface water sample. Figure 2-2 provides sediment sample locations. Sampling procedures are provided in Section 2.1.3.

4.2.5.2 Sediment Analysis - Due to the fact that this was a single sampling event and sediment deposition is not uniform, the results of this investigation can only indicate what SFL's contribution to sediment contamination may be. Analytical results indicate petroleum hydrocarbons, metals, and other inorganic constituents present in the sediment samples collected. Table 4-23 provides positive results of the sediment sample analyses. Results of the organic analyses performed indicated no measurable level of organic contamination of the sediments sampled in the vicinity of the SFL (with the exception of TRPH and methylene chloride). Methylene chloride was detected at consistent concentrations in samples from both upstream and downstream locations indicating that the landfill did not contribute to the concentration of this compound. Although methylene chloride is a common laboratory contaminant, its presence cannot be attributed to laboratory contamination because the associated laboratory method blank did not contain this compound. However, the trip blanks for five of the seven samples were contaminated with methylene chloride. Therefore, the methylene chloride may be the result of sample handling and shipping rather than being a site-related constituent.

Many metals are naturally occurring in sediment. To evaluate the impact of the SFL to the concentrations of metals in the sediments, a comparison must be made between metal concentrations upstream and downstream of the site. Small variances (less than 25 percent) in concentrations may be the result of the analytical uncertainty inherent in the analytical methodology; therefore, these will not be discussed. The analytical uncertainty value is derived from the accuracy data quality objective and control limits established for this project.

Arsenic was detected in all sediment samples collected. One downstream sample, KRSD-03, was slightly higher (33 percent) than the upstream samples. However, the duplicate of this sample was not higher than 25 percent criteria, possibly due to natural variability. Chromium was not detected in the samples collected upstream of the landfill but had positive results in the duplicate of KRSD-03 and KRSD-05 which may be a result of SFL activities. Barium, calcium, iron, sodium, and vanadium were detected at comparable levels in the upstream and downstream sediment samples from the Kansas River, indicating that the SFL is not contributing to the concentration of the metals. Lead, aluminum, manganese, magnesium, potassium, and zinc were

TABLE 4-23

POSITIVE HITS FOR SEDIMENT SAMPLES
SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS

PARAMETER	Upstream		Downstream				Upstream	Downstream
			Sample	Duplicate				
	KRSD01	KRSD02	KRSD03	KRSD06	KRSD04	KRSD05	TCSD01	TCSD02
Sample Depth	(0-2')	(0-2')	(0-2')	(0-2')	(0-2')	(0-2')	(0-2')	(0-2')
Date Collected	5-27-92	5-27-92	5-27-92	5-27-92	5-26-92	5-26-92	5-28-92	5-28-92
VOLATILE ORGANICS (μg/kg):								
Methylene chloride	19 (T)	13 (T)	20 (T)	19 (T)	13	15	16 (T)	27 (T)(R1)
PESTICIDES/PCBs (μg/kg):	--	--	--	--	--	--	--	--
SEMI-VOLATILE ORGANICS (μg/kg):	--	--	--	--	--	--	--	--
TOTAL MERCURY (mg/kg):	--	--	--	--	--	--	--	--
TOTAL FURNACE METALS (mg/kg):								
Arsenic	0.7	0.9	1.2	1.0	0.9	0.8	1.9	2.1
Lead	1.1	1.6	1.7	1.5	1.5	2.1	17	5.9
TOTAL ICP METALS (mg/kg):								
Aluminum	440	710	400	610	450	1900	13000	8200
Barium	37	61	22	26	20	51	190	150
Beryllium	0.3	--	--	--	--	--	0.5	0.2
Cadmium	--	--	--	--	--	--	1.7	1.6
Calcium	35000	5700	2600	2800	6600	10000	31000	17000
Chromium	--	--	--	2.2	--	2.3	14	9.8
Cobalt	2.2	2.7	--	--	--	1.9	9.0	6.2
Copper	--	--	--	--	--	1.3	10	6.2
Iron	2600	2600	2100	2200	1700	3700	13000	9900
Magnesium	460	290	160	220	200	710	4400	2900
Manganese	92 (M2)(E)	60 (M2)(E)	51 (M2)(E)	58 (M2)(E)	34 (M2)(E)	130 (M2)(E)	310 (M2)(E)	200 (M2)(E)
Nickel	--	--	--	--	--	--	15	10
Potassium	150	210	140	180	160	470	2600	1900
Silver	--	--	--	--	--	--	--	--

TABLE 4–23

POSITIVE HITS FOR SEDIMENT SAMPLES
SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS

	Upstream		Downstream				Upstream	Downstream
			Sample	Duplicate				
PARAMETER	KRSD01	KRSD02	KRSD03	KRSD06	KRSD04	KRSD05	TCSD01	TCSD02
Sample Depth	(0–2')	(0–2')	(0–2')	(0–2')	(0–2')	(0–2')	(0–2')	(0–2')
Date Collected	5–27–92	5–27–92	5–27–92	5–27–92	5–26–92	5–26–92	5–28–92	5–28–92
TOTAL ICP METALS (mg/kg)(CONT'D):								
Sodium	59	120	44	66	41	65	200	200 (R2)
Thallium	--	--	--	--	--	--	--	--
Vanadium	10	6.3	3.4	3.6	3.1	7.6	22	22
Zinc	5.5	5.9	4.0	4.8	4.7	10	48	30
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/Kg):	84 (M2)	17 (M2)	32 (M2)	20 (M2)	-- (M2)	-- (M2)	38 (M2)	20 (M2)
WET CHEMICAL INORGANICS (mg/Kg):								
Total Organic Carbon	840.00	1390.00	780.00	370.00	450.00	710.00	16300.00	6600.00
Total cyanide	--	--	--	--	--	--	--	--
ORGANOPHOSPHORUS PESTICIDES (mg	--	--	--	--	--	--	--	--
ACID HERBICIDES (mg/Kg):	--	--	--	--	--	--	--	--

E – MS/MSD RPD exceeds control limit. Estimated result due to poor precision.
M2 – Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.
R1 – Samples results are less than 10 times the amount detected in the rinsate. Result is estimated.
R2 – Samples results are less than 5 times the amount detected in the rinsate. Result is estimated.
T – Sample results are less than 10 times the amount detected in trip blank. Result is estimated.
-- Not detected
Note: All sample results were reported using dry weight.

detected in all sediment samples analyzed. The concentrations of these metals are consistent upstream and downstream of the SFL; however, significant increases in concentrations were noted in KRSD-05 which is located farthest downstream of the landfill. This indicates an impact on sediment quality from a source downstream of the landfill between sampling stations KRSD-04 and KRSD-05. Beryllium and cobalt were detected in upstream sediment samples, but not downstream.

Concentrations of all metals, except calcium, silver, and zinc, detected in samples from Threemile Creek were significantly higher than Kansas River values. Both samples upstream and downstream of the SFL contained the metals at consistent concentrations indicating no influence from the landfill. The difference may be attributable to other water sources (e.g., WWTP) upstream of the SFL. The available effluent data for 1992 and 1993 were obtained from Fort Riley for the Custer Hill WWTP, which discharges to a tributary of Threemile Creek upstream of SFL. The routine effluent analyses include pH, total suspended solids, biological oxygen demand, and chemical oxygen demand; they do not include metals analysis. Therefore, this data could not be used to determine if the WWTP is contributing to the metals concentrations in the Threemile Creek sediments.

Other parameters with positive results include TRPH and total organic carbon. TRPH and total organic carbon results both upstream and downstream sediment samples were at consistent levels, indicating the SFL did not contribute significantly to the concentrations present.

4.2.5.3 Historical Sediment Data - Sediment samples were collected from the Republican and Smokey Hill Rivers upstream of the SFL from 1976 through 1978. Results of the metals analysis are provided in Table 4-24. The results of the current (Law, 1992) study were compared to the historical data. All metals concentrations were within the range of values detected historically. These historical sediment data are provided in Appendix C.

4.3 SUMMARY AND INTERPRETATION OF NATURE AND EXTENT OF CONTAMINATION

This section summarizes the nature and extent of contamination at the SFL. Included are discussions of the analytical results of groundwater, surface and subsurface soils, surface water, and sediments.

4.3.1 Groundwater

In summary, organic constituents were detected in all of the eight well clusters. Methylene chloride (not associated with method blank contamination) was sporadically detected in all well

TABLE 4-24

COMPARISON OF HISTORICAL DATA TO CURRENT KANSAS RIVER SEDIMENT DATA
Southwest Funston Landfill
Fort Riley, Kansas

Constituent	EH (1976-1978)	Law 1992
Arsenic, mg/kg	NA	0.7 - 1.2
Cadmium, mg/kg	< QL	< 1.0
Chromium, mg/kg	29.7	2.2 - 2.3
Copper, mg/kg	1.4 - 5	< 1.0 - 1.3
Iron, mg/kg	1900 - 17000	1700 - 3700
Lead, mg/kg	4 - 14.3	1.1 - 2.1
Manganese, m/kg	92 - 200	34 - 130
Zinc, mg/kg	11 - 143	4.0 - 10

NA - Not Available
QL - Quantitation Limit Not Provided
EH - Kansas Department of Health & Environment, Environmental Health Laboratories

clusters. However, most of the methylene chloride hits were associated with trip blank contamination. Additional organics were detected at the landfill in monitoring well SFL92-601 for the baseline sampling event and were detected in samples collected in the first three quarterly sampling events. Well SFL92-601 is in a downgradient position relative to groundwater flow at the SFL during all sampling events. Organics were also detected in baseline samples at monitoring well clusters 5 (SFL92-501 and SFL92-503) and 8 (SFL92-801 and SFL92-803) but not in the following quarterly sampling events. The presence of contaminants in the baseline event only may have been due to processes within the unsaturated zone in response to the antecedent rainfall, which may have mobilized contaminants in the capillary fringe/water table zone (Section 3.6.2.6), or the direction of groundwater flow due to elevated Kansas River levels. The contaminants detected in SFL92-801 and SFL92-803 may be the result of the localized dumping in this area or migration from the SFL. The contaminants detected in SFL92-501 and SFL92-503 may be associated with the activities at Camp Funston or be influenced by the Kansas River/Threemile Creek. The presence of significantly lower levels or absence of volatiles in the clusters 6 and 7, which are between 5 and 8, indicate that the contaminants detected at the 5 and 8 clusters are possibly unrelated and localized. Additionally, the presence of Threemile Creek (which acts as a hydraulic boundary to groundwater flow) between the two areas indicates the contamination is localized. Contamination of these areas is intermittent.

Table 4-25 summarizes the constituents which exceeded ARARs for groundwater. The MCLs and KALs were exceeded for vinyl chloride, 1,1,2-trichloroethane, and cis-1,3-dichloropropene in the groundwater samples in clusters 5 and 8. The MCLs and KALs were exceeded for vinyl chloride and benzene at cluster 6.

The sources of these organic compounds which are indicated to be in the landfill are described below. The solvents (1,1,2,2-tetrachloroethane, 1,1,1,2-tetrachloroethane, 1,1,2-trichloroethane, pentachloroethane) and their breakdown products (trans-1,2-dichlorethene, methyl chloride, and vinyl chloride) are indicative of degreasing solvents used in motor vehicle maintenance shops. Methyl isobutyl ketone and 1,2,3-trichloropropane are used as paint thinners and removers. The presence of 1,2-dibromoethane and cis 1,3-dichloropropene may be from their use as insecticides. Ethyl methacrylate and styrene are used to make plastic and may indicate the presence of plastic waste. Benzene and xylenes are indicative of fuels or may be used as solvents. Bromoform, chlorodibromomethane and trichlorofluoromethane are used for water treatment and, therefore, indicate the presence of WWTP waste. Trichlorofluoromethane is also used as a refrigerant and a degreasing solvent (Howard, 1990; and toxicological profiles - Appendix N).

Although metals were detected in the groundwater at the site, the only MCL exceeded was for antimony: secondary MCLs for manganese, iron, and aluminum were also exceeded (Table 4-25). Additionally, beryllium concentrations in every well exceeded KALs. All of these elements were detected in samples from the Fort Riley and city of Ogden drinking water wells, both upgradient and downgradient from SFL, indicating that the metals are naturally occurring above MCLs in this area. Iron concentrations were higher than background in the wells SFL92-601, SFL92-602, and SFL92-603. This may be indicative of a nearby iron source or may be attributed to changes in groundwater chemistry at the boundary of a plume. Iron (III) may be

TABLE 4-25

EXCEEDANCES OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) AND TO BE CONSIDERED (TBC) REQUIREMENTS FOR GROUND WATER

Southwest Funston Landfill
Fort Riley, Kansas

PARAMETER	SAMPLE NO.	SAMPLE CONC'N (µg/L)	FEDERAL MCL[a] (µg/L)	KAL[b] (µg/L)	KNL[c] (µg/L)
Vinyl Chloride	SFL92-501 SFL92-601	14 18	2	2	0.2
1,2-Dichloroethane	SFL92-501, 502, 601	6.8-16	5	5	0.5
1,1,2,2-Tetrachloroethane	SFL92-503, 801, 803	6.3-15	---	1.7	0.17
Benzene	SFL92-601	14	5	5	0.005
1,1,2-Trichloroethane	SFL92-801	8.8	5	6.1	0.61
cis-1,3-Dichloropropene	SFL92-801 SFL92-803	5.9 5.4	---	2	0.2
Antimony	SFL92-703, 303	26-31	6	143	---
Beryllium	SFL92-101, 102, 103, 201, 202, 203, 303, 401, 403, 501, 503, 504, 601, 602, 603, 701, 703, 801, 803, IRRWELL	1.0-4	4*	0.13	---
Manganese	ALL	320-2700	50[d]	50	---
Aluminum	SFL92-102, 103 203, 302, 303, 602, 703, 803	110-460	50-200[d]	5000	---
Iron	SFL92-101, 102, 201, 202, 203, 301, 302, 303, 401, 403, 501, 503, 504, 601, 602, 603, 701, 703, 801, IRRWELL	550-35000	300[d]	300	---

[a] – Maximum Contaminant Level (40 CFR 141 Subpart B)
[b] – Kansas Action Level
[c] – Kansas Notification Level
[d] – Secondary MCL
* – Effective January 17, 1994

reduced to iron (II), which is more soluble, at the boundary of a plume resulting in an increase in iron concentrations in this zone. This is due to terminal electron accepting processes as electron receptors are added or depleted as a function of recharge events along the front of a contaminant plume (Vroblesky and Chapelle, 1993). Possible metal sources are described below.

Engine wear metals primarily consist of iron, chromium, cadmium, lead, and zinc and would be present in spent vehicle maintenance waste oils and degreasing solvents. However, these metals were not present exceeding the background concentrations in any of the wells. This indicates that this source of metals is not impacting the groundwater at measurable levels beneath the landfill. The other primary source of metals is the sludge from the WWTPs. These sludges may contain a variety of metals and may be contributing to the metal concentrations found in the groundwater samples. This cannot be confirmed because analytical data on the sludges disposed at SFL are not available. Even though certain metals exceeded the background wells, their concentrations are within the regional ranges for the Kansas River alluvium (USGS, 1975; Fader, 1974). Groundwater concentrations of iron and manganese in wells screened in the Kansas River alluvium in Riley and Geary counties have historically been shown to range from 160 to 4,300 μg/L and 200 to 2,000μg/L, respectively. Iron concentrations and manganese have been shown as high as 30,000 μg/L and 2,800 μg/L, respectively, in alluvial wells in Wyandotte County (Fader, 1974)..

4.3.2 Surface and Subsurface Soil

The landfill surface soils were analyzed for lead, copper, and zinc by XRF. Metals were the only constituents expected in the landfill cover because 60 percent of this soil originated from a berm at the rifle range. The results of the XRF surface soil analysis for lead, copper, and zinc indicate the presence of lead throughout the central eastern portion of the landfill at concentrations consistent with background in the majority of the samples analyzed.

The purpose of the subsurface soil investigation was to determine if there were releases from the landfill. The results characterize subsurface soils at the periphery of the landfill to accomplish that objective. The chemical results of the subsurface soil analysis indicate the presence of volatile organics, a pesticide degradation product (DDE), Aroclor-1248, and phthalates. The volatile and pesticide concentrations are below all RCRA CALs (see Table 4-17). The phthalate contamination occurs at all depths and throughout the site; however, concentrations are below CALs. The Aroclor-1248 concentration exceeded the CAL in monitoring well boring SFL92-201 (Table 4-26). Various metals were detected in the soil samples upgradient and downgradient of the site. Only beryllium and thallium concentrations in the soil samples analyzed exceeded CALs in samples from both upgradient and downgradient locations. Petroleum hydrocarbons (as TRPH) were detected in samples taken from locations upgradient and downgradient of the site.

TABLE 4-26

EXCEEDANCES OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) AND TO BE CONSIDERED (TBC) REQUIREMENTS FOR SOILS

Southwest Funston Landfill

Fort Riley, Kansas

PARAMETER	SAMPLE	SAMPLE CONC'N (mg/kg)	RCRA CAL[a] (mg/kg)
Aroclor-1248	SFLSB-201	0.25	0.09
Beryllium	SFLSB-102	0.5	
	SFLSB-201	1	0.2
	SFLSB-203	0.6	
	SFLSB-303	1.6	
	SFLSB-403	0.5	
	SFLSB-502	0.4	
	SFLSB-503	0.3	
	SFLSB-703	2.3	
	SFLSB-803	0.5	
Thallium	SFLSB-101	15	
	SFLSB-203	21	7
	SFLSB-602	17	

(a) - RCRA Corrective Action Levels - Federal Register, Vol 55, No. 145, 27 July 1990. Pages 30798-30884. Corrective Action for Solid Waste Managements Facilities, Proposed Rule

In order to interpret the soil chemical data with site specific conditions, Law compared boring log information, sample depth, soil and groundwater chemistry, and background conditions.

All soil samples were collected in the saturated zone. Therefore, the soil results may be biased by the groundwater results because constituents dissolved within the water would have been analyzed and presented as a total soil concentration.

The soil stratigraphy documented in background boring SFL92-103 and in boring SFL92-203 differed slightly from the other well borings. Background boring SFL92-103 contained silt, clay, and clayey silt layers from surface to 22 feet and 44 to 51 feet with sand units in between. The intermediate sample collected from the clayey silt layer contained the highest amounts of constituents as compared to the shallow and deep soil samples which were collected from the sand units. The elevated concentrations detected in the intermediate soil sample are indicative of the higher adsorptive capacity of clayey silts (see Section 5.4).

The boring log of SFL92-203 indicated that plastic and metal debris was encountered from surface to 4 feet and again at 16 to 20 feet. Soil sample SB201 was collected from the debris zone. This would explain why the phthalates were detected. Phthalates are used as plasticizers in plastic products. The pesticide (DDE) and the Aroclor (1248) detected are probably indicative of pesticide waste containers and transformer oils that were placed in the landfill. Methyl chloride is a breakdown product of chlorinated ethanes or ethenes and probably indicates the presence of solvents such as carbon tetrachloride, tetrachloroethene or trichloroethane (used as degreasing solvents). Pesticides, PCBs, and phthalates have low solubilities and high adsorption coefficients (Section 5.2.3) and are not likely to migrate. Therefore, these compounds indicate that the source is nearby or was actually sampled (i.e., plastic and metal debris).

The metals in this boring (Table 4-18) are consistent with regional geology (USGS, 1975). Lead and aluminum concentrations were elevated compared to the other soil data. This may be attributed to the metal landfill debris encountered.

The remaining soil boring logs indicated that well borings in clusters 4, 5, 6, and 8 consisted of silty sands to 16 feet below surface with sand to the bedrock, respectively, and well borings in clusters 3 and 7 consisted entirely of sandy soils.

Sand is very transmissive with low adsorptive capacity. This would indicate that the constituents detected are not adsorbed to the sand and may be very mobile (Section 5.4). Trends in the soil data are not evident.

4.3.3 Surface Water and Sediments

The surface water and sediment results indicate that the SFL is not contributing any organic contaminants to the Kansas River. Methylene chloride was detected but concentrations were similar upstream to downstream indicating no landfill contribution. The results of the groundwater samples collected from the monitoring wells located beside the river confirm this. Metals were detected in both upstream and downstream samples at similar concentrations.

4.3.4 Data Sufficiency

The data collected for the SFL investigation are sufficient to perform the risk assessment, with some qualifications, and to evaluate remedial alternatives at this site. The data collected from the surface soils are sufficient to determine that RCRA CALs are not exceeded for the metals suspected to be present in the landfill cap. However, the surficial soil data to be used in the risk assessment are biased high by design. Over 100 surficial soil samples were collected from across the landfill and analyzed for copper lead and zinc using XRF. The ten samples with the highest concentration were submitted to the CLP laboratory for analysis. The CLP analytical results were used in the risk assessment. Because these results are based on the ten highest detected XRF values, they are biased high in terms of determining surficial soil concentrations across the entire landfill.

The surface water and sediment data collected are limited to only one round of data thus do not reflect seasonal fluctuations in water chemistry. The data indicate that there is no apparent differences in the water chemistry of the Kansas River upstream and downstream of the SFL. Thus, the SFL does not appear to be impacting the river.

4.4 FOURTH QUARTER GROUNDWATER DATA SUMMARY

Groundwater samples were obtained from the site in September 1993. The results of the analysis of these samples are provided in the Fourth Quarter Groundwater Quality Control Summary Report (Law, 1993d). The results are summarized in Table 4-27, Table 4-28, and Figure 4-12, and are discussed below.

Volatile organic compounds were detected in only two well clusters in the fourth quarter groundwater samples. Tetrachloroethene was detected in Well Cluster 300 in the fourth quarter, the only time it was identified in the groundwater at the site. Benzene, chloroethane, 1,1-dichloroethane, and vinyl chloride were detected in Well Cluster 600. With the exception of chloroethane, the detection of these compounds in Well Cluster 600 is consistent with previous groundwater analytical results. The detection of chloroethane in Well Cluster 600 is the only time it was identified in the groundwater at the site.

Inorganic compounds were detected at concentrations greater than background in all seven of the (non-background) well clusters in the fourth quarter. These inorganic compounds were

TABLE 4-27

POSITIVE RESULTS FOR FOURTH QUARTER (SEPTEMBER 1993) GROUNDWATER SAMPLES
Southwest Funston Landfill
Fort Riley, Kansas

CONSTITUENT	FREQUENCY OF DETECTION	BACKGROUND RANGE	DETECTED CONCENTRATION
Volatile Organics:			
1,1-Dichloroethane	1/18	ND	3.0
Benzene	2/18	ND	3.2 - 7.6
Chloroethane	1/18	ND	19
Tetrachloroethene	1/18	ND	5.4
Vinyl chloride	2/18	ND	14 - 50
Total Furnace Metals:			
Arsenic	15/18	2.3 - 8.2	2.1 - 22
Lead	6/18	ND	1.1 - 16
Selenium	2/18	1.4 - 4.9	1.0 - 1.1
Total ICP Metals:			
Barium	18/18	220 - 320	150 - 1600
Cadmium	1/18	4.0	7.0
Chromium	2/18	ND	18 - 20

All units are µg/L
ND - not detected

TABLE 4–28

METALS RESULTS EXCEEDING BACKGROUND CONCENTRATIONS FOURTH QUARTER (SEPTEMBER 1993) GROUNDWATER SAMPLES

Southwest Funston Landfill
Fort Riley, Kansas

METAL	MAXIMUM BACKGROUND CONC'N*	SAMPLES EXCEEDING MAXIMUM BACKGROUND CONCENTRATIONS		MCL
Total Arsenic, µg/L	8.2	SFL92–201	9.2 µg/L	50
		SFL92–203	15 µg/L	
		SFL92–302	22 µg/L	
		SFL92–303	21 µg/L	
		SFL92–503	15 µg/L	
		SFL92–504	15 µg/L	
		SFL92–601	13 µg/L	
		SFL92–602	21 µg/L	
		SFL92–603	22 µg/L	
		SFL92–701	12 µg/L	
		SFL92–703	12 µg/L	
		SFL92–801	12 µg/L	
Total Lead, µg/L	ND	SFL92–201	10 µg/L	15
		SFL92–301	1.1 µg/L	
		SFL92–403	16 µg/L	
		SFL92–504	1.2 µg/L	
		SFL92–701	1.5 µg/L	
		SFL92–703	1.3 µg/L	
Total Selenium, µg/L	4.9	none		50 (s)
Total Barium, µg/L	320	SFL92–201	440 µg/L	2000
		SFL92–401	760 µg/L	
		SFL92–403	600 µg/L	
		SFL92–503	390 µg/L	
		SFL92–504	400 µg/L	
		SFL92–601	1600 µg/L	
		SFL92–602	1000 µg/L	
		SFL92–701	410 µg/L	
Total Cadmium, µg/L	4.0	SFL92–201	7.0 µg/L	5.0
Total Chromium, µg/L	ND	SFL92–201	18 µg/L	100
		SFL92–501	20 µg/L	

ND – not detected
MCL – Maximum Contaminant Level
(s) – secondary MCL
* Background concentrations were obtained from SFL92–101, SFL92–102 and SFL92–103.

Sources:
Federal Register, Volume, 56, No. 20, January 30, 1991
40 CFR, Section 141.11 (July 1, 1987 Edition)
40 CFR, Section 141.62 (January 31, 1991 Edition)
40 CFR, Volume 56, No. 126, July 1, 1991.

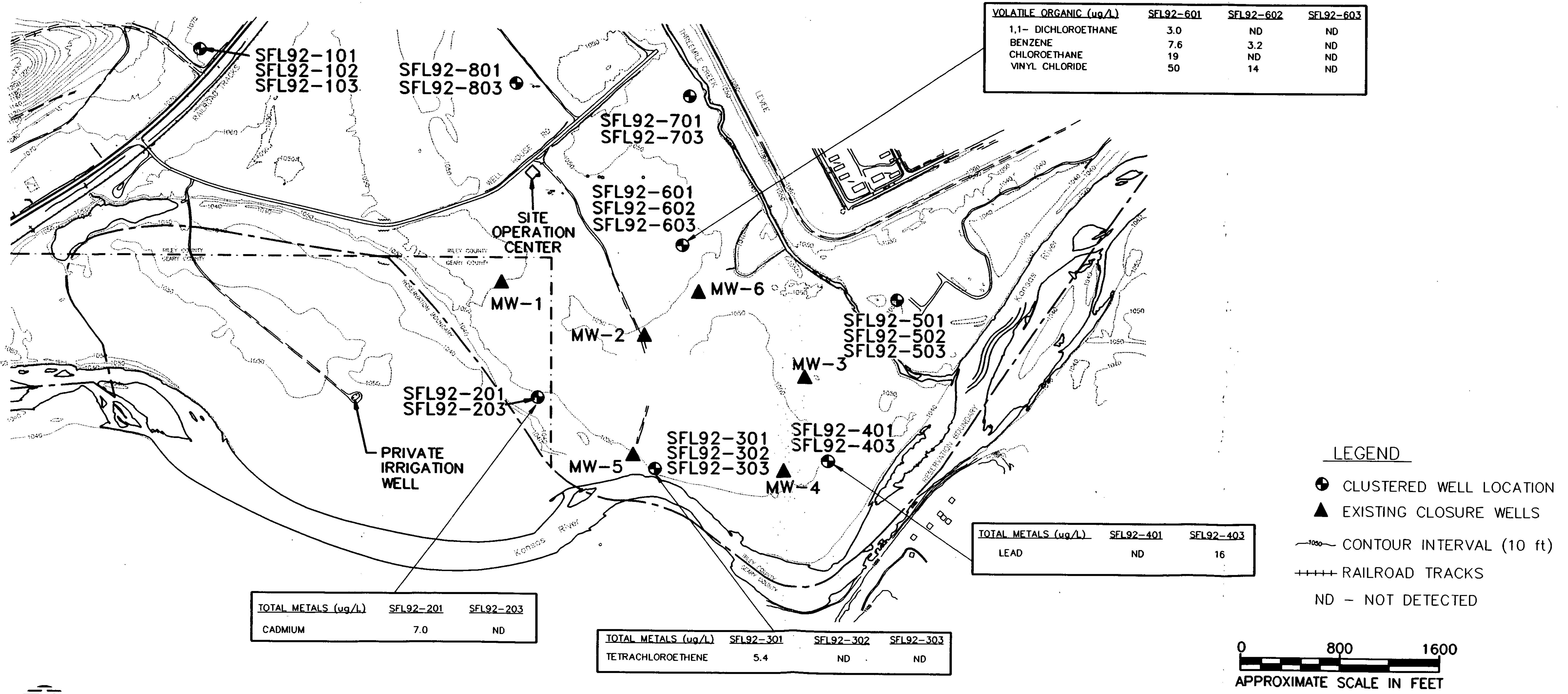
FIGURE 4-12

GROUND-WATER ANALYTICAL RESULTS*
FOURTH QUARTER (SEPTEMBER 1993)
SOUTHWEST FUNSTON LANDFILL

FORT RILEY, KANSAS

NOTE

*THIS INCLUDES ALL POSITIVE ORGANIC RESULTS AND METALS RESULTS WHICH EXCEED FEDERAL MCLS.



VOLATILE ORGANIC (ug/L)	SFL92-601	SFL92-602	SFL92-603
1,1- DICHLOROETHANE	3.0	ND	ND
BENZENE	7.6	3.2	ND
CHLOROETHANE	19	ND	ND
VINYL CHLORIDE	50	14	ND

TOTAL METALS (ug/L)	SFL92-401	SFL92-403
LEAD	ND	16

TOTAL METALS (ug/L)	SFL92-201	SFL92-203
CADMIUM	7.0	ND

TOTAL METALS (ug/L)	SFL92-301	SFL92-302	SFL92-303
TETRACHLOROETHENE	5.4	ND	ND

arsenic, barium, cadmium, chromium, and lead. Considering the locations where arsenic was detected and the concentrations at which it was detected, the fourth quarter results are consistent with previous results. Fourth quarter results for the other four inorganic compounds show an increase in the number of well clusters in which they were detected and/or the concentrations. In general, the changes are considered to be small; however, lead was detected for the first time in non-background wells during the fourth quarter (once slightly above its MCL). In addition, cadmium was also detected slightly above its MCL in the fourth quarter.

Groundwater samples were also obtained from existing wells at Camp Funston, which borders the site to the northeast. Camp Funston was established during World War I, and was initially used to house troops. Since that time, the uses of Camp Funston have diversified. In addition to providing housing for troops, other facilities/operations at Camp Funston have included automobile service stations (including USTs), incinerators, painting booths, tracked vehicle maintenance, engine testing, and vapor degreasing. Potential constituents associated with these facilities/operations include volatile organic compounds/solvents, petroleum hydrocarbons, and metals (Berger, 1992; Dames & Moore, 1992).

The results of the analysis of the samples from Camp Funston wells are provided in Law, 1993d. These results are summarized in Table 4-29 and in the following paragraph (also see Section 5.6). These fourth quarter data represent the only data currently available for the Camp Funston wells.

Volatile organic compounds were detected at six of the eleven wells sampled for organics at Camp Funston. These compounds were: acetone; benzene; chloroform; dichlorodifluoromethane; ethylbenzene; methylene chloride; toluene; and xylenes. In addition, semi-volatile organic compounds were detected at three of the eleven wells. These compounds were: 2,4-dimethylphenol; 2-methylnaphthalene; 2-methylphenol; 3 & 4-methylphenol; naphthalene; and bis(2-ethylhexyl)phthalate. Finally, metals were detected at all twelve of the Camp Funston wells sampled and analyzed for inorganic constituents. The inorganic compounds detected were: arsenic; barium; cadmium; chromium; lead; and selenium.

TABLE 4-29

POSITIVE RESULTS FOR FOURTH QUARTER (SEPTEMBER 1993)
GROUNDWATER SAMPLES
Camp Funston
Fort Riley, Kansas

CONSTITUENT	FREQUENCY OF DETECTION	RANGE OF DETECTED CONCENTRATIONS
Volatile Organics:		
Acetone	1/11	830
Benzene	3/11	1.2 – 30,000
Chloroform	1/11	16
Dichlorodifluoromethane	2/11	270 – 310
Ethylbenzene	3/11	62 – 2,900
Methylene chloride	3/11	10 – 150
Toluene	3/11	2.2 – 23,000
Xylenes (total)	3/11	200 – 8,300
Dissolved Furnace Metals:		
Arsenic	11/12	3.4 – 84
Lead	2/12	4.6 – 9.2
Selenium	2/12	1.7 – 13
Thallium	1/12	1.0
Dissolved ICP Metals:		
Barium	12/12	260 – 1,600
Cadmium	1/12	4.0
Chromium	1/12	9.0
Semi-Volatile Organics:		
2,4-Dimethylphenol	2/11	6.7 – 14
2-Methylnaphthalene	3/11	22 – 68
2-Methylphenol	1/11	20
3&4-Methylphenol	1/11	38
Naphthalene	3/11	94 – 120
bis(2-Ethylhexyl)phthalate	1/11	13
Total Furnace Metals:		
Arsenic	12/12	6.1 – 100
Lead	10/12	1.5 – 12
Selenium	5/12	1.3 – 13
Total ICP Metals:		
Barium	12/12	270 – 1,600
Cadmium	3/12	4.0 – 5.0
Chromium	7/12	8.0 – 17

All units are μg/L

5.0 CONSTITUENT FATE AND TRANSPORT

The fate and transport of site constituents depends upon the site's physical conditions, the physical and chemical characteristics of the constituents, and the nature and extent of the constituent release. In regards to constituent fate and transport related to the SFL, the following topics are discussed in this section:

- Chemical and physical characteristics of constituents
- Potential routes of constituent migration
- Persistence of constituents
- Fate and transport of constituents of concern
- Summary and conclusions

5.1 CHEMICAL AND PHYSICAL CHARACTERISTICS OF CONSTITUENTS

Chemical and physical characteristics for the organic and inorganic compounds detected at the SFL are summarized in Tables 5-1 through 5-4. The information included in these tables is used in discussions throughout this section. A brief description of these characteristics and their significance is presented below.

5.1.1 Solubility

The solubility of a compound is defined as the mass which dissolves in a given volume of water at a given temperature. Compounds which are highly soluble are generally more likely to remain dissolved in the water column and to be transported more quickly and for greater distances in surface waters, saturated soils, or groundwater, than compounds with lower solubilities. Often, highly soluble compounds are less likely to volatilize (see Table 5-1).

5.1.2 Vapor Pressure

The vapor pressure of the constituent indicates its potential to volatilize, or to transform into a gas. Compounds with higher vapor pressures are more likely to volatilize than those with lower vapor pressures (see Table 5-1).

TABLE 5-1

ORGANIC CONTAMINANT FATE AND TRANSPORT DATA
Southwest Funston Landfill
Fort Riley, Kansas

CONSTITUENT	MOLECULAR WEIGHT (g/mole)	SOLUBILITY IN WATER (mg/L) (25+/- 5° C)	ref.	VAPOR PRESSURE (atm) (25+/- 5° C)	ref.	HENRY'S LAW CONSTANT (atm-m^3/mole) (25+/- 5° C)	ref.	SPECIFIC GRAVITY (25+/- 5° C)	ref.	AQUATIC BIOCONCENTRATION FACTOR (BCF)	ref.
VOLATILES:											
Benzene	78.11	1.80E+03	1	1.25E-01	1	5.48E-03	1	0.87	1	5.20E+00	2
Bromoform	252.73	3.13E+03	1	7.37E-03	1	5.32E-04	1	2.89	1	ND	
Carbon Disulfide	76.13	1.70E+03	1	4.74E-01	1	2.12E-02	1	1.26	1	7.90E+00	5
Chlorodibromomethane	208.28	4.00E+03	1	1.00E-01	1	7.83E-03	1	2.44	1	1.50E+00	5
1,2-Dibromoethane	187.87	4.31E+00	5	1.45E-02	5	3.18E-04	7	2.70	5	2.70E+00	7
trans-1,4-Dichloro-2-butene	125.00	ND		ND		ND		1.18	6	ND	
1,1-Dichloroethane	98.96	5.06E+03	1	3.08E-01	1	5.45E-03	1	1.17	1	ND	
1,2-Dichloroethane	98.96	8.52E+03	4	1.04E-01	4	9.77E-04	4	1.25	1	8.00E+00	4
trans-1,2-Dichloroethene	96.94	6.30E+03	4	4.47E-01	4	6.72E-03	4	1.27	1	2.20E+01	4
1,2-Dichloropropane	112.99	2.80E+03	1	6.58E-02	1	2.94E-03	1	1.16	1	2.00E+00	5
cis-1,3-Dichloropropene	110.97	2.70E+03	1	5.66E-02	1	1.30E-03	1	1.22	1	ND	
2-Hexanone	100.16	3.50E+04	1	5.00E-03	1	1.75E-03	1	0.81	1	ND	
Methyl Chloride	50.48	7.40E+03	1	6.50E-03	1	1.00E-02	1	0.92	1	ND	
Methylene Chloride	84.93	1.67E+04	1	5.99E-01	1	2.69E-03	1	1.33	1	5.00E+00	2
Methyl Isobutyl Ketone	100.16	1.70E+04	1	1.97E-02	1	1.49E-05	1	0.80	1	5.00E+00	5
Methylacrylonitrile	67.1	2.57E+04	8	5.26E-02	8(a)	ND		0.80	8	ND	
Methylene Bromide	173.85	1.18E+04	7	4.87E-02	7	7.50E-04	7	2.48	6	2.10E+00	7
Pentachloroethane	202.30	4.80E+02	4	4.61E-03	4	1.94E-03	5	1.67	5	6.70E+01	5
Styrene	104.15	1.60E+02	1	8.49E-03	1	2.61E-03	1	0.91	1	ND	
1,1,1,2-Tetrachloroethane	167.85	1.10E+03	4	1.58E-02	4	2.42E-03	5	1.60	6	1.20E+01	5
1,1,2,2-Tetrachloroethane	167.85	2.97E+03	1	7.89E-03	1	4.56E-04	1	1.59	1	1.00E+01	5

TABLE 5-1

ORGANIC CONTAMINANT FATE AND TRANSPORT DATA
Southwest Funston Landfill
Fort Riley, Kansas

CONSTITUENT	MOLECULAR WEIGHT (g/mole)	SOLUBILITY IN WATER (mg/L) (25+/- 5° C)	ref.	VAPOR PRESSURE (atm) (25+/- 5° C)	ref.	HENRY'S LAW CONSTANT (atm-m³/mole) (25+/- 5° C)	ref.	SPECIFIC GRAVITY (25+/- 5° C)	ref.	AQUATIC BIOCONCENTRATION FACTOR (BCF)	ref.
VOLATILES (continued):											
1,1,2-Trichloroethane	133.40	4.50E+03	1	2.50E-02	1	9.09E-04	1	1.44	1	0.00E+00	5
Trichloroethene	131.39	1.10E+03	1	9.74E-02	1	9.90E-03	1	1.46	1	1.06E+01	2
Trichlorofluoromethane	137.38	1.08E+03	4	1.06E+00	4	9.70E-02	4	1.48	1	ND	
1,2,3-Trichloropropane	147.43	1.75E+03	3	2.63E-03	5	3.17E-04	3	1.42	5	9.20E+00	3
Vinyl Chloride	62.50	1.10E+03	1	3.50E+00	1	5.60E-02	1	0.91	1	1.17E+00	2
o-Xylene	106.17	2.04E+02	1	8.68E-03	1	5.35E-03	1	0.88	1	2.00E+00	5
m-Xylene	106.17	1.73E+02	1	1.09E-02	1	6.30E-03	1	0.88	1	2.00E+00	5
p-Xylene	106.17	2.00E+02	1	1.15E-02	1	6.30E-03	1	0.86	1	2.00E+00	5
SEMI-VOLATILES:											
Bis(2-ethylhexyl)phthalate	390.00	4.00E-01	1	8.16E-11	1	1.10E-05	1	0.99	1	6.20E+03	7
Butyl Benzyl Phthalate	312.37	4.22E+01	1	8.25E-06	1	1.30E-06	1	1.11	1	6.63E+02	7
PESTICIDES/PCBs:											
4,4'-DDE	319.03	1.20E-02	1	8.54E-09	1	2.34E-05	1	ND		5.10E+04	2
Aroclor 1248 (PCB)	288.00	6.00E-02	1	4.94E-04	1	3.50E-03	1	1.41	1	3.43E+05	3

1. Montgomery and Welkom, 1990.
2. Superfund Public Health Evaluation Manual, 1986.
3. ATSDR, Toxicology Profiles, 1987-93.
4. Howard, 1990.
5. Verschueren, 1983.
6. Aldrich, 1990-91.
7. IRPTG, 1989.
8. IRIS, 1993.

a: obtained at 12.8°C
ND: No Data.

TABLE 5-2

ORGANIC PARTITION COEFFICIENTS AND RETARDATION FACTORS

Southwest Funston Landfill
Fort Riley, Kansas

CONSTITUENT	LOG ORGANIC CARBON PARTITION COEFFICIENT (LOG K_{OC})	ref.	LOG OCTANOL-WATER PARTITION COEFFICIENT (LOG K_{OW})	ref.	PARTITION COEFFICIENT (K_d)		RETARDATION FACTOR (R)	
					f_{OC} = 0.223%	f_{OC} = 0.012%	f_{OC} = 0.223%	f_{OC} = 0.012%
VOLATILES:								
Benzene	1.92	1	1.95	1	1.85E-01	9.98E-03	2.2	1.1
Bromoform	2.06	1	2.30	1	2.56E-01	1.38E-02	2.7	1.1
Carbon Disulfide	1.80	5	1.84	1	1.41E-01	7.57E-03	1.9	1.1
Chlorodibromomethane	1.92	1	2.08	1	1.85E-01	9.98E-03	2.2	1.1
1,2-Dibromoethane	1.45	4	1.76	4	6.28E-02	3.38E-03	1.4	1.0
trans-1,4-Dichloro-2-butene	ND		ND		ND	ND	ND	ND
1,1-Dichloroethane	1.48	1	1.78	1	6.73E-02	3.62E-03	1.4	1.0
1,2-Dichloroethane	1.30	1	1.48	3	4.45E-02	2.39E-03	1.3	1.0
trans-1,2-Dichloroethene	1.56	3	2.06	3	8.10E-02	4.36E-03	1.5	1.0
1,2-Dichloropropane	1.43	1	2.28	1	6.00E-02	3.23E-03	1.4	1.0
cis-1,3-Dichloropropene	1.36	1	1.41	1	5.11E-02	2.75E-03	1.3	1.0
2-Hexanone	2.13	1	1.38	1	3.01E-01	1.62E-02	3.0	1.1
Methyl Chloride	1.40	1	0.90	1	5.60E-02	3.01E-03	1.4	1.0
Methylene Chloride	0.94	1	1.30	1	1.94E-02	1.05E-03	1.1	1.0
Methyl Isobutyl Ketone	0.79	1	1.09	1	1.38E-02	7.40E-04	1.1	1.0
Methylacrylonitrile	ND		ND		ND	ND	ND	ND
Methylene Bromide	1.42	4	1.64	4	5.87E-02	3.16E-03	1.4	1.0
Pentachloroethane	2.39	3	3.05	3	5.47E-01	2.95E-02	4.6	1.2
Styrene	2.87	1	2.95	1	1.65E+00	8.90E-02	12	1.6
1,1,1,2-Tetrachloroethane	2.00	5	3.03	3	2.23E-01	1.20E-02	2.5	1.1
1,1,2,2-Tetrachloroethane	1.66	1	2.39	1	1.02E-01	5.49E-03	1.7	1.0

TABLE 5-2

ORGANIC PARTITION COEFFICIENTS AND RETARDATION FACTORS
Southwest Funston Landfill
Fort Riley, Kansas

CONSTITUENT	LOG ORGANIC CARBON PARTITION COEFFICIENT (LOG K_{OC})	ref.	LOG OCTANOL-WATER PARTITION COEFFICIENT (LOG K_{OW})	ref.	PARTITION COEFFICIENT (K_d)		RETARDATION FACTOR (R)	
					f_{OC} = 0.223%	f_{OC} = 0.012%	f_{OC} = 0.223%	f_{OC} = 0.012%
VOLATILES (continued):								
1,1,2-Trichloroethane	1.75	1	2.18	1	1.25E-01	6.75E-03	1.8	1.0
Trichloroethene	1.98	1	2.72	1	2.13E-01	1.15E-02	2.4	1.1
Trichlorofluoromethane	2.20	1	2.53	3	3.53E-01	1.90E-02	3.4	1.1
1,2,3-Trichloropropane	1.99	2	1.98	2	2.18E-01	1.17E-02	2.5	1.1
Vinyl Chloride	0.39	1	0.60	1	5.47E-03	2.95E-04	1.0	1.0
o-Xylene	2.11	1	2.95	1	2.87E-01	1.55E-02	2.9	1.1
m-Xylene	3.20	1	3.20	1	3.53E+00	1.90E-01	25	2.3
p-Xylene	2.31	1	3.15	1	4.55E-01	2.45E-02	4.0	1.2
SEMI-VOLATILES:								
Bis(2-ethylhexyl)phthalate	5.00	1	4.20	1	2.23E+02	1.20E+01	1488	81
Butyl Benzyl Phthalate	4.45	4	4.77	1	6.28E+01	3.38E+00	420	24
PESTICIDES/PCBs:								
4,4'-DDE	5.34	1	5.77	1	4.88E+02	2.63E+01	3253	176
Aroclor 1248 (PCB)	5.64	1	6.11	1	9.73E+02	5.24E+01	6491	350

1. Montgomery and Welkom, 1990.
2. ATSDR, Toxicology Profiles, 1987-93.
3. Howard, 1990.
4. IRPTG, 1989.
5. Verschueren, 1983.

ND: No Data.

TABLE 5-3

METAL CONTAMINANT FATE AND TRANSPORT DATA
Southwest Funston Landfill
Fort Riley, Kansas

CONSTITUENT	MOLECULAR WEIGHT (g/mole)	DOMINANT SOLUBLE SPECIES IN NATURAL FRESH WATERS	ref.	CONDITIONS WHICH FAVOR MOVEMENT IN SUBSURFACE ENVIRONMENT	ref.	AQUATIC BIOCONCENTRATION FACTOR (BCF)	ref.
Aluminum	26.98	$AL(OH)_4^-$	3	– low pH – high dissolved organic matter	1	ND	
* Antimony	121.75	$SbOH_6^-$	3	– ordinary pH and Eh – low organic matter and low metal oxides	2	40–16,000	2
* Arsenic	79.92	$HAsO_4^{2-}$, $H_2AsO_4^-$	3	– high salinity – reducing conditions (As^{3+} dominates) – high pH (>7) – biomethylation	1,2	300–6,000	2
Barium	137.33	Ba^{2+}	3	– low pH – high concentration Cl^-, NO_3^-, etc. – complexation with fatty acids (i.e., from landfill leachate)	1	100–1,000	1
Beryllium	9.01	$BeOH^+$	3	– complexation with OH^- at high pH	2	20–100	2
* Cadmium	112.40	Cd^{2+}, $CdOH^+$	3	– low to neutral pH	1,2	1000–10,000	2
* Chromium	51.99	$Cr(OH)_3^o$, CrO_4^{2-}	3	– aerobic conditions (Cr^{6+} dominates)	1,2	70–4,000	2
Cobalt	58.93	Co^{2+}, $CoCO_3^o$	3	– low pH – presence of complexing agents – reducing conditions	1	40–4,000	1
Copper	63.55	$CuCO_3^o$, $CuOH^+$	3	– reducing conditions – high salinity – low pH	1,2	12–30,000	2
Lead	207.20	$PbCO_3^o$, $Pb(CO_3)_2^{2-}$	3	– high salinity – low pH and low organic matter content – biomethylation	1,2	60–200	2

TABLE 5–3

METAL CONTAMINANT FATE AND TRANSPORT DATA
Southwest Funston Landfill
Fort Riley, Kansas

CONSTITUENT	MOLECULAR WEIGHT (g/mole)	DOMINANT SOLUBLE SPECIES IN NATURAL FRESH WATERS	ref.	CONDITIONS WHICH FAVOR MOVEMENT IN SUBSURFACE ENVIRONMENT	ref.	AQUATIC BIOCONCENTRATION FACTOR (BCF)	ref.
* Manganese	54.94	Mn^{2+}, $MnCl^{+}$	3	– oxidizing conditions – high pH	1	800–40,000	1
Mercury	200.59	$Hg(OH)_2{}^{o}$, HgOCl	3	– high chloride concentration – low clay content – biomethylation	2	1,000–100,000	2
Nickel	58.71	Ni^{2+}, $NiCO_3{}^{o}$	3	– aerobic conditions and pH<9 – high dissolved organic matter	1,2	40–260	1
Selenium	78.96	$SeO_3{}^{2-}$	3	– aerobic conditions – high pH – biomethylation	1,2	100–1,000	1,2
Silver	107.87	Ag^{+}	3	– high salinity	1,2	200–4,000	2
Thallium	204.38	Tl^{+}	3	– highly oxidizing conditions – low cation exchange capacity	1,2	10–100,000	2
Vanadium	50.94	$H_2VO_4{}^{-}$, $HVO_4{}^{2-}$	3	– aerobic conditions – neutral to high pH	1	ND	
Zinc	65.37	$ZnOH^{+}$, Zn^{2+}, $ZnCO_3{}^{o}$	3	– low pH (<6) – high salinity – anaerobic conditions – high dissolved solids	1,2	100–10,000	2

1. ATSDR, 1987–93.
2. Callahan, et al., 1979.
3. Stumm and Morgan, 1981.

ND: No Data.
* may be mobile under current site conditions.

TABLE 5-4

ORGANIC CONTAMINANT DEGRADATION DATA
Southwest Funston Landfill
Fort Riley, Kansas

CONSTITUENT	HALF-LIFE SOIL	ref.	HALF-LIFE SURFACE WATER	ref.	HALF-LIFE AIR	ref.	HALF-LIFE GROUNDWATER	ref.	AEROBIC HALF-LIFE	ref.	ANAEROBIC HALF-LIFE	ref.	HYDROLYSIS HALF-LIFE	ref.
VOLATILES:														
Benzene	5-16 d	1	5-16 d	1	2-21 d	1	10 d-2 y	1	5-16 d	1	16 w-2 y	1	ND	
Bromoform	4 w-6 m	1	4 w-6 m	1	54 d-1.5 y	1	8 w-1 y	1	4 w-6 m	1	16 w-2 y	1	687 y	1
Carbon Disulfide	3 m-1 y	2	3 h-9 d	2	9 d	2	3 m-1.1 y	2	3 m-1 y	2	ND		1.1 y	2
Chlorodibromomethane	4 w-6 m	1	4 w-6 m	1	43 d-1.2 y	1	2 w-6 m	1	4 w-6 m	1	4 w-6 m	1	275 y	1
1,2-Dibromoethane	4 w-6 m	1	4 w-6 m	1	11-107 d	1	20-120 d	1	4 w-6 m	1	2-15 d	1	2.2 y	1
trans-1,4-Dichloro-2-butene	ND		ND		ND		ND		ND		ND		ND	
1,1-Dichloroethane	32 d-22 w	1	32 d-22 w	1	10-103 d	1	64 d-22 w	1	32 d-22 w	1	128 d-88 w	1	ND	
1,2-Dichloroethane	100 d-6 m	1	100 d-6 m	1	12-122 d	1	100 d-1 y	1	100 d-6 m	1	1-2 y	1	1 y	1
trans-1,2-Dichloroethene	4 w-6 m	1	4 w-6 m	1	1-12 d	1	8 w-8 y	1	4 w-6 m	1	16 w-24 m	1	ND	
1,2-Dichloropropane	167 d-3.5 y	1	167 d-3.5 y	1	3-27 d	1	334 d-7.1 y	1	167 d-3.5 y	1	668 d-14.1 y	1	15.8 y	1
cis-1,3-Dichloropropene	6-11 d	1	6-11 d	1	5 h-3 d	1	6-11 d	1	7 d-4 w	1	28 d-16 w	1	6-11 d	1
2-Hexanone	ND		ND		36 h	2	ND		ND		ND		ND	
Methyl Chloride	7 d-4 w	1	7 d-4 w	1	61-613 d	1	2-8 w	1	7 d-4 w	1	28 d-16 w	1	292 d	1
Methylene Chloride	7 d-4 w	1	7 d-4 w	1	19-191 d	1	14 d-8 w	1	7 d-4 w	1	28 d-16 w	1	704 y	1
Methyl Isobutyl Ketone	1-7 d	1	1-7 d	1	2 d	1	2 d-2 w	1	1-7 d	1	4-28 d	1	ND	
Methylacrylonitrile	ND		ND		ND		ND		ND		ND		ND	
Methylene Bromide	7 d-4 w	1	7 d-4 w	1	36-355 d	1	2-8 w	1	7 d-4 w	1	28 d-16 w	1	183 y	1
Pentachloroethane	ND		1.8 y	2	1.8 y	2	ND		ND		ND		ND	
Styrene	2-4 w	1	2-4 w	1	1-7 h	1	4-30 w	1	2-4 w	1	8-16 w	1	ND	
1,1,1,2-Tetrachloroethane	16 h-67 d	1	16 h-67 d	1	93 d-2.6 y	1	16 h-67 d	1	4 w-6 m	1	6 m-16 w	1	67 d	1
1,1,2,2-Tetrachloroethane	11 h-45 d	1	11 h-45 d	1	9-89 d	1	11 h-45 d	1	4 w-6 m	1	7 d-4 w	1	45 d	1

TABLE 5-4

ORGANIC CONTAMINANT DEGRADATION DATA
Southwest Funston Landfill
Fort Riley, Kansas

CONSTITUENT	HALF-LIFE SOIL	ref.	HALF-LIFE SURFACE WATER	ref.	HALF-LIFE AIR	ref.	HALF-LIFE GROUNDWATER	ref.	AEROBIC HALF-LIFE	ref.	ANAEROBIC HALF-LIFE	ref.	HYDROLYSIS HALF-LIFE	ref.
VOLATILES (continued)														
1,1,2-Trichloroethane	4.5 m-1 y	1	4.5 m-1 y	1	8-82 d	1	4.5 m-2 y	1	6 m-1 y	1	2-4 y	1	37 y	1
Trichloroethene	6 m-1 y	1	6 m-1 y	1	1-11 d	1	11 m-4.5 y	1	6 m-1 y	1	98 d-4.5 y	1	11 m	1
Trichlorofluoromethane	6 m-1 y	1	6 m-1 y	1	14.7-147 y	1	1-2 y	1	6 m-1 y	1	2-4 y	1	ND	
1,2,3-Trichloropropane	6 m-1 y	1	6 m-1 y	1	3-26 d	1	1-2 y	1	6 m-1 y	1	2-4 y	1	44 y	1
Vinyl Chloride	4 w-6 m	1	4 w-6 m	1	10-97 h	1	8 w-8 y	1	4 w-6 m	1	16 w- 2 y	1	ND	
o-Xylene	1-4 w	1	1-4 w	1	5 h-2 d	1	2 w-1 y	1	1-4 w	1	6 m-1 y	1	ND	
m-Xylene	1-4 w	1	1-4 w	1	3 h-1 d	1	2-8 w	1	1-4 w	1	4-16 w	1	ND	
p-Xylene	1-4 w	1	1-4 w	1	4 h-2 d	1	2-8 w	1	1-4 w	1	4-16 w	1	ND	
SEMI-VOLATILES:														
Bis(2-ethylhexyl)phthalate	5-23 d	1	5-23 d	1	3-29 h	1	10-389 d	1	5-23 d	1	42 d-1.1 y	1	2000 y	1
Butyl Benzyl Phthalate	1-7 d	1	1-7 d	1	6 h-3 d	1	2 d-6 m	1	1-7 d	1	4 w-6 m	1	ND	
PESTICIDES/PCBs:														
4,4'-DDE	2-15.6 y	1	15 h-6 d	1	18 h-7 d	1	16 d-31.3 y	1	2-15.6 y	1	16-100 d	1	ND	
Aroclor 1248 (PCB)	ND		ND		13 d-10 m	3	ND		ND		ND		ND	

1. Howard et al., 1991.
2. Howard, 1990.
3. ATSDR, 1987-93.

ND: No Data

h: hours
d: days
w: weeks
m: months
y: years

5.1.3 Henry's Law Constant

The Henry's Law Constant indicates the compound's tendency to volatilize from water. The larger the value of this constant, the more rapidly the compound is likely to volatilize from water (see Table 5-1).

5.1.4 Specific Gravity

Specific gravity indicates whether a constituent (in the form of free product) in water tends to "float" (specific gravity less than 1) or "sink" (specific gravity greater than 1). Those constituents which float as free product on top of the water table are called light nonaqueous phase liquids (LNAPLs); those which sink as free product are called dense nonaqueous phase liquids (DNAPLs). Examples of LNAPLs include fuel products. Most chlorinated solvents are DNAPLs (see Table 5-1).

5.1.5 Bioconcentration Factor

The bioconcentration factor (BCF) indicates how likely a compound is to accumulate in aquatic organisms when dissolved or suspended in water. Constituents with higher BCFs are more likely to accumulate in aquatic organisms than those with lower BCFs (see Tables 5-1 and 5-3).

5.1.6 Organic-Carbon Partition Coefficient

The organic-carbon partition coefficient, K_{oc}, is an indicator of the constituent's tendency to adsorb to organic carbon. This adsorption of organic constituents is treated as an equilibrium-partitioning process between the aqueous phase (i.e., surface or groundwater) and the organic carbon present on the solid phase (i.e., sediment, soil, or aquifer material). The K_{oc} value is a function of the constituent's affinity towards organic carbon. This parameter is inversely related to the solute solubility and it is typically directly related to the BCF. Constituents with high K_{OC} values are considered to be strongly adsorbed and are less likely to migrate in surface and groundwater. Table 5-2 presents the logarithm of K_{OC} for each constituent.

5.1.7 Octanol-Water Partition Coefficient

The octanol-water partition coefficient, K_{ow}, is an indicator of a compound's tendency to partition between an organic compound, which is represented by octanol, and water. High values of K_{ow} are typical of lipophilic (or fat soluble) compounds which typically bioaccumulate in aquatic organisms and have a greater tendency for adsorption to organic carbon in soils and sediments. K_{OW} can be related directly to K_{OC}. Octanol-water partition coefficients are presented as the logarithm of K_{ow} in Table 5-2.

5.1.8 Distribution coefficient

The distribution, or partition coefficient, K_d, represents an equilibrium-partitioning process which characterizes the adsorption of ions and molecules to solid surfaces such as soil, aquifer material, and sediments. This process is defined as follows:

$$K_d = \frac{\text{mass of solute on the solid phase per unit mass of solid}}{\text{concentration of solute in the aqueous phase}}$$

The equilibrium distribution coefficient is specific to individual chemical species and depends on both the aqueous and solid phase characteristics. In general, the lower the K_d, the less the constituent is adsorbed to the solid phase and the more likely it is to migrate in surface water and groundwater.

There are a number of physico-chemical forces which are responsible for the adsorption of ions and molecules to a solid phase. "Hydrophobic bonding" is believed to be the dominant process responsible for the adsorption of neutral organic compounds. Therefore, K_d can be estimated based on K_{oc} and the fraction of organic carbon in the solid phase (f_{OC}) as follows:

$$K_d = K_{oc} \times f_{OC}$$

By measuring or estimating the fraction of organic carbon present in a given soil, the degree of adsorption of an organic chemical to that soil can be calculated. It should be noted, however, that this method of determining K_d may actually underestimate the actual adsorption because it ignores the contribution of the inorganic surfaces (i.e., mineral surfaces) to the overall sorption. However, methods for estimating K_d for adsorption to organic-free surfaces are not well developed (Walton, 1988). Table 5-2 presents the K_d values for each constituent at two different organic carbon contents. The f_{OC} values chosen here are based on the range of total organic carbon (TOC) values obtained from the soil boring samples. The lowest value, 0.012 percent, was obtained from sample SB701. This value was used because it represents the lowest organic carbon content from all the samples, including the background samples, and it is believed to be representative of sand and gravel aquifers. The value at the upper range, 0.223 percent, was obtained from the background sample, SB101. Higher organic carbon contents were measured in downgradient samples but these are not expected to be representative of the f_{OC} of the soil because of the potential contribution of organic constituents to the measured TOC.

5.1.9 Retardation Factor

When a mixture of reactive contaminants enters an aquifer system, constituents will typically segregate due to their various characteristics and interactions with aquifer material. Sorption is the primary process responsible for separating individual constituents. Each chemical species may travel at a different rate reflecting its relative velocity. The solute mixture will segregate into different zones, each advancing in the same direction but at different velocities.

Sorption of constituents to the soil and aquifer material causes solute plumes to be retarded with respect to advection. Advection refers to the transport of contaminants at the same speed as the average linear velocity of groundwater. Advection is defined by the following equation:

$$v = \frac{Ki}{n_e}$$

where:
v = average linear velocity
K = hydraulic conductivity
i = head gradient
n_e = effective porosity

The other term used in describing groundwater flow through porous media is hydrodynamic dispersion. Hydrodynamic dispersion accounts for the spreading of a stream or discrete volume of contaminants as it flows through the subsurface. Hydrodynamic dispersion includes both mechanical dispersion and molecular diffusion. Mechanical dispersion is caused by both microscopic and macroscopic effects. On a microscale, the velocity variations are caused by processes such as water in the center of a pore space traveling faster than the water near the pore wall (solid surface interface). Additionally, diversion of flow paths around individual grains of porous material causes variations in average velocity. On a macroscopic scale, dispersion is caused by the presence of large-scale heterogeneities within the subsurface (i.e., clay lenses within a sand/gravel aquifer). Molecular diffusion occurs as species move from higher to lower concentrations (Anderson, 1984).

For cases where sorption can be adequately described by the distribution coefficient, retardation is described by the following relation (Cherry et al., 1984):

$$R = \frac{v}{v_c} = 1 + \frac{p_b K_d}{n_e}$$

where:
R = retardation factor
v_c = groundwater velocity at the 0.5 point on the concentration profile of the retarded chemical species (i.e., the middle of the dispersed front)
p_b = bulk mass density of dry aquifer system skeleton (mass per unit volume of dry porous materials)

The rate of advance of the contaminant mass can be calculated by dividing the average groundwater velocity by the retardation factor. It should be noted that this calculation does not account for dispersion. A retardation factor of 1 indicates that a solute is not effectively retained by the aquifer material and that the solute moves at essentially the same rate as the groundwater. Table 5-2 presents the retardation factors for the constituents detected in the groundwater and soil at this site for two values of organic carbon content. The bulk density of the aquifer material is assumed to be 2.0 g/cm^3, as calculated by the following equation:

$$p_b = D_a * (1 - n_t)$$

where: D_a = density of aquifer material
n_t = total porosity

The density of the aquifer material is assumed to be 2.65 g/cm^3 representing an average density of mineral soils (Freeze and Cherry, 1979).

5.1.10 Half-Life in Soil

The half-lives from the fastest degradation reactions applicable for the constituents in soil are listed in Table 5-4. Aerobic biodegradation rate values are used for all the constituents except cis-1,3-dichloropropene; 1,1,1,2-tetrachloroethane; and 1,1,2,2-tetrachloroethane; for which hydrolysis rates are used (Howard et al., 1991). These ranges do not include volatilization, which can be a significant removal process of volatile organic compounds (VOCs) from surficial soils.

5.1.11 Half-life in Air

The half-life in air given in Table 5-4 is the fastest degradation process for each constituent in air. Reaction with hydroxyl radicals was selected for most of the constituents. Hydrolysis is considered, in addition to photo-oxidation, for those constituents which undergo hydrolysis; for example, cis-1,3-dichloropropene; 1,1,1,2-tetrachloroethane; and 1,1,2,2-tetrachloroethane (see Table 5-4) (Howard et al., 1991).

5.1.12 Half-life in Surface Water

Again, the fastest degradation process applicable in water was selected for this characteristic. Photo-oxidation, biodegradation, and hydrolysis are the most common degradation processes in surface water. When more than one reaction is of importance, a range containing all significant processes is presented (Howard et al., 1991). At a minimum, biodegradation rates were considered for constituents. Photo-oxidation is also considered for carbon disulfide and pentachloroethane. Hydrolysis is also considered for cis-1,3-dichloropropene; 1,1,1,2-tetrachloroethane; and 1,1,2,2-tetrachloroethane. The stated ranges do not include volatilization, which is a primary removal process of VOCs from surface water (see Table 5-4).

5.1.13 Half-life in Groundwater

The range of half-lives in groundwater presented in Table 5-4 was selected based on the most significant degradation process or processes. In particular, biodegradation and hydrolysis, or a combination of the two, were considered. The biodegradation values represent data obtained from surface water studies which were adjusted to account for the decreased number and enzymatic capabilities typical of subsurface microbes. Also, because groundwater is more likely to be anaerobic depending on its depth and distance from recharge areas, both aerobic and anaerobic biodegradation rates are considered (Howard et al., 1991).

5.1.14 Aerobic Half-life

The aerobic half-life data provided in Table 5-4 represent the aerobic biodegradation half-lives of the constituents, obtained from a review of available literature by Howard et al. (1991). These rate values include data obtained from grab samples, field studies, and screening studies found in the literature, or were based on scientific judgment by Howard et al. (1991) if no pertinent data were found.

5.1.15 Anaerobic Half-life

The anaerobic half-life values provided in Table 5-4 consist of rates obtained from a review of the literature or estimated based on scientific judgment (Howard et al., 1991).

5.1.16 Hydrolysis Half-life

The hydrolysis half-life values provided in Table 5-4 represent relatively fast and slow hydrolysis half-lives calculated from first or second order rate constants determined at pH 5, 7, and 9, and temperatures of 20°C to 25°C (Howard et al., 1991). Table 5-4 values are also based on results obtained from the PCGEMS program HYDRO, which was used to estimate hydrolysis rates for constituents that lacked experimental data (Howard et al., 1991).

5.2 POTENTIAL ROUTES OF CONSTITUENT MIGRATION

Constituent migration occurs in several ways, depending upon the characteristics of the element or compound in question, the medium in which it is located, and the type(s) of media in close proximity. Various physical processes may be involved. The transport of constituents by water to receptors is a central theme because of the importance of water to life, its contribution to the generation of leachate, and its ability to mobilize constituents from source areas. Constituent transport in water may occur in either the dissolved, solid, or adsorbed phase.

Additionally, transformation into a gaseous state (volatilization) is an important transport process, particularly for VOCs. Accumulation within the body of organisms (bioaccumulation) may also be a migration pathway from water, soils, or sediments if an organism carries the constituents away from the source and releases them by excretion or during the decaying process following death.

A general discussion of the potential transport processes of the constituents detected at the SFL is presented below. The metals are addressed individually because their behavior is somewhat complicated. The semi-volatile organics are also discussed individually because only four constituents from this class of compounds were detected. Because of the large number of VOCs detected in the groundwater, this class of constituents is addressed in groups. The constituents discussed below include:

- Nineteen metals detected in soil, groundwater, surface water, and sediment samples
- Twenty-eight VOCs detected in subsurface soil and groundwater samples
- Four semi-volatile organics detected in subsurface soil samples

5.2.1 Metals

Predicting the migration of metals in the environment is complicated because metals can exist in a variety of forms. For instance, they may exist as charged particles, such as ions in solution, or in an uncharged or neutral state. Metals may also interact with both inorganic and organic species to form a variety of different compounds with various solubilities. Multiple oxidation states of some metals further complicate their behavior.

In any case, the potential for migration depends upon the solubility of the metal species in water. Metals in solution exist in an ionic form. These ions may be transported as such, or undergo processes such as adsorption to organic matter or mineral surfaces of sediment, soils, and suspended solids. Non-ionic forms tend to precipitate and remain bound to sediments and soil, but may be transported as suspended solids. Colloidal transport of metals is of significance at this site because landfill leachate typically contains a high amount of dissolved organic matter and colloids and because the nature of the aquifer material (predominately sand and gravel) permits movement of colloidal material. However, metals may cycle between aqueous and solid phases with limited actual transport.

Two properties describing environmental conditions which are of primary importance in determining the behavior of metals are pH and redox potential, Eh. These properties control which metal species are stable under given conditions. Other characteristics of importance include cation exchange capacity and the presence of competing ligands (ions or molecules which complex with the metal). This discussion is based on the estimated pH of the soil (5 to 8) and the measured pH of the groundwater (6.2 to 7.1) at the SFL site. Based on the predominance of sulfide over sulfate, and calculated Eh values ranging from -0.181 to -0.365 volts (see Appendix Mg), reducing conditions are believed to exist in the groundwater at this site (Manahan, 1991). These measured or estimated site parameters are used to predict the likely forms and behavior of the metals at this site. It should be noted, however, that additional site-specific data regarding the metal species present at the site, the quality of the surrounding water, and additional properties of the soil would be needed to describe the chemical-specific transport and fate of the metals detected at this site. It may be helpful to refer to Table 5-3 while reviewing the following sections.

5.2.1.1 Aluminum - Aluminum is highly reactive and, in nature, is found in combination with other substances such as oxygen, fluorine, and silica. Only one oxidation state exists for aluminum, 3+; therefore, its behavior depends primarily on its coordination chemistry. Major transport processes include geochemical leaching from soil and rock formations and particulates, complexation, and adsorption onto soil or sediment particulates. Aluminum partitions between solid and liquid phases by reacting and complexing with water, electron rich anions (such as chloride, fluorine, sulfate, nitrate, and phosphate), and negatively charged functional groups in clay and humic material. At a pH greater than 5.5, most of the aluminum is in an insoluble form (that is, gibbsite or aluminosilicates) except when in the presence of high organic matter which binds with the aluminum in a soluble form. In general, the mobility of aluminum increases as the pH decreases for monomeric forms. Adsorption onto clay and suspended particulates is a significant and rapid process (ATSDR, 1990).

Aluminum was detected in groundwater and soil samples collected from this site, and surface water and sediment samples collected adjacent to the site. Based on the soil pH (estimated at 5 to 8), most of the aluminum will likely be immobilized and retained in the soil due to the formation of insoluble aluminum hydroxides/sesquioxides.

5.2.1.2 Antimony - Antimony is quite soluble in water and, as a result, generally quite mobile in the aquatic environment. Antimony can exist in the 3-, 0, 3+, or 5+ valance states. Under moderately oxidizing conditions, antimony is present in the 3+ state as the hydrated trioxide, $Sb_2O_3(H_2O)_n$. In highly oxidizing environments, Sb^{5+} exists as an acid, H_3SbO_4. In natural waters, antimony exists as the oxides antimonide and antimonate, which are highly soluble. Sorption to clay and other mineral surfaces and coprecipitation with hydrous iron, manganese, and aluminum oxides may remove some antimony from solution. It is possible for heavy metals in solution to react with antimonide or antimonate to form insoluble species. However, precipitation is likely to occur only in cases of extremely high loading. Remobilization of adsorbed, precipitated, or coprecipitated antimony may occur by processes such as bioaccumulation and possibly biomethylation. Also, under highly reducing conditions (for example, in sediments), adsorbed or coprecipitated antimony may be transformed into stibine (SbH_3), a volatile and highly soluble compound. Stibine is not stable in aerobic waters, however, and is hydrolyzed to form the oxide (Callahan et al., 1979).

Antimony was detected in groundwater samples collected from this site. Based on the measured groundwater pH (6.2 to 7.1) and anticipated redox conditions, antimony will likely be present in its reduced states (i.e., Sb or Sb^{3-}). Antimony will likely be translocated to groundwater and eventually may be discharged to the Kansas River or Threemile Creek. In surface water, antimony will likely be hydrolyzed to form the oxide and remain soluble and mobile or be adsorbed onto mineral surfaces (in sediments).

5.2.1.3 Arsenic - Because of its multiple oxidation states and its tendency to form soluble complexes, the geochemistry of arsenic is both intricate and not well characterized. Arsenic is mobile in the aquatic environment; it cycles through water columns, sediments, and biota. The solubility of arsenic varies widely according to the oxidation state. In the natural environment, four oxidation states are possible for arsenic: 3-, 0 (metallic), 3+, and 5+. The 3+ and 5+ states are common in a variety of complex minerals and in dissolved salts in natural waters. The element most commonly associated with arsenic in nature is sulfur. The oxo acids [arsenious acid (H_3AsO_3) and arsenic acid (H_3AsO_4)] are prevalent forms of arsenic in aerobic waters. Arsenic can form complexes with a number of organic compounds, most of which increase its water solubility.

The adsorption of arsenic onto clays, ion oxides, and organic (humic) material are important fate processes. Coprecipitation or sorption of arsenic with hydrous oxides of iron is probably the most important removal process. Arsenic may also be isomorphously substituted for phosphate in phosphate minerals. The rate and extent of adsorption decreases with increasing salinity and increasing pH. Adsorption is highest in aerobic, acidic, and freshwater systems.

Arsenic is relatively immobile in soils due to its binding to soil particles, but may be leached under the appropriate conditions. It binds to clay, iron oxides, aluminum hydroxides, and organic matter. Microbes are capable of methylating arsenic to trimethylarsenic, which is a more volatile and mobile (yet less toxic) form than inorganic arsenic. Bioconcentration of arsenic may be significant (Callahan et al., 1979; ATSDR, 1987).

Arsenic was detected in groundwater, soil, surface water, and sediment samples collected from this site. It is likely that much of the arsenic present in the soil will be immobile under current conditions, due to binding with mineral surfaces. Arsenic in groundwater at this site is likely to be present in its reduced states (i.e., As or As^{3+}) (Eary et al., 1990). The oxo acids and arsenic acid are the predicted forms of arsenic in surface water. Arsenic in surface water tends to cycle between the water column, sediments, and biota.

5.2.1.4 Barium - In natural systems, barium exists in the 2+ valance state as a salt. Several salts including the most common, barite ($BaSO_4$) and witherite ($BaCO_3$), have low solubility so precipitation into sediments is likely. Aqueous phase barium may also adsorb to suspended particulate matter. In general, barium is not very mobile in soil. Mobility is limited by adsorption to soil and precipitation of $BaCO_3$ and $BaSO_4$. Mobility is enhanced by the formation of more soluble salts such as $BaCl_2$ and by the complexation of barium with fatty acids. Bioaccumulation of barium is not a common migration process except in systems in which the barium concentration exceeds that of calcium and magnesium (ATSDR, 1991).

At this site, barium was detected in groundwater, soil, surface water, and sediment samples. Based on the soil pH (estimated at 5 to 8), most of the barium present in the soil will be converted to $BaCO_3$, precipitate, and accumulate. Translocation to groundwater, and potentially surface water, is not likely to occur to a significant degree. Therefore, migration from the site will likely be minimal.

5.2.1.5 Beryllium - The behavior of beryllium is controlled chiefly by precipitation, adsorption, and complexation. Soluble beryllium salts are hydrolyzed in natural waters to form insoluble beryllium hydroxide, $Be(OH)_2$. Adsorption to clay and minerals is important at low pH. The coordination chemistry of beryllium is complicated; it can form complexes, oxycarboxylates, and chelates with a variety of materials resulting in increased solubility of the beryllium species. Despite this, in natural waters, the concentration of dissolved beryllium is very low. Most of the beryllium is found in particulate form, either adsorbed (low pH) or precipitated (high pH). Bioconcentration is a minor process (BCF ranges from 20 to 100) (Callahan et al., 1979).

Beryllium was detected in groundwater, and soil samples, and in one downstream sediment sample collected from this site. Most of the beryllium will likely exist in a particulate form in soil, primarily precipitated as $Be(OH)_2$, due to the near neutrality of the groundwater and soil pH values. Therefore, off-site migration is expected to be minimal.

5.2.1.6 Cadmium - Complexation, adsorption, coprecipitation, isomorphous substitution, and bioaccumulation are processes which affect the movement of cadmium in the environment. Cadmium exists in one oxidation state, 2+. Compared to the other heavy metals, cadmium is relatively mobile and may be transported as either hydrated cations or as organic or inorganic complexes. Cadmium forms complexes with humics, CO_3^{2-}, OH^-, Cl^-, and SO_4^{2-}. Sorption to mineral surfaces generally increases as the pH increases and is responsible for removal of cadmium from the aqueous phase. Other processes which serve to remove cadmium from water include adsorption onto organic matter, coprecipitation with hydrous metal oxides, and isomorphous substitution in carbonate minerals. Cadmium in soil may leach, especially in acidic conditions. Sorption/desorption, precipitation, dissolution, complexation, and ion exchange are important processes in soil and in surface water/sediment systems. Cadmium is strongly accumulated by organisms at all trophic levels (Callahan et al., 1979; ATSDR, 1991).

At this site, cadmium was detected in one groundwater, one soil, and one downstream sediment sample. Most of the cadmium present in the soil will probably be adsorbed onto mineral surfaces (due to the soil pH being near neutral) and retained in the soil matrix. However, some cadmium may be translocated to groundwater and potentially to surface water.

5.2.1.7 Chromium - Chromium exists primarily in two oxidation states in aqueous systems: 3+ and 6+. The hexavalent form is the most common form in natural waters (Callahan et al., 1979, ATSDR, 1991). This species is soluble, existing in solution as an anion complex which may eventually precipitate. Hexavalent chromium is a strong oxidizing agent and reacts with organic or other reducing material to form trivalent chromium. Hexavalent chromium does not adsorb strongly to clays or hydrous metal oxides. It does, however, adsorb strongly to activated carbon, which is an indication that it may be retained by organic matter.

Hexavalent chromium is quite mobile in the environment. Trivalent chromium is less mobile as it combines with aqueous hydroxide ion (OH^-) to form insoluble chromium hydroxide [$Cr(OH)_3$]. Precipitation of this hydroxide is thought to be the dominant removal process of chromium in natural waters. Adsorption processes also result in removal of dissolved chromium to the bed sediments. Chromium in soil can occur as the insoluble oxide dichromate (Cr_2O_3) and may be aerosolized into the atmosphere or transported to surface water and groundwater in run-off and leachates. Chromium is bioaccumulated by aquatic organisms, and passage of chromium through the food chain has been documented (Callahan et al., 1979; ATSDR, 1991).

Chromium was detected in groundwater, soil, and sediment samples collected from this site. It is unclear in which form chromium exists without additional speciation. However, chromium in groundwater likely exists in the trivalent form (see Appendix Mg). This form of chromium is not highly mobile and may form insoluble chromium hydroxide. Formation of this insoluble species is believed to be the dominant removal process of chromium from surface water.

5.2.1.8 Cobalt - Most (about 98 percent) of the cobalt in natural waters exists in the precipitated or adsorbed state. The predominant precipitated forms involve the carbonate and hydroxide species. Increased solubility may occur under acidic and anoxic conditions and in the presence of excess chloride ions or organic and inorganic chelating agents. In soils, cobalt is retained by metal oxides, crystalline minerals, and organic matter. Again, mobilization may occur under specific pH and redox conditions and in the presence of chelating/complexing agents. Bioaccumulation can be significant in some species (ATSDR, 1990).

Cobalt was detected in one groundwater sample and in several soil and sediment samples collected on and nearby this site. Most of the cobalt present in the soil will probably be in the form of a precipitate or be retained by adsorption to metal oxides and crystalline minerals present in the soil. Thus, the potential for off-site migration is likely minimal.

5.2.1.9 Copper - The transport of copper is controlled by complexation, adsorption, and precipitation. Copper exists in two oxidation states, 1+ and 2+. The only cuprous (Cu^+) compounds that are stable in aqueous solutions are highly insoluble (for example, CuCl, CuF and CuCN). Most of the cupric salts (Cu^{2+}) are also relatively insoluble; exceptions include $CuCl_2$, $Cu(NO_3)_2$, and $CuSO_4$. Cu^{2+} forms coordination compounds or complexes with inorganic and organic ligands such as ammonia, chloride, and humic acids. These strong complexes tend to enhance both its solubility and its adsorption to clay and other surfaces. Strong adsorption of copper to hydrous metal oxides, clays, carbonate minerals, and organic matter is an effective control on dissolved copper concentration. In soils, copper is strongly adsorbed and most of it remains within the upper few centimeters of soil. Adsorption to organic matter, carbonate minerals, clay and hydrous iron, and manganese oxides is an important process. The greatest potential for copper to leach occurs in sandy soils with low pH. In general, copper binds to soil more strongly than the other divalent cations. Copper is also strongly bioaccumulated and can be toxic to aquatic organisms at high concentrations (Callahan et al., 1979; ATSDR, 1990).

Copper was detected in one groundwater sample and in several soil and sediment samples from this site. Based on anticipated site conditions, copper is believed to exist in the Cu^+ state, possibly precipitated with sulfides or oxides (Eary et al., 1990). Copper mobility from soil is not likely to be significant. It is likely that most of the copper will adsorb onto soil mineral surfaces or precipitate with sulfide.

5.2.1.10 Iron - Iron is involved primarily in redox reactions in natural waters. The oxidation/reduction of iron in soil and groundwater determines the iron content of these waters. A number of igneous minerals contain iron primarily in the 2+ valence state. These minerals are relatively easily weathered because the 2+ valence state is unstable in the presence of oxygen. The higher oxidation state of iron, 3+, is very insoluble and these ions tend to accumulate during soil development (Bohn et al, 1985).

At pH values typical of soils, Fe^{3+} is hydrolyzed to $Fe(OH)_2^+$. The concentrations of Fe(III) is very low at normal pH values (i.e., pH 5 to 9). The major reaction by which Fe(III) accepts electrons in soils is the reduction of Fe(III) hydroxyoxide. Fe^{2+} and FeOOH are the predominant states in typical well-aerated soils. Under acidic and reduced conditions, FeOOH dissolves to Fe^{3+}. Fe(III) predominates under strongly acidic and oxidizing conditions. Whether FeOOH, $FeCO_3$, or FeS_2 is the stable solid phase depends on the electron potential and on the CO_2 and sulfur concentrations (Bohn et al, 1985).

At this site, iron was detected in groundwater, soil, surface water, and sediment samples. Given the anticipated redox conditions (Eh) and pH of the groundwater at this site, it is likely that iron is present predominately in the Fe^{2+} state, possibly precipitated as FeS_2 or $FeCO_3$ (Snoeyink and Jenkins, 1980). Migration of iron from soil is expected to be minimal.

5.2.1.11 Lead - Lead is transferred continuously between air, water, and soil. Sorption to sediments is the dominant fate process of lead in natural waters. Precipitation with hydroxides, carbonate, sulfate, and sulfide results in decreased dissolved lead concentrations. Complexation of lead with organic matter increases its adsorptive affinity for clays and other mineral surfaces. Lead is strongly retained by most soils. Lead undergoes specific adsorption at mineral interfaces, precipitation of sparingly soluble solids, and formation of relatively stable organic-metal complexes/chelates with organic matter. Benthic microbes methylate lead to tetramethyl lead which tends to volatilize to the atmosphere. Lead bioconcentrates slightly, but it does not appear to biomagnify throughout the food chain (Callahan et al., 1979; ATSDR, 1988).

At this site, lead was detected in groundwater, soil, and sediment samples. Lead will likely exist in the soil in insoluble forms (as lead hydroxides and carbonates). The insoluble forms of lead may be translocated to groundwater, and potentially to surface water, but will probably remain in the insoluble form (due to the moderate pH of the groundwater and soil). The insoluble forms of lead in the surface water will likely accumulate in sediments.

5.2.1.12 Manganese - Four oxidation states exist for manganese: 2+, 3+, 4+, and 7+. From pH 4 to pH 7, Mn^{2+} is the predominant state; above pH 8, the higher oxidation states dominate. The principle anion associated with Mn is CO_3^{2-}; $MnCO_3$ is relatively insoluble. In oxidizing environments, manganese solubility is controlled by oxidation of Mn^{2+} to Mn^{3+} and Mn^{4+}. In reducing environments, manganese solubility is controlled by the poorly soluble manganese sulfide. Manganese is often transported in water by adsorbing to suspended particulates. Manganese may become fixed to soil at low concentrations, but at high concentrations it may be desorbed by ion exchange reactions. Adsorption in soil is highly variable and depends on such factors as cation exchange capacity, organic matter content, and the presence of competing ions (ATSDR, 1991).

Manganese was detected in groundwater, soil, surface water, and sediment samples collected from this site. The principal redox state of manganese will likely be Mn^{2+} (based on measured pH and assumed redox conditions). Some of the Mn^{2+} will probably be complexed with available carbonate or sulfide as an insoluble salt (Stumm and Morgan, 1981). In surface water, Mn^{2+} will likely be oxidized to Mn^{3+} and Mn^{4+}.

5.2.1.13 Mercury - The major removal mechanism for mercury from a natural system is adsorption onto the surfaces of clay particles and subsequent settling as part of the sediment. The majority of dissolved mercury is removed in this manner within a relatively short time, generally in the immediate vicinity of the source. Much smaller portions of the dissolved mercury are ingested by aquatic biota or transported by current movement and dilution. Secondary transformations of mercury in the sediments can occur; these include precipitation as mercury sulfide and methylation reactions caused by bacteria. Because mercury itself is not destroyed, these inorganic and organic forms of mercury may then release ionic or metallic mercury into the water column as part of a recycling process. Resuspension of sediments by turbulence or the activity of benthic organisms can also release these compounds of mercury directly into the water column (Callahan et al., 1979; ATSDR, 1988).

At this site, mercury was detected in one surface soil sample. Most of the mercury will likely remain bound to soil particles because mercury was detected only in the surface soils where the clay content is relatively high.

5.2.1.14 Nickel - The fate of nickel is dominated by complexation and adsorption. In aerobic, natural waters, the dominant species is the hexahydrate, $Ni(H_2O)_6^{2+}$. Nickel in water is typically associated with suspended particulates. Soluble nickel may be removed by precipitation (that is, nickel ferrite) and coprecipitation (that is, with hydrous iron and manganese oxides). Soluble complexes with species such as OH^-, SO_4^{2-}, and Cl^- are formed to a lesser extent. Above pH 9.5, $Ni(OH)_2^\circ$ is the dominant species. The relatively insoluble species, nickel sulfide, is predominant under anaerobic conditions when sulfur is present. In soil, nickel tends to be immobilized in soil minerals and amorphous iron and manganese oxide complexes. In general, mobility increases as the pH decreases. Nickel has a slight potential to bioaccumulate (ATSDR, 1991; Callahan et al., 1979).

At this site, nickel was detected in groundwater and soil samples, and in one downstream sediment sample. Much of the nickel will probably remain immobilized in soil minerals and amorphous iron and manganese complexes. Reduced nickel mobility is expected, due to the moderate pH of the soil (estimated at 5 to 8) and the near neutral pH of the groundwater (measured as 6.2 to 7.1). Thus, much of the nickel will remain bound to the soil.

5.2.1.15 Selenium - The primary controlling factor affecting selenium in the environment is its ability to exist in multiple oxidation states. Selenium is stable in four states: 2-, 0, 4+ and 6+. Both elemental and the heavy metal selenides (2-) are insoluble in water; while the inorganic alkali selenites (4+) and selenates (6+) are soluble. The forms most commonly found in surface water and soil pore water are the salts of selenic and selenious acids. Sodium selenate is one of the most mobile selenium compounds in the environment due to its high solubility and low potential to adsorb to soil particles. The diselenite ion predominates in waters between pH 3.5 and 9. Elemental selenium is stable in soil and is often found coprecipitated with sediments in water. The soluble selenates are taken up by plants and converted to organic forms of selenium. Heavy metal selenides and selenium sulfides are common insoluble species in the soil and predominate in acidic soils of high organic matter. Sodium and potassium selenites dominate in neutral, well-drained mineral soils, and some soluble metal selenites may be found as well. Selenates dominate in oxidized soils of $pH > 7.5$; these species are highly mobile and bioavailable. Selenium tends to bioconcentrate significantly, and some evidence exists that it biomagnifies (ATSDR, 1989; Callahan et al., 1979).

At this site, selenium was detected in groundwater samples, two soil samples, and one downstream surface water sample. At the measured pH and assumed redox conditions of the SFL groundwater, and the estimated pH of the SFL soil, most of the selenium present will likely exist in the 2- valence state (as selenides) and/or in the 0 valence state (as elemental selenium) (Eary, 1990). Much of the selenium will remain in the soil. Selenium present in surface water is likely to be in the form of selenic and selenious acids.

5.2.1.16 Silver - Silver exists in four oxidation states: 0, 1+, 2+, and 3+. Silver occurs primarily as sulfides and in association with iron, lead, tellurides, and gold. In surface water, silver exists as a monovalent ion, as part of more complex ions with chlorides and sulfates, and by adsorbing onto particulate matter. Metallic silver is also stable in water; formation of this metal, which has a very low solubility, may affect the mobility of silver. In oxidizing aqueous environments, silver exists predominantly in conjunction with bromides, chlorides, and iodides. The free metal and silver sulfide dominate in reducing aqueous environments. Both the silver halides and silver sulfide have very low aqueous solubilities. Soil mobility is affected by drainage, redox conditions, pH, and organic matter content. Silver is strongly adsorbed to manganese and iron oxides and clay minerals. Bioaccumulation may be significant for silver, but it has a short biological half-life, and biomagnification does not appear to occur (Callahan et al., 1979; ATSDR, 1990).

At this site, silver was detected in groundwater and soil samples. Because of the anticipated reducing conditions, much of the silver will exist as the free metal or silver sulfide, both of which are highly insoluble.

5.2.1.17 Thallium - Thallium typically exists in the environment combined with other elements such as oxygen, sulfur, and the halogens. These compounds are generally quite soluble in water. Thallium is typically found as the monovalent ion (Tl^{1+}), but may be trivalent (Tl^{3+}) in very oxidizing environments. In extremely reducing water, thallium may precipitate as a sulfide (Tl_2S); in oxidizing water, it may be removed from solution as $Tl(OH)_3$. Soluble thallium tends to adsorb to soils and sediments and bioconcentrate in biota (Callahan et al., 1979; ATSDR, 1990).

At this site, thallium was detected in two soil samples. Thallium will likely be present in the soil in the soluble Tl^{1+} oxidation state. The soluble thallium will likely adsorb to soil or precipitate as Tl_2S.

5.2.1.18 Vanadium - Six oxidation states exist for vanadium: 1-, 0, 2+, 3+, 4+, and 5+. In natural aqueous systems vanadium exists as part of or adsorbed onto particulate matter, as the soluble species VO^{2+} and $VO(OH)^+$ under reducing conditions, and as $H_2VO_4^-$ and HVO_4^{2-} under oxidizing conditions. Both V^{4+} and V^{5+} bind strongly to mineral or biogenic surfaces. Vanadium is fairly mobile in neutral and alkaline soils, but mobility decreases in acidic soils. Vanadium is somewhat mobile under oxidizing, unsaturated conditions and is very immobile under reducing, saturated conditions (ATSDR, 1990).

At this site, vanadium was detected in groundwater, soil, and sediment samples. Vanadium will likely be relatively immobile, given the apparent reducing, saturated conditions of site soils. This is supported by the presence of vanadium in 23 soil samples and all the sediment samples, but only four groundwater samples. Vanadium tents to from hydroxide solids under reducing conditions. Off-site migration of vanadium will likely not occur.

5.2.1.19 Zinc - Most of the zinc released to the environment partitions to water, soil, and sediments. Zinc occurs in the environment in the 2+ oxidation state. In the aqueous environment, zinc can occur in both the suspended and dissolved forms. Dissolved zinc may exist as the free hydrated ion or as dissolved complexes formed with a variety of ligands. Suspended zinc may be released following minor changes in the water chemistry or may be adsorbed to suspended matter. Sorption is the dominant removal process resulting in accumulation of zinc in the sediments. In aerobic water, zinc is partitioned into the sediments through adsorption onto hydrous iron and manganese oxides, clay minerals, and organic material. In reducing, high pH and highly polluted waters, precipitation with carbonates, hydroxides, sulfides, and organic ligands becomes significant. Under these conditions, complexation with organic matter, resulting in increased solubility, is also possible. At low pH, zinc tends to remain as the free ion, Zn^{2+}, and adsorb to and travel with suspended solids. Zinc is strongly adsorbed in soils; in general, it is more readily adsorbed at higher pH ($pH > 7$) than lower pH. Also, salinity affects adsorption by displacement of zinc by the alkali and alkaline earth cations. Under anaerobic conditions, zinc sulfate is fairly mobile. Biological activity affects the mobility of zinc in the aqueous environment. Bioconcentration is significant for some biota (Callahan et al., 1979; ATSDR, 1989).

At this site, zinc was detected in groundwater, soil, surface water, and sediment samples. Zinc present in the soil and groundwater will probably adsorb to soil particles or precipitate with carbonates and sulfides, and be retained in the soil matrix. Zinc encountered in surface water at this site will probably adsorb to sediments and become immobile.

5.2.1.20 Summary - In general, at groundwater pH values between about 6 and 9, the mobility of dissolved species of most metals is greatly reduced. Colloidal transport, however, may be of significance at this site because landfill leachate often contains a significant amount of dissolved and suspended organics and the sand and gravel components of the soil at the SFL permit this type of transport. In conclusion, antimony, and to a lesser degree, arsenic, cadmium, chromium, and manganese are believed to have the greatest potential to migrate, based on observed and assumed site conditions.

5.2.2 Volatile Organic Compounds

The primary transport process for VOCs is volatilization. Volatile compounds may be transported great distances before degradation processes or deposition to land and surface water remove them from the atmosphere. The distance traveled depends on factors such as the rates of atmospherically important degradation processes (i.e., photodegradation and hydrolysis), water solubility, and climatic conditions. Typically, volatilization is not a significant process in the subsurface environment (i.e., subsurface soil and groundwater).

The volatile compounds detected at this site range from slightly soluble (4.31 to 480 mg/L) to highly soluble (1,100 to 35,000 mg/L), and adsorption of these compounds to solid surfaces is a minor process (log K_{oc} ranges from 0.39 to 3.20). Therefore, vertical and horizontal transport in landfill leachate and in surface water runoff are possible processes. Transport in the aqueous phase may increase the volume of affected soil and may carry constituents to the groundwater and adjacent surface waters. Dissolved species will travel in the direction of groundwater and surface water flow (see Table 5-1 and 5-2).

Bioconcentration (BCF ranges from 0 to 67) is insignificant for this class of compounds. Bioconcentration is not considered to be a mechanism for migration of VOCs (see Table 5-1).

5.2.3 Semi-Volatile Organic Compounds

In general, semi-volatile compounds tend to be somewhat durable and may cycle between the aqueous and solid phases with only limited transport occurring. The semi-volatiles detected at this site (bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, 4,4'-DDE, and Aroclor 1248) have similar transport properties. The solubilities of these compounds are relatively low (0.01 to 42.2 mg/L), and the adsorption coefficients are relatively high (log K_{oc} ranges from 4.45 to 5.64). These properties suggest that the semi-volatile compounds will likely adsorb to soils and sediments with little or no migration (see Tables 5-1 and 5-2).

All of these compounds have a potential to bioaccumulate (BCF ranges from 663 to 343,000; see Table 5-1). However, because these constituents were detected in subsurface soils where biota are not likely to have access, and because these constituents are unlikely to migrate with the groundwater to surface water, the bioaccumulation potential at the SFL site is considered to be insignificant.

The vapor pressures and Henry's Law Constants are relatively low for these semi-volatile constituents (vapor pressures = 5×10^{-4} to 8×10^{-11} atm and Henry's Law Constants = 4×10^{-3} to 1×10^{-6} atm-m^3/mole; see Table 5-1). For this reason, and because the semi-volatiles were detected in subsurface soil samples, volatilization is not considered to be a significant transport process at the SFL site.

5.3 PERSISTENCE OF CONSTITUENTS

The persistence of a constituent in a particular environmental medium is a measure of the length of time that it remains in that medium. Processes of constituent removal include degradation, transformation, and transport to another environmental compartment. The longer a compound remains in a compartment, the more persistent it is in that media. The term half-life is often used when discussing persistence. The half-life of a compound is the time required for the concentration of the chemical to decrease to one half of the original concentration. The half-lives presented in Table 5-4 are based only on transformation/degradation processes. Transport to another medium (i.e., volatilization) is not considered.

Processes such as adsorption may influence the persistence of a compound by affecting biodegradation, volatilization, or biological uptake. Bioaccumulation may increase a chemical's persistence by protecting it from processes of environmental degradation.

The potential for persistence of the constituents detected in groundwater, surface water, sediments, and soils at the SFL is discussed in the following sections.

5.3.1 Metals

Because metals are not actually degraded, persistence is addressed in terms of the transport of the metals from one media to another (i.e., from sediment to surface water or from soil to groundwater). As might be expected from their ability to exist in a variety of forms, metals were detected in groundwater, soil, surface water, and sediment samples collected from this site. In general, migration through leaching is expected for metals forming soluble organic or ionic complexes, whereas insoluble metal compounds and adsorbed metals tend to persist in surface soils and sediments. Migration of metals adsorbed to particulates is also possible.

The constituents currently in the soil and sediment may be transported to groundwater or surface water in the future. The metals in the soil and sediment are either ionic and adsorbed to the solid phase or are in a non-ionic, precipitated form. A variety of factors determine whether or not these metals will be mobilized in the future. For instance, the adsorbed species may be removed by ion-exchange reactions, and the solid phases may be dissolved by infiltrating rain water or surface water runoff. Most of the metals detected at this site will likely remain in the soil/sediment unless changes occur in the physical and chemical characteristics of the aqueous or solid phases. These characteristics include pH, the presence of competing ions for ion exchange sites, and the presence of complexing/chelating agents which may solubilize some metals. Changes in the redox conditions of the soil will directly affect the metal species with multiple oxidation states and may indirectly affect other metal species.

Section 5.2.1 specifically addresses the behavior of the metal species of interest at this site. Based on an interpretation of actual site conditions, it seems likely that aluminum, arsenic, barium, beryllium, cadmium, cobalt, copper, chromium, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, vanadium, and zinc will persist in soil.

5.3.2 Volatile Organic Compounds

The persistence of a particular VOC at this site depends on the properties of the constituent and the environmental compartment in which it exists. Low levels of VOCs were detected in soil and groundwater from this site.

Carbon disulfide was detected in one soil sample. Considering the depth at which it was detected in the soil (16 to 20 feet), volatilization is likely to be hindered. Furthermore, biodegradation is expected to be a relatively slow process (half-life in soil ranges from 3 months to 1 year), and adsorption is expected to be minor (log K_{oc} is 1.80; see Tables 5-2 and 5-4). The solubility of carbon disulfide is relatively high (1700 mg/L; see Table 5-1). Based on these characteristics, carbon disulfide may migrate in percolating rainwater to groundwater and nearby surface waters.

Methyl chloride was detected in one soil and two groundwater samples at this site. Again, volatilization of methyl chloride from the soil is probably somewhat hindered, but biodegradation proceeds at a moderate rate (half-life in soil ranges from 7 days to 4 weeks) (see Table 5-4). Considering the high solubility (7,400 mg/L; see Table 5-1), low log K_{oc} (1.40; see Table 5-2), and moderate rate of degradation, the soil may act as a source to future groundwater contamination.

The remainder of the VOCs were detected in groundwater samples collected at this site. This is attributed to the moderate to high solubilities and the low adsorption coefficients of this class of compounds (see Tables 5-1 and 5-2). The persistence of these constituents in groundwater varies from nonpersistent to highly persistent. In general, because volatilization is often hindered in the subsurface, degradation processes such as biodegradation and chemical degradation are typically most significant.

For the purpose of discussing persistence, other VOCs at the site are divided into three groups. Group 1 constituents are relatively nonpersistent in groundwater and include the following organics:

- cis-1,3-Dichloropropene
- Methyl isobutyl ketone
- 1,1,1,2-Tetrachloroethane
- 1,1,2,2-Tetrachloroethane

The half-lives of these compounds in groundwater range from 11 hours to 67 days (see Table 5-4). Biodegradation and/or hydrolysis are responsible for the removal of these constituents from groundwater. These compounds are not expected to persist or migrate considerably in the groundwater.

Group 2 constituents are moderately persistent in the groundwater. This group includes:

- Chlorodibromomethane
- 1,2-Dibromoethane
- 1,1-Dichloroethane
- Methyl chloride
- Methylene bromide
- Methylene chloride
- Styrene
- m-Xylene
- p-Xylene

The half-lives of these compounds in groundwater range from two weeks to seven months (see Table 5-4). Biodegradation is the dominant process responsible for the degradation of these compounds. In general, the potential for off-site migration of these compounds is greater than for the Group 1 compounds.

Group 3 constituents are highly persistent in the groundwater and include:

- Benzene
- Bromoform
- 1,2-Dichloroethane
- trans-1,2-Dichloroethene
- 1,2-Dichloropropane
- 1,1,2-Trichloroethane
- Trichloroethene
- Trichlorofluoromethane
- 1,2,3-Trichloropropane
- Vinyl chloride
- o-Xylene

The half-lives of these compounds range from 10 days to 8 years (see Table 5-4). Biodegradation is primarily responsible for the removal of these constituents from the groundwater. Due to the potential persistence of this class of constituents, off-site migration is possible.

Literature information was not located regarding the persistence of 2-hexanone; ethyl methacrylate; trans-1,4-dichloro-2-butene; methylacrylonitrile; and pentachloroethane in groundwater. In general, the methyl chloride and carbon disulfide detected in the soil may act as a source of future constituent migration to groundwater and surface water. The remainder of the volatiles detected in subsurface regions, where volatilization is not expected, range from slightly to highly persistent and may continue to migrate in the direction of groundwater flow until they are naturally degraded or discharged to surface water (where they will likely volatilize).

5.3.3 Semi-Volatile Organic Compounds

The semi-volatile organics at this site were detected in subsurface soil samples. The dominant removal process of these constituents from soil is biodegradation. The two phthalates are relatively non-persistent; half-lives in soil range from 1 to 23 days (see Table 5-4). These phthalates are not expected to persist or migrate considerably.

Aroclor 1248 and 4,4'-DDE are highly persistent in the environment. The half-life of DDE in the soil is 2 to 15 years (see Table 5-4). The persistence of PCBs depends on the number of chlorine atoms in the mixture. Aroclor 1248 is comprised of 2 percent $C_{12}H_8Cl_2$, 18 percent $C_{12}H_7Cl_3$, 40 percent $C_{12}H_6Cl_4$, 36 percent $C_{12}H_5Cl_5$, and 4 percent $C_{12}H_4Cl_6$. In general, the Cl_1-, Cl_2-, and Cl_3-containing species biodegrade quickly in the environment. The more heavily chlorinated species, however, may persist for many years in the soil (see Table 5-4). In any case, considering the low water solubilities and high adsorption coefficients of 4,4'-DDE and Aroclor 1248, they are expected to remain in the soil with little or no migration until they are naturally degraded.

The semi-volatile compounds range from highly persistent to non-persistent in the environmental media of interest. However, most of these constituents are expected to remain in the soil with little or no migration until they are degraded.

5.4 FATE AND TRANSPORT OF CONSTITUENTS OF CONCERN

There are a number of transport pathways for migration of constituents at the SFL site. The Kansas River and Threemile Creek affect the movement of constituents from the landfill by influencing the elevation of the groundwater table and the direction and velocity of groundwater flow. Seasonal variations in precipitation may also affect the elevation of the groundwater table. Other transport processes of importance include the infiltration/percolation of rain water through the landfill cover and surface water runoff across the landfill surface. Based on available elevation data and on inference, Threemile Creek and the Kansas River alternate between areas of recharge or discharge to the shallow aquifer system under the SFL. Constituents carried in the groundwater and surface water runoff are eventually discharged to these surface water bodies. Therefore, off-site migration may occur by transport in the creek or river. It should be noted, however, that the Kansas River and Threemile Creek do not appear to be impacted by the landfill, based on the absence of site-related constituents above background concentrations.

5.4.1 Soil

Infiltrating river and creek water into the landfill can affect the migration of contaminants from the landfill. It has been estimated that there is approximately 60,000 to 3,000,000 ft^3/yr of river water influx to the landfill, raising the water table (as much as 3 to 4 feet) and potentially leaching contaminants from the buried waste and soil (see Section 3.6.2.5.2 and Appendix P). At lower river stages, leached contaminants may be carried with the groundwater and eventually discharge to the creek or river.

Regional water table fluctuations may result from a seasonal cycle with a rising water table in the SFL during spring and summer, followed by a draining and lowering of the water table during fall and winter. This indicates that the regional water table fluctuations at the SFL undergo at least one seasonal rise and fall cycle per year which saturates and then drains a portion of the fill. It is estimated that approximately 13,000,000 ft^3 of water was in contact with the landfill material in April 1993. This would be expected to drain from the landfill at least on a yearly basis. Approximately 70 to 90 percent of the 13,000,000 ft^3 of water is believed to be a result of the regional water table fluctuation. The remaining 10 to 30 percent results from infiltration through the SFL cover and river influx (see Section 3.6.2.5.3).

Infiltration and surface runoff of rainwater are other important processes affecting the migration of constituents from the landfill. It has been estimated that approximately 2 to 3 inches of rainfall infiltrates the landfill each year. This corresponds to an infiltration rate of approximately 50,000 to 80,000 gallons/acre/year, based on the HELP Model (see Section 3.6.2.4). The infiltrating rain water may leach constituents from the underlying waste or soil and carry them to the groundwater.

A portion of the remaining rainfall is expected to run off the landfill surface. Surface runoff flows to the east-southeast toward Threemile Creek and the Kansas River. Surface runoff may mobilize constituents present in the cover material of the landfill (e.g., lead, copper, and zinc), but it should not affect the underlying waste or soil.

Aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, selenium, silver, thallium, vanadium, and zinc were detected in the soil boring samples collected at this site. As discussed in Section 5.2.1, it is believed that arsenic, cadmium, and chromium have the greatest potential to be leached from the soil, based on assumed site conditions. These constituents are expected to be mobilized primarily as dissolved species or as adsorbed species on particulate matter or dissolved organic matter. The remaining metals are expected to persist in the soil. Human and ecological receptors are not likely to come into contact with the subsurface soil.

Two VOCs, methyl chloride and carbon disulfide, were detected in SFL soil samples. Both of these constituents have relatively low K_{OC} values. Based on the range of organic carbon content measured for site soils (0.012 percent to 0.223 percent), carbon disulfide has calculated K_d values of 7.57×10^{-3} to 1.41×10^{-1} and methyl chloride has calculated K_d values of 3.01×10^{-3} to 5.60×10^{-2} (see Table 5-2). The K_d values indicate that both of these VOCs have a greater tendency to partition into the groundwater than onto the soil.

Despite the low K_d values for these VOCs, they do not appear to have vertically migrated far from their apparent source. Carbon disulfide was detected in one sample, SB201, at a depth of 16 to 20 feet; the estimated bottom of the landfill trenches (18 feet) falls within this depth range. Methyl chloride was also detected in only one sample, SB701, at a depth of 14 to 22 feet. Again, the assumed bottom of the trenches falls within this range. Additionally, these VOCs were not detected in deeper soil samples at either of these sampling locations or in any groundwater samples.

Four semi-volatile compounds were also detected in soil samples from the SFL. Bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, 4,4'-DDE, and Aroclor-1248 were detected in soil sample SB201. Again the trench bottoms fall within the range of the depth of this soil sample, 16 to 20 feet. Butyl benzyl phthalate, 4,4'-DDE, and Aroclor-1248 were not detected in deeper soil samples from this or other sampling locations and these constituents were not detected in any groundwater samples. Based on these observations and the K_d values for these constituents at the SFL (ranging from 3.38 to 2860), it is likely that these constituents will not migrate far from their source (see Table 5-2).

Despite the moderately high K_d values for bis(2-ethylhexyl)phthalate (ranging from 12 to 655), this constituent was detected in eight samples at depths ranging from 16 to 64 feet (see Table 5-2). The concentrations of bis(2-ethylhexyl)phthalate detected in these samples range from 37 to 9700 μg/kg. It should be noted, however, that 430 μg/kg of this constituent was also detected in the upgradient sample SB101. Despite the horizontal and vertical distribution of this phthalate, bis(2-ethylhexyl)phthalate is not expected to migrate off-site because it was not also detected in any groundwater or surface water/sediment samples. Colloidal transport may be responsible for the occurrence of this constituent in the deeper soil samples.

5.4.2 Groundwater

Groundwater transport processes are described in detail in Sections 3.6.2 and 5.4. The following sections address the results of the individual sampling events.

5.4.2.1 Baseline Sampling Event - The estimated river stage during this sampling event (July, 1992) was approximately 1041 feet msl. The groundwater gradient near the Kansas River on this date was from the south to the north, away from the river. Threemile Creek under these conditions was acting as source of recharge to the groundwater. This caused the area northwestward of the SFL to behave as a local sink for groundwater. The groundwater at the SFL seemed to be flowing from all directions towards wells SFL92-801 and SFL92-803.

The gradients near the river (0.008 feet/foot) and creek (0.025 feet/foot) were relatively steep, but the gradients declined to 0.002 feet/foot approximately 1,000 feet north of the river. Based on an assumed effective porosity of 0.30 and using a hydraulic conductivity range of 10 to 500 feet/day, groundwater velocities of 0.07 and 3.4 feet/day were calculated, using an average gradient of 0.002 feet/foot.

During the baseline sampling event, metals and VOCs were detected in the groundwater. The metals present in the groundwater were likely dissolved or adsorbed onto colloidal matter. In either case, the metals are expected to be transported in the direction of groundwater flow, which during this sampling event was towards wells SFL92-801 and SFL92-803.

For the baseline sampling event for VOCs, wells SFL92-501 and SFL92-503 contained the following constituents (the numbers in parentheses are the calculated retardation factors for each constituent):

- 1,2-dibromoethane (R = 1.0 - 1.4)
- trans-1,4-dichloro-2-butene
- trans-1,2-dichloroethene (R = 1.0 - 1.5)
- ethyl methacrylate
- methylacrylonitrile
- methyl chloride (R = 1.0 - 1.1)
- methylene bromide (R = 1.0 - 1.4)
- pentachloroethane (R = 1.2 - 4.6)
- 1,1,1,2-tetrachloroethane (R = 1.1 - 2.5)
- 1,1,2,2-tetrachloroethane (R = 1.0 - 1.7)
- trichlorofluoromethane (R = 1.1 - 3.4)
- 1,2,3-trichloropropane (R = 1.1 - 2.5)
- vinyl chloride (R = 1.0)
- xylenes (total) (R = 1.1 - 25)

Most of these constituents were detected in both SFL92-501 and SFL92-503, indicating the existence of these VOCs throughout the vertical extent of the shallow aquifer. Since this sampling location is on the eastern side of Threemile Creek, which is believed to be a hydraulic boundary to groundwater flow from the landfill, these constituents may not have originated from the landfill.

Considering a fraction of organic carbon of 0.012 to 0.223 percent, these constituents have calculated retardation factors of 1.0 to 4.6, except xylenes. This indicates that most of these constituents will move at a rate similar to the groundwater (disregarding dispersion). m-Xylene is the only constituent that may be subject to significant retardation; however, this is only the case at the higher fraction of organic carbon (R = 25; see Table 5-2). Because the soil in the vicinity of wells SFL92-501 and SFL92-503 is predominately sand and gravel, it is likely that the lower retardation factors (i.e., those based on the f_{oc} value of 0.012 percent) describe the system more accurately. Therefore, VOCs at this location are expected to migrate at approximately the same velocity and in the direction of groundwater flow (which was east to northeast during the baseline sampling event).

Two VOCs, benzene and vinyl chloride, were detected in monitoring well SFL92-601. These constituents were not detected in the samples collected in the deeper portion of the aquifer indicating that vertical migration had likely not occurred for these constituents at this location. The calculated retardation factors for benzene (R = 1.1 to 2.2) and vinyl chloride (R = 1.0) indicate that these constituents should migrate at approximately the same speed as the groundwater.

A number of VOCs were detected in monitoring wells SFL92-801 and SFL92-803. The constituents detected at this location and their corresponding retardation factors are presented below:

- benzene (R = 1.1 - 2.2)
- bromoform (R = 1.1 - 2.7)
- chlorodibromomethane (R = 1.1 - 2.2)
- 1,2-dichloropropane (R = 1.0 - 1.4)
- cis-1,3-dichloropropene (R = 1.0 - 1.3)
- 2-hexanone (R = 1.1 - 3.0)
- methyl isobutyl ketone (R = 1.0 - 1.1)
- styrene (R = 1.6 - 12)
- 1,1,2,2-tetrachloroethane (R = 1.0 - 1.7)
- 1,1,2-trichloroethane (R = 1.0 - 1.8)
- xylenes (total) (R = 1.1 - 25)

Most of these constituents were detected in both SFL92-801 and SFL92-803, indicating the existence of these constituents throughout the vertical extent of the shallow aquifer. At the time of sampling, the water-table contours suggest that groundwater flow directions were from all surrounding areas towards this monitoring well. Infiltrating rain water through the silty surface soil may also be responsible for the presence of the observed constituents. The retardation factors indicate that at an organic carbon content of 0.012 percent, little or no retardation of the constituents is expected to occur. At higher organic carbon contents, however, some of the constituents (i.e., styrene and m-xylene) should be significantly sorbed by the soil (see Table 5-2).

No organic constituents were detected in monitoring well clusters 2, 3, and 4 (i.e., the wells nearest to the river) during the baseline sampling event as they were effectively upgradient of landfill source material. Additionally, the influx of river water due to high river stage which may have effectively diluted groundwater concentrations. The more mobile constituents may have been previously leached from the soil and waste near the river during previous high water stages.

5.4.2.2 First Quarter Sampling Event - The estimated river stage and water table configuration during this sampling event (November, 1992) is believed to be similar to the October, 1992 conditions based on almost equivalent peak gage data of both occasions (see Table 3-5). The groundwater gradient on this date was southeast towards the Kansas River. For this event, Threemile Creek is interpreted as an area of recharge in the northern portion of the SFL area, and as an area of groundwater discharge in the southern portion. The magnitude of the gradient was 0.0008 feet/foot, indicating groundwater flow velocities ranging from 0.03 feet/day to 1.3 feet/day, based on a hydraulic conductivity range of 10 to 500 feet/day.

During the first quarter groundwater sampling event, metals and VOCs were detected. The metals were detected at approximately the same frequency and concentrations as they were in the previous sampling event. Again, the metals are expected to be transported in the direction of groundwater flow, which eventually discharges to the Kansas River.

1,2-Dichloroethane was detected in wells SFL92-501 and SFL92-502. This constituent was not detected in well SFL92-503. This constituent was not detected in these wells during the baseline sampling event. Furthermore, none of the organic constituents detected at this location during the baseline sampling event were detected during the first quarter sampling episode. Since these baseline constituents were all detected at low levels, it is possible that processes such as dispersion and degradation attenuated these VOCs below their detection limits. Like the other chlorinated solvents previously detected at this site, 1,2-dichloroethane retardation is not expected to be significant (R = 1.0 to 1.3; see Table 5-2). This indicates that it should travel at approximately the same velocity and in the same direction as the groundwater flow.

1,2-Dichloroethane was also detected in SFL92-601, and benzene was detected in SFL92-601 and SFL92-602. Benzene was detected at this sampling location during the previous (baseline) sampling event; this suggests that a source of benzene may be present near this location. 1,2-Dichloroethane was not previously detected at this location. As mentioned above, retardation is not expected to be significant for 1,2-dichloroethane; benzene may migrate at slightly slower rates than groundwater (R = 1.1 to 2.2; see Table 5-2). Both constituents should migrate in the same direction as groundwater (generally to the southeast).

None of the constituents which were detected in wells SFL92-801 and SFL92-803 during the baseline sampling episode were detected during this sampling event. The initially detected constituents may have migrated beyond the influence of these wells, as supported by the low retardation factors of this group of compounds, or the constituents may have been attenuated below their detection limits by processes such as dispersion and degradation.

5.4.2.3 Second Quarter Sampling Event - The river stage during the second quarter sampling episode (February, 1993) was approximately 1033 feet msl. The groundwater gradient was eastward towards the Kansas River downstream of the SFL. For this event, Threemile Creek is interpreted as a source of groundwater recharge in the northern portion of the SFL area, and as an area of groundwater discharge in the southern portion. The calculated groundwater velocities ranged from 0.03 feet/day to 1.5 feet/day, based on a hydraulic conductivity range of 10 to 500 feet/day and a gradient of 0.001.

During this sampling event, metals and VOCs were detected. Most of the metals were detected at about the same frequency and concentration as during the previous sampling events. One exception is cobalt which was detected in seven samples from this sampling event but in only one sample during the baseline event. Again, the metals are expected to be transported in the direction of groundwater flow, which eventually discharges to Threemile Creek and the Kansas River.

Trans-1,2-Dichloroethene was detected in SFL92-501 and SFL92-502, as it was during the baseline sampling event. Benzene was detected again in SFL92-601 and SFL92-602. This constituent was detected in both of these samples during the first quarter sampling episode and in SFL92-601 during the baseline sampling event. These constituents should migrate at approximately the same velocity and in the same direction as the groundwater (see Table 5-2).

5.4.2.4 Third Quarter Sampling Event - The river stage during this sampling event (May, 1993) was approximately 1039 feet msl and the groundwater was flowing generally toward the east. For this event, Threemile Creek is interpreted as a line source of recharge to the groundwater. The calculated groundwater velocities ranged from 0.02 feet/day to 1.2 feet/day, based on a hydraulic conductivity range of 10 to 500 feet and a gradient of 0.0007 feet/foot.

Again, metals and VOCs were detected during the third quarter groundwater sampling event. With the exception of zinc, all the metals were detected in approximately the same frequency and concentrations as during previous sampling events. Zinc was not detected during this sampling episode, but it was detected in 12 to 16 samples from previous events.

Trichlorofluoromethane was detected in sample SFL92-401. Trans-1,2-Dichloroethene was detected in SFL92-501, as it was during the baseline sampling event. Benzene, 1,1-dichloroethane and trans-1,2-dichloroethene were detected in SFL92-601. Benzene was detected during the three previous sampling events at this location. Trichloroethene was detected in SFL92-701; this is the first organic constituent detected in the groundwater at this location. None of these constituents detected during this round of sampling were found in deeper groundwater samples. These constituents are expected to migrate at the same velocity and in the same direction as the groundwater.

5.4.2.5 Summary - Based on available site data and our interpretations, both dissolved species and species adsorbed to particulates or colloids are transported in groundwater at the SFL site. The VOCs are transported primarily as dissolved species, given their relatively high solubilities and low partition coefficients. Based on the calculated retardation factors, most of these volatile compounds should travel at approximately the same velocity as the groundwater (see Table 5-2). Despite the seasonal variations in groundwater flow direction at this site, the groundwater from the surficial aquifer will eventually discharge to either Threemile Creek or the Kansas River. This is an important fate process for the VOCs because they will volatilize quickly if they are discharged to surface water.

The metal species may be transported as both dissolved and adsorbed species depending on the conditions of the surrounding environment. The metals transported in the surficial aquifer may also eventually discharge to Threemile Creek and the Kansas River. Discharge to surface water is significant to the fate of the metals because the physical and chemical properties of groundwater and surface water may be quite different; and release to the surface water system may alter the partitioning of metals between the dissolved, adsorbed, and solid phases.

Because there are no human or ecological receptors on-site who are exposed to the constituents detected in the groundwater, it is of interest to determine how long it would take a particular constituent to migrate off-site. Since groundwater from beneath the landfill is interpreted to discharge to Threemile Creek and the Kansas River, these two surface water bodies represent the nearest off-site exposure point. Assuming intermittent groundwater flow under Threemile Creek, Camp Funston might also be an off-site exposure point. Based on interpretation of available data, there is no evidence suggesting significant transport from the SFL area to Camp Funston, but the possibility cannot be precluded. Although the groundwater flow direction and velocity change over space and time at the SFL site, "net" groundwater flow velocities ranging from 0.02 feet/day to 0.83 feet/day were calculated based on estimated average groundwater and river elevations (see Section 3.6.2.2.6), and on a hydraulic conductivity range of 10 feet/day to 500 feet/day. The distance from the center of the landfill in a southeasterly direction to the Kansas River is approximately 2000 feet. Based on these values, it would take approximately 7 years to 274 years for a constituent in the center of the landfill to migrate in a southeasterly direction to the Kansas River. Constituents which were detected in groundwater samples collected from wells which are closer to the river could potentially reach the creek or river in a shorter amount of time. For instance, wells SFL92-301, SFL92-302, and SFL92-303 are located approximately 200 feet from the river (in a southeast direction). Therefore, it would take about 6 months to 27 years for a constituent detected at this location to migrate to the river. These time periods are approximations because changes in groundwater flow direction will likely increase the residence time and decrease the concentration (by the effects of dilution) of a constituent within the landfill area. Additionally, effects of dispersion, retardation, and degradation were not considered in this calculation. Dispersion has the effect of decreasing the time required for a constituent to migrate a given distance, while retardation tends to increase the constituents residence time. Degradation has the effect of decreasing the concentration of a constituent over time.

5.4.3 Surface Water/Sediment

Contamination of nearby surface water bodies may occur via surface water runoff or groundwater discharge. Surface water runoff may potentially transport constituents present in the surface soils. Runoff flows generally in a southeastward direction towards Threemile Creek and the Kansas River. As discussed above, groundwater beneath the SFL also discharges into Threemile Creek and the Kansas River.

Metals were the only constituents detected in surface water and sediment samples collected from the Kansas River and Threemile Creek. However, the concentrations detected in the downstream samples were not significantly higher than those detected in the upstream samples. These comparisons suggest that the metals present at the landfill are relatively immobile.

It is unknown whether or not VOCs detected in groundwater samples at the SFL have discharged to the adjacent surface water bodies. No VOCs were detected in the Kansas River or Threemile Creek, but detection of volatile species in surface water is unlikely given their low vapor pressures (i.e., high potential to volatilize).

Since no semi-volatile organic compounds were detected in the surface water or sediments, it is likely that they are relatively immobile, or migrating at a slow rate. Of the four semi-volatile compounds detected in soil samples, only bis(2-ethylhexyl)phthalate was detected throughout the vertical extent of the aquifer. The absence of this constituent from surface water and sediment samples suggests that it has not migrated off-site.

5.5 SUMMARY AND CONCLUSIONS

The dominant fate and transport processes of importance at the SFL include:

- Infiltration of rainwater through underlying waste and soils, both in areas where landfill activities are known to have occurred and areas where suspected dumping may have occurred (e.g., near wells SFL92-801 and SFL92-803). Such infiltration may contribute to groundwater contamination.
- Groundwater movement toward the river, and any episodic, high river-stage event that temporarily reverses groundwater flow away from the river along portions of the southern (and possibly eastern) boundary of the landfill.

Surface water runoff across the landfill cover soils to the east-southeast constitutes a minor pathway.

Based on analytical data and apparent site conditions, it appears that low levels of constituents may be leached from soil or waste via infiltration associated with rainfall events, due to river influx, and generally because of seasonal water table elevations. Although there is a net flow of groundwater to the river and creek, given the retention time within the landfill boundaries and the low levels of constituents apparently leached from the SFL media it appears that groundwater constituents are significantly degraded or diluted by the time they reach the landfill boundaries. In this respect, it does not appear that the landfill constituents are migrating off-site at concentrations of concern.

5.5.1 Metals

Leaching, precipitation, and adsorption are likely transport processes for metals as indicated by the presence of metals in both soil and groundwater. Migration of metals present in the soil could occur if future changes in the physical and chemical properties of the soil and pore water occur which favor dissolution and/or desorption. However, it is likely that the metals in the soil are fairly immobile because most tend to adsorb to soil particles or precipitate to solid phases. This interpretation of relative immobility is supported by there being no significant difference between the concentration of metals detected during the various sampling events.

Metals in the groundwater likely result from percolation of rainwater down through the soil or upward migration of groundwater during high water conditions. Both of these processes mobilize ionic species, and possibly fine-grained particulates containing adsorbed metals. Mobile metals in the groundwater are expected to travel in the direction of groundwater flow. The absence of metals in surface water and sediments of the Kansas River and Threemile Creek above the upstream concentrations suggests that off-site migration of metals is not occurring to a degree that is of concern.

5.5.2 Volatile Organic Compounds

Volatile organic compounds (VOCs) were detected in the soil and groundwater. The VOCs in the soil may be transported to the groundwater or surface water by the leaching action of rainwater or groundwater (during periods of high river stage or rising groundwater table). The constituents dissolved in the groundwater are expected to migrate in the direction of groundwater flow. The VOCs detected on-site range from non-persistent to highly persistent in the natural environment. The potential discharge of groundwater into Threemile Creek and the Kansas River would substantially decrease the persistence of VOCs because these constituents volatilize quickly from surface waters.

As mentioned earlier, increased infiltration during and following heavy rainfall may affect constituent migration. A number of VOCs were detected in groundwater samples collected during the baseline sampling event (which took place following a period of increased rainfall) that were not detected during subsequent sampling events (which took place under more normal rainfall conditions). An explanation for this is that residual VOCs were present in the capillary fringe zone. Increases in hydraulic pressure due to infiltrating rain water could have caused water-table fluctuations into the capillary fringe and introduced the previously immobile VOCs into the water table (saturated zone) prior to the sampling event.

5.5.3 Semi-Volatile Organic Compounds

The semi-volatile compounds detected at the SFL site were in soil samples. It appears that the semi-volatiles found at this site have not migrated very far from their point of application or release to the environment. Adsorption to soil particles is the likely explanation for the persistence of these compounds. Because of this sorption, the semi-volatiles detected in the soil are not expected to represent a significant source of release for these constituents to other media, such as groundwater. Although bis(2-ethylhexyl)phthalate was detected in soil samples at multiple depths, the absence of this constituent in the sediments of adjacent surface water bodies suggests that it has not migrated off-site. Furthermore, the potential for these compounds to bioaccumulate is low considering their depth in the soil.

5.6 FOURTH QUARTER GROUNDWATER DATA

The river stage during this sampling event (September, 1993) was approximately 1041 feet msl and the groundwater was flowing generally toward the east. For this event, Threemile Creek is interpreted as a line source of groundwater discharge. The magnitude of the groundwater gradient in the SFL area was 0.0009 feet/foot, indicating groundwater flow velocities ranging from 0.03 feet/day to 1.5 feet/day, based on a hydraulic conductivity range of 10 to 500 feet/ day.

During this sampling event, metals and VOCs were detected. Most of the metals were detected at about the same frequency and concentration as during the previous sampling events. The metals are expected to be transported in the direction of groundwater flow, which eventually discharges to Threemile Creek and the Kansas River.

In the fourth quarter, 1,1-dichloroethane was detected in SFL92-601, as it was during the third quarter sampling event. Benzene was detected in the fourth quarter in SFL92-601 and SFL92-602. Benzene was detected during the four previous sampling events at SFL92-601, and during the first and second quarter sampling events at SFL92-602. Chloroethane and tetrachloroethane were detected in the fourth quarter sampling event in SFL92-601 and SFL92-301, respectively. Neither of these constituents were detected in previous groundwater sampling events at the site. Vinyl chloride was detected in SFL92-601 and SFL92-602. Vinyl chloride had been detected in SFL92-601 and SFL92-501 during the baseline sampling event. These organic constituents should migrate at approximately the same velocity and in the same direction as the groundwater.

To examine the possibility of transport of constituents between SFL and Camp Funston, fourth quarter groundwater data were analyzed for similarities in chemicals detected and concentrations (Tables 4-27 and 4-29). The analysis focused on whether it was plausible that constituents detected at both sites have common sources.

The fourth quarter groundwater data show that eleven constituents were detected at SFL and twenty at Camp Funston. Of the eleven constituents detected at SFL, five were volatile organic compounds and six were inorganic constituents. Of the twenty constituents detected at Camp Funston, eight were volatile organic compounds, six were semi-volatiles, and six were inorganic constituents. The chemicals detected at both sites consisted of one volatile (benzene) and six inorganics.

To examine the plausibility of a common source for the benzene detected at both sites, the locations and detected concentrations were compared. During the fourth quarter, in SFL wells, benzene was only detected in the 600 Series wells. These wells are near the center of SFL. Detected concentrations of benzene in these wells during the fourth quarter were 3.2 and 7.6 μg/L. In the Camp Funston wells, benzene was detected at concentrations of 1.2, 160, and 30,000 μg/L during the fourth quarter. The Camp Funston wells in which benzene was detected (AEHA-MW7, DM-1637, and DM-1245) are near the eastern edge of Camp Funston (i.e., farthest away from SFL). Benzene was not detected in other Camp Funston wells closer to SFL. Therefore, based on the differences in detected concentrations at the two sites and the physical distance between the wells where benzene was detected, it is considered unlikely that a common source exists for the benzene detected at SFL and Camp Funston.

Regarding the detection of volatile organic compounds in SFL wells, in general, their presence in the 500 Series wells (in sampling events prior to the fourth quarter) indicates that groundwater flow beneath Threemile Creek may occur. That is, the source of these compounds may be located in the landfill. However, a review of historical operations and activities at Camp Funston (see Section 4.4) indicates that a number of potential sources exist (or have existed) at Camp Funston. Currently, there is not enough information to positively correlate organic contaminants in the 500 Series wells (and/or their sources) with solely SFL or Camp Funston.

The six inorganics identified in SFL wells during the fourth quarter were the same as those identified in the Camp Funston wells (arsenic, barium, cadmium, chromium, lead, and selenium). However, because there are many natural sources of inorganic compounds in the environment, it is still useful to examine the locations and detected concentrations of these constituents. This is done below in summary fashion for each of the detected inorganic constituents.

Arsenic

- Detected frequently in wells throughout both sites.
- The greatest concentration detected (22 μg/L) in SFL wells was not in the wells nearest Camp Funston. The greatest concentrations (100 μg/L) in Camp Funston wells are in wells near SFL.

Barium

- Detected frequently in wells throughout both sites.
- The greatest concentration detected (1,600 μg/L) in SFL wells was not in the wells nearest Camp Funston. The greatest concentration (1,600 μg/L) in Camp Funston wells was in wells both near to and farthest away from SFL.

Cadmium

- Detected infrequently in wells at both sites.
- The only detection in SFL wells was in a well relatively far from Camp Funston.

Chromium

- Detected infrequently (twice) in the SFL wells and in approximately 50 percent of the Camp Funston wells.
- Detected in SFL wells both near and far from Camp Funston (the maximum concentration was 20 μg/L). The greatest concentration (17 μg/L) in Camp Funston wells was in the wells near SFL.

Lead

- Detected less than 50 percent of the time in the SFL samples. Detected frequently in the Camp Funston wells.
- The greatest concentration detected (16 μg/L) in SFL wells was in a well relatively near Camp Funston. The greatest concentration detected (12 μg/L) in the Camp Funston wells was in wells both near and farthest away from SFL.

Selenium

- Not detected above background concentrations in SFL wells. Detected in approximately 50 percent of the Camp Funston wells.

On the basis of this information, the fate and transport information presented earlier in this section, and the fact that data from Camp Funston is limited, it is considered unlikely that common anthropogenic sources exist for the inorganic compounds detected at SFL and Camp Funston.

6.0 BASELINE RISK ASSESSMENT

This section presents the results of the baseline risk assessment for the SFL at Fort Riley. The baseline risk assessment includes a human health evaluation and an environmental evaluation of the SFL site, which are based on the results of the baseline and quarterly sampling episodes conducted from July, 1992 to May, 1993.

6.1 HUMAN HEALTH EVALUATION

A risk assessment approach, consistent with that presented in the USEPA "Risk Assessment Guidance for Superfund" (USEPA, 1989a), is used to evaluate potential impacts to public health as a result of existing contamination at the SFL. The objective of the baseline human health evaluation is to determine the effects of the existing conditions on the exposed and potentially exposed populations if no action is taken to remediate conditions at the site. The results are used to determine whether further study and/or remedial actions are necessary.

The baseline human health evaluation consists of four steps. The discussion in this section will be presented according to these four steps as outlined below:

1. Data evaluation and identification of chemicals of potential concern

2. Exposure Assessment

    - Characterization of exposure setting
    - Identification of exposure pathways
    - Quantification of exposure
    - Identification and assessment of uncertainties

3. Toxicity Assessment

    - Identification of Applicable or Relevant and Appropriate Requirements (ARARs)
    - Characterization of toxicological properties of chemicals of potential concern
    - Identification of critical toxicity values

4. Risk Characterization

    - Characterization of potential risks due to exposure to carcinogenic chemicals of concern

- Characterization of potential risks due to exposure to noncarcinogenic chemicals of concern
- Identification and assessment of uncertainties

6.1.1 Identification of Chemicals of Potential Concern

The results of the data collection and data evaluation efforts are presented in this section. Based on the results of the data evaluation, a subset of chemicals present at the site was selected for chemicals of potential concern.

6.1.1.1 Data Collection - The following section summarizes the data collection efforts performed prior to July 1, 1993.

6.1.1.1.1 Historical Data Collection - Six monitoring wells were installed at the landfill in May 1983 as part of the July 1982 approved closure plan for SFL. From 1984 to 1986, the six closure monitoring wells were sampled once per year; from 1987 to 1990, the wells were sampled between one and three times per year. Results of these sampling events are summarized in Appendix B.

Previous groundwater sampling results have shown detectable concentrations of arsenic, cadmium, copper, lead, nickel, and zinc in the monitoring wells, as well as high levels of iron. In addition, petroleum hydrocarbons were found in all six wells in 1984, but subsequent testing of the closure wells for total recoverable petroleum hydrocarbons (TRPH) was not performed during this time period (i.e., 1985 to 1990). Volatile organic compounds (VOCs), including vinyl chloride, trichloroethene, trans-1,2-dichloroethene, benzene, and ethylbenzene, were also detected at measurable concentrations on several sampling occasions.

More information regarding the previous groundwater sampling conducted at the site, along with an evaluation of the data generated from these sampling efforts, can be found in Section 1.2.3 of this report.

6.1.1.1.2 Current Sample Collection - Law collected soil, macroinvertebrate, groundwater, sediment, and surface water samples at the site during the baseline sampling episode from March to July 1992. The second (November 1992), third (February 1993), and fourth (May 1993) quarterly groundwater sampling events have also been completed. One more groundwater sampling event occurred in August 1993; the results of this sampling event are not included in this report. This section summarizes the results of the data collection efforts for the baseline sample collection/analysis episode through the May 1993 sampling episode for each medium of potential concern.

Soil - Soil sample collection efforts for the SFL included the collection of a total of 23 subsurface soil samples, collected from the deepest boring at each of the 8 monitoring well clusters. Soil samples were analyzed for volatile and semi-volatile organic compounds, chlorinated pesticides/PCBs, organophosphorus pesticides, herbicides, and target analyte list metals (as given in USEPA, 1986b).

Planning Research Corporation, Inc. (PRC) was contracted by the U.S. Army Corps of Engineers - Kansas City District (CEMRK) through an Interagency Agreement (IAG) with the USEPA to perform a landfill cap study at the SFL which included soil sampling and screening analysis using x-ray fluorescence (XRF) field analyses for lead, copper, and zinc. The investigation was focused on the cover material of the landfill because of suspected contamination from small arms bullets. The cover material was excavated from a rifle range area north of the SFL site. The PRC report is provided in Appendix G.

A total of 10 of the 114 shallow soil samples collected by PRC were reanalyzed using Level 4 (CLP) data analysis to confirm the data generated from the XRF screening methods. The 10 samples with the highest "hits" from the XRF method were chosen for reanalysis. The results of this latter analysis (provided in Appendix G) revealed that the XRF screening method results were biased high, resulting in a conservative approach for determining risk. PRC recalculated the data to provide an estimate of the lead levels and re-issued the report in March, 1993.

Macroinvertebrate - Artificial substrate samplers, sediment grab samples, and sweep net samples were placed at seven locations (Figure 2-4) on July 15 and 16, 1992. Section 2.1.8.1 describes this effort and the resulting decision to terminate this activity.

Groundwater - Twenty additional new groundwater monitoring wells were installed at or around the SFL to evaluate the extent of possible contaminant migration by groundwater and to better define the hydrogeologic conditions at the site. Groundwater samples were collected from each of the wells and analyzed for volatile and semi-volatile organic compounds, chlorinated pesticides/PCBs, organophosphorus pesticides, herbicides, and the target analyte list metals. In addition, groundwater samples were analyzed for the "wet" inorganic compounds (sulfate, sulfide nitrate, chloride, bicarbonate, and total organic carbon). Analyses for TRPH and explosives were also performed. The results are provided in Appendix L.

Surface Water and Sediments - Surface water and sediment samples were collected from seven separate locations in the vicinity of the SFL site. Five surface water/sediment samples were obtained from the Kansas River to the south of the site; and two surface water/sediment samples were obtained from Threemile Creek, located east of the SFL. The surface water samples collected were analyzed for volatile and semi-volatile organic compounds, chlorinated pesticides/PCBs, organophosphorus pesticides, herbicides, inorganic anions, and metals (total and dissolved). Sediment samples were analyzed for the same parameters with the exception of the inorganic anions.

Media Not Sampled - Air samples were not collected at the site. Surface soils at the site were not analyzed for organic compounds. Therefore, exposures to possible volatile gas emissions from the landfill cannot be quantified. However, field observations and measurements including PID readings, odor observations, soil gas sampling, and condition of landfill vegetation can be used to qualitatively evaluate the potential air emissions. Air exposures will be addressed in the risk assessment by evaluating fugitive dust exposures from surface soil.

6.1.1.1.3 Sampling Methods and Locations - The sample collection procedures and analytical methods for the SFL field efforts were performed in accordance with the Work Plans (Law, 1991; Law, 1992a). The Quality Control (QC) samples collected during these efforts included field blanks (rinsates and trip blanks), split and duplicate samples, laboratory blanks (method blanks), and matrix spike/matrix spike duplicate samples. Upgradient samples were collected to establish background data for each medium of potential concern. Sample locations are identified in Figures 2-2, 2-3, and 2-9.

6.1.1.2 Data Evaluation - The human health and environmental evaluations provided in the Baseline Risk Assessment are based on the results of the RI data collection efforts. The objective of the RI data collection efforts was to evaluate the nature and extent of contamination at the SFL site and to provide the data necessary to evaluate the risk associated with the site in the Baseline Risk Assessment.

The coding for the data qualifiers used to examine the data set is defined below. According to risk assessment guidance (USEPA, 1989a; USEPA, 1992a), qualified data should not be eliminated from the data set as long as the uncertainties associated with the data are clearly defined.

Qualifier	Definition
H	Holding time exceeded. Results are biased low.
B_1	Sample results are less than 5 times the amount detected in the method blank. Result is estimated.
B_2	Sample results are less than 10 times the amount detected in the method blank. Result is estimated.

Qualifier	Definition
T	Sample results are less than 10 times the amount detected in the trip blank. Result is estimated.
M_1	Matrix spike recovery is high due to sample matrix effect. Sample result is a false positive or biased high.
M_2	Matrix spike recovery is low due to sample matrix effect. Sample result is biased low.
R_1	Sample result is less than 10 times the amount detected in the rinsate. Result is estimated.
R_2	Sample result is less than 5 times the amount detected in the rinsate. Result is estimated.
J	Estimated result based upon QC data
JB	Estimated quantitation; possibly biased high or false positive based on blank data.
JE	Sample concentration is estimated due to poor precision.
JL	Sample concentration is estimated due to poor precision; sample is biased low.
JR	Sample concentration is estimated; constituent associated with rinsate.
F	Estimated result, relative percent difference (RPD) exceeds the control limit.
E	Estimated result, quantitation uncertain due to poor duplicate precision.
L	Estimated result, possible false negative or biased low results based on laboratory control sample recovery.
C	Estimated result based on poor Method of Standard Addition correlation coefficient.

The results of the current RI study for the SFL focused on evaluating the extent of contamination at the site, characterizing the possible migration of these constituents by groundwater flow and the discharge of contaminants to surface water and sediments adjacent to the site. This information was used to support the Baseline Risk Assessment.

Surface soil, subsurface soil, and monitoring well soil boring samples were collected to evaluate the nature and extent of contamination in site soils. Monitoring wells were designed and installed after the geologic and hydrogeologic characteristics of the area were investigated. Monitoring well samples were used to provide data on soil and groundwater contaminants migrating from suspected sources. Surface water and sediment samples were designed to address impacts from the possible migration of site-related constituents into the adjacent aquatic ecosystem.

The analytical data were evaluated according to the data evaluation procedures specified in USEPA's "Risk Assessment Guidance" (USEPA, 1989a) and the USEPA's "Guidance for Data Useability in Risk Assessment" (USEPA, 1992a). These procedures outline specific aspects of data quality which must be addressed in compiling a data set to be used in quantitative risk assessment. The following aspects are addressed in the evaluation of the data set:

- Analytical methods
- Quantitation limits
- Use of qualified data
- Contamination of blank samples
- Comparison of site samples with background.

6.1.1.2.1 Analytical Methods and Quantitation Limits - The analytical methods used to evaluate subsurface soil, groundwater, surface water, and sediment were appropriate for quantitative risk assessment. The XRF-generated data are Level 2 data, and thus are inappropriate for quantitative risk assessment. However, the 10 confirmation samples submitted by PRC for reanalysis using Level 4 analytical procedures are appropriate for quantitative risk assessment. The quality of the data produced was scientifically correct and legally defensible, as USEPA-approved methods with known limits of precision and accuracy were used.

The Method Detection Limit (MDL) is the lowest amount of chemical that can be "seen" above the normal, random noise of an analytical method, taking into account the reagents, sample matrix and preparation steps applied to a sample in specific analytical methods. Sample MDLs were compared to regulatory criteria, such as Maximum Contaminant Levels (MCLs), to determine whether the methods used were sensitive enough for the purpose of regulatory review. In most cases, the MDLs provided by the laboratory were less than the relevant health-based standards for the constituents detected at the site. An exception for groundwater constituents was thallium, which with an MDL of 0.1 mg/L did not meet the final promulgated MCL of 0.002 mg/L (effective with the Phase V Rule, May 1992). Also, the Practical Quantitation Limit (PQL) for vinyl chloride in groundwater is 0.01 mg/L; however, the MCL is 0.002 mg/L. Therefore, the laboratory would report any result between 0.002 mg/L and 0.01 mg/L as an estimated concentration. All positive results for vinyl chloride exceeded 0.01 mg/L, so the data were unaffected. Note, a PQL is the quantitation limit which is considered to be the lowest level at which a chemical may be accurately and reproducibly quantitated.

Exceptions also occurred for some surface water constituents. The MDL for methylene chloride (0.005 mg/L) did not meet the Ambient Water Quality Criteria (AWQC) for the protection of human health from ingestion of water and fish (0.00019 mg/L). The MDLs for cadmium (0.005 mg/L) and inorganic chloride (0.500 mg/L) exceeded both the acute and chronic AWQC for the protection of aquatic life. The AWQC for these two constituents are as follows:

CONSTITUENT	ACUTE AWQC	CHRONIC AWQC
Cadmium	0.0039 mg/L	0.0011 mg/L
Inorganic chloride	0.019 mg/L	0.011 mg/L

6.1.1.2.2 Qualified Data - Matrix interference was noted with several samples. Several soil samples exhibited internal standard responses below the QC limit for volatile and semi-volatile organic compounds analyses (SFLSB701, SFLSB702, and SFLSB703). These samples also had responses below the QC limit which can be attributed to the low internal standard response. The specific analytes (e.g., perylene, chrysene) which exhibited these responses were not detected in associated samples; therefore, the undetected results are qualified as estimated values. Data qualifier coding is defined earlier in this section.

Sample results qualified with a "J" mean that the numerical value is an estimated quantity.

The matrix spike/matrix spike duplicate (MS/MSD) recoveries for antimony in soil samples were below the laboratory established control limits, indicating poor accuracy. All soil antimony results are flagged with the identifier "M_2" to indicate matrix interference which may cause a false negative or biased low results. In addition, the arsenic result from sample SFLSB703 is qualified with a "C", indicating an estimated value due to a poor Method of Standard Additions correlation coefficient.

The MS/MSD recoveries for TRPH in soil sample SFLSB103 exceeded the laboratory control limit. Since the other sample (SFLSB801) on which MS/MSD analyses were performed had acceptable recoveries, the high recoveries noted in sample SFLSB103 are most likely sample specific. The TRPH results in this sample are flagged with the appropriate qualifiers, "M_1" and "E", indicating possible false positive results or high biased results and poor precision.

The extraction holding times for organophosphorus pesticides were exceeded in two soil samples, by a total of one day for sample SFLSB603 and by 13 days for sample SFLSB102. The organophosphorus results for these two samples are flagged with the "H" identifier and estimated as possible false negatives based on holding time.

In sample SFLSB201, an Aroclor-1248 "hit" of 0.25 mg/kg was noted; however, it was not detected in the duplicate sample. The chromatographs of both the sample and its duplicate verify the reported results. This inconsistency is probably due to the nonhomogeneous nature of the soils. Aroclor-1248 in sample SFLSB201 is qualified "F" as an estimated result.

Matrix interference was also noted for manganese results in sediments. The MS/MSD recoveries for manganese are low, indicating poor accuracy due to matrix interference. All manganese results in soils are flagged with the identifiers "M_2" and "E" to indicate a matrix interference which may cause false negative or biased low results and poor precision.

The MS/MSD analysis performed on sediment sample SFLKRSD01 for TRPH gave low MS/MSD recoveries, indicating poor accuracy due to matrix interference. All TRPH results are flagged with an "M_2" to indicate matrix interference which may cause false negative or biased low results.

All pesticide/PCB samples in soil and sediment were diluted by a factor of at least two times due to gel permeation cleanup procedures. This dilution does not affect the accuracy or precision of the sample.

Matrix interferences are common occurrences in soil and sediment samples, and are due to the heterogeneity of the sample media. These data should be qualified and used with care.

Matrix interference was also noted in surface water samples. The MS/MSD recoveries for lead are below the QC limits, while the MS/MSD recoveries for arsenic are below the QC limit and the MS/MSD RPD values exceed the control limit. All lead results in surface water are flagged with an "M_2" identifier, indicating a matrix interference which may cause a false negative or biased low results. All positive arsenic results are flagged with the identifier "M_2" and "E" to indicate an estimated result with matrix interference which may cause results to be biased low or falsely negative.

Matrix interference was also noted in surface water samples analyzed for semi-volatile organics, chlorinated pesticides/PCBs, and organophosphorus pesticides. The MS/MSD recoveries for the semi-volatile organic compounds analysis exceed the laboratory established control limit for 4-nitrophenol, indicating a possible false positive or high bias. However, 4-nitrophenol was not detected in any surface water samples, and, therefore, the matrix interference does not affect the data. The chlorinated pesticide/PCB MS/MSD recoveries in surface water are below the control limits for the following compounds:

- Gamma-BHC (Lindane)
- Heptachlor
- Aldrin
- Dieldrin
- Endrin
- 4,4-DDT

In addition, the RPD for heptachlor also exceeds the control limit. The matrix interference (indicating poor accuracy) is most likely sample-specific, and all compounds are flagged with the identifier "M_2" as estimated due to a possible low bias or false negative. Any positive results for heptachlor would have been flagged with the additional "E" identifier as estimated (due to high RPD); however, heptachlor was not detected in any surface water samples.

To assess accuracy for organophosphorus pesticide surface water samples, the laboratory submitted duplicate laboratory control samples in lieu of a MS/MSD. The recoveries for malathion were below the control limit; these results are flagged with an "M_2" and estimated as a possible low bias or a false negative. All malathion and guthion RPDs exceeded the control limits, and positive results for these compounds would have been flagged with an "E" as estimated, had they occurred.

Likewise, matrix interference was observed in the groundwater samples during the baseline sampling episode. The MS/MSD RPDs for gamma-BHC (lindane) and aldrin in groundwater sample SFL92-103 exceed the laboratory established control limits, indicating poor precision. These compounds were not detected in the samples; therefore, no results are qualified. For acid herbicides, the MSD recovery for dalapon is below control limits, and the MS/MSD RPD exceeds the control limit. The dalapon result in sample SFL92-103 is flagged with the identifier "M_2" and estimated as a possible low bias or a false negative. The matrix spike recovery for total organic carbon is above the laboratory established control limit. All positive total organic carbon results are flagged "M_1" indicating possible false positive or high bias results. The duplicate RPD for sulfide also exceeds the control limit. All sulfide results are flagged with an "E" identifier and estimated based on poor precision. Lastly, the matrix spike recovery for amenable cyanide is below the laboratory established control limit. All amenable cyanide results are flagged with an "M_2", indicating a possible low bias or a false negative.

The laboratory failed to analyze the private irrigation well for total organic carbon, total and amenable cyanide, explosives, and sulfide in the baseline sampling episode. However, with the exception of total organic carbon and sulfide, these parameters were not detected in any other groundwater samples, so the omission of these analyses is not of concern.

6.1.1.2.3 Contamination of Blank Samples - In addition, several chemicals were detected in the blank and rinsate samples. Methylene chloride, a common laboratory contaminant, was noted in the trip blanks of all media sampled, as well as in the method blanks for soil and groundwater samples. Affected samples are flagged with a "B" or "T", whichever is appropriate, indicating possible laboratory contamination or cross-contamination, respectively.

Several metals were also detected in the method blanks. Chromium and nickel were found in the method blanks associated with soil samples, and calcium and zinc were found in the method blanks associated with soil rinsate samples. Any samples associated with the method blanks of concern having positive detection of these metals less than five times the amount detected in the blank are flagged with the identifier "B_1" and estimated due to possible laboratory contamination.

Zinc, sodium, and methylene chloride were detected in the rinsate samples collected at the site. Zinc and sodium were detected in the rinsate sample associated with soils; sodium was not detected in the method blank and is qualified with an "R_2", indicating possible cross-contamination during sampling or inadequate decontamination of equipment. Zinc was found in the method blank associated with the rinsate samples; thus, the zinc values associated with the rinsate samples are not flagged as cross-contamination because its presence is most likely due to laboratory contamination. Rinsate samples for surface water contained sodium and methylene chloride. Because neither of these compounds were detected in the method blanks, the results are qualified with an "R_1" and "R_2" and are biased high due to possible cross-contamination during sampling or inadequate decontamination. The rinsate sample collected from sediment was found to contain methylene chloride and sodium. Neither of these compounds were detected in their associated method blanks; therefore, positive results cannot be attributed to laboratory contamination. Results are flagged with an "R_1" or "R_2" qualifier indicating a possible high bias due to cross-contamination or inadequate decontamination.

6.1.1.2.4 Summary of Data Evaluation - The quality of the data generated for this investigation is scientifically correct and legally defensible; USEPA-approved methods with known limits of precision and accuracy were used to evaluate the data. In general, the data quality was sufficient to determine the nature and extent of contamination at the site, for the purposes of potential remedial actions and controls. While some data required qualification based on quality control performance (e.g., the soil data), no data were discarded as unusable.

The QA objectives for measuring data are expressed in terms of precision, accuracy, completeness, representativeness, and comparability. Laboratory and field accuracy and precision goals were met for most of the analyses. Problems did occur in some surface water, soil, and sediment samples, as stated earlier, but the problems associated with soil and sediment samples are most likely due to the heterogeneous nature of the sample media. The presence of various constituents in the method blanks were accounted for during the analysis of the data. In general, the analytical completeness goal of 90 percent was accomplished, while the field completeness goal of 100 percent was lowered to 96 percent because one soil sample was not collected.

The samples collected from the SFL site are, for the most part, representative of the site. The rationale for sampling locations was provided in the approved Field Sampling Plan (Law, 1992b). Subsurface soil samples were not collected from depths between 1 and 14 feet. Because there are no data from these depths, exposure to these soils (for the utility worker scenario) was not quantified. This should not be of major concern, since the few utility lines that run through the area are located north of Well House Road, and therefore are not within the boundaries of the landfill.

If organic contamination exists in surface soils, the risks contributed by these constituents cannot be quantified because surface soils were only analyzed for metal constituents. However, this should not limit the risk assessment. The surficial soil data collected should be representative of the surface soil conditions, because this soil originated at a firing range and was moved to the SFL to be used in the cover. Metals, which were included in the analysis of surface soils, are the only constituents that would be expected in these soils.

Furthermore, the limited number of the surface soil samples reanalyzed by CLP methods should not limit the risk assessment because the samples chosen for reanalysis are those which appeared to have the highest level of contamination (using the XRF screening method). Therefore, the use of these seven samples in the risk assessment represents a conservative approach for determining risk as it introduces biased high soil data. The data is included since it is the only surface soil data available for the site.

Finally, the ten re-analyzed PRC surface soil samples, along with the subsurface soil, groundwater, sediment, and surface water samples generated Level 3 or Level 4 analytical data which allows for the comparison of the results to ARARs. The analytical data generated from the sampling of the six monitoring wells installed at SFL in 1984 were not able to be compared to data generated during the RI investigation, because the accepted procedure for purging the monitoring wells may not have been properly performed. In addition, these wells are screened at three distinct intervals within a single bore, and the wells were purged and sampled without isolating the appropriate water-bearing zone. The purged water was therefore produced by the most permeable screened zone, and any contamination may have been diluted by water from less contaminated zones.

The groundwater data from the irrigation well sampled during the RI investigation is also not directly comparable to data from the monitoring wells installed for the RI investigation because of the different screened interval depth and length and sampling methodology. The irrigation well is screened from 39 to 59 feet, which spans both intermediate and deep screened intervals in the monitoring wells. Samples were collected from a spigot at the well head after the turbine pump had been on for several minutes. Therefore, positive results from the irrigation well cannot be compared to the results collected from the more discreet sample intervals of the monitoring wells. In addition, the presence of glued joints in the irrigation well may affect the groundwater chemistry. However, this should not affect the risk assessment, since the private irrigation well was sampled in order to (qualitatively) identify any constituents that may reach the irrigated crops.

6.1.1.3 Summary of Contamination - The data used for the risk assessment are summarized in Tables 6-1 through 6-8. In these tables, the 95 percent upper confidence limit (UCL) on the arithmetic mean was calculated assuming that non-detect values were equal to one-half the MDL for a constituent. Also, in accordance with USEPA guidance, samples containing a blank-related

TABLE 6-1

CHEMICALS DETECTED IN GROUND WATER
Southwest Funston Landfill
Fort Riley, Kansas

		RESULTS BY (QUARTERLY) SAMPLING EPISODES:								RESULTS FOR ENTIRE DATA SET:				
		BASELINE (July 1992)		FIRST QUARTER (November 1992)		SECOND QUARTER (February 1993)		THIRD QUARTER (May 1993)						
Parameter	MDL (a)	Freq. (b)	Range (c)	Freq. (b)	Range (c)	Freq. (b)	Range (c)	Freq. (b)	Range (c)	Freq. (b)	Range (c)	Arithmetic Mean (d)	95% UCL (e)	Maximum Backgrnd. Conc. (f)
TOTAL METALS :														
Aluminum	0.11	8/14	0.11 - 0.21	1/14	0.25 - 0.35	1/14	0.17	2/14	0.1	12/56	0.11 - 0.35			0.46
*Antimony	0.023	0/14	BDL	1/14	0.031	2/14	0.022 - 0.023	0/14	BDL	4/56	0.022 - 0.031	0.012	0.012	BDL
*Arsenic	0.002	11/14	0.0026 - 0.023	11/14	0.0023 - 0.045	12/14	0.0021 - 0.019	13/14	0.0023 - 0.022	46/56	0.002 - 0.045	0.012	0.019	0.0093
*Barium	0.02	14/14	0.068 - 2.0	14/14	0.1 - 1.7	14/14	0.13 - 1.8	14/14	0.11 - 1.8	56/56	0.068 - 2.0	0.462	0.569	0.37
*Beryllium	0.001	12/14	0.001 - 0.0032	14/14	0.001 - 0.004	14/14	0.001 - 0.004	7/14	0.002 - 0.003	47/56	0.001 - 0.004	0.002	0.002	0.003
*Cadmium	0.005	0/14	BDL	1/14	0.005	0/14	BDL	2/14	0.004	3/56	0.004 - 0.005	0.003	0.003	BDL
Calcium	0.074	14/14	44 - 330	14/14	97 - 330	14/14	93 - 320	14/14	71 - 300	56/56	44 - 330			170
Chromium	0.006	0/14	BDL	0/14	BDL	4/14	0.01 - 0.015B1	1/14	0.009	5/56	0.009 - 0.015 B1			0.01 B1
Cobalt	0.01	1/14	0.01	0/14	BDL	7/14	0.008 - 0.012	0/14	BDL	8/56	0.008 - 0.012			0.01
Copper	0.005	0/14	BDL	0/14	BDL	2/14	0.004 - 0.015	3/14	0.008 - 0.009	5/56	0.004 - 0.015			0.004
Iron	0.045	14/14	0.23 - 35	14/14	0.063 - 28	14/14	0.055 - 32	13/14	1.3 - 36	55/56	0.055 - 36			1.8
Lead	0.005	0/14	BDL	0/14	BDL	0/14	BDL	0/14	BDL	0/56	BDL			0.0079
Magnesium	0.081	14/14	6.8 - 68	14/14	18 - 77	14/14	18 - 70	14/14	11 - 68	56/56	6.8 - 77			26
*Manganese	0.003	14/14	0.41 - 2.5	14/14	0.43 - 2.4	14/14	0.45 - 2.3	14/14	0.34 - 2.7	56/56	0.34 - 2.7	1.462	1.748	1
Nickel	0.009	0/14	BDL	3/14	0.020 0.029	8/14	0.013 - 0.021	1/14	0.28	12/56	0.013 - 0.28			BDL
Potassium	0.13	14/14	4.8 - 15	14/14	4.3 - 19	14/14	5.7 - 16	14/14	4.4 - 14	56/56	4.3 - 19			8.5
Selenium	0.001	6/14	0.001 - 0.0022	3/14	0.001M2 - 0.005M2	0/14	BDL	0/14	BDL	9/56	0.001 - 0.005 M2			0.0031
Silver	0.002	0/14	BDL	0/14	BDL	9/14	0.003 - 0.008	0/14	BDL	9/56	0.003 - 0.008			0.005
Sodium	0.21	14/14	28 - 140	14/14	29 - 140	14/14	30 - 130	14/14	28 - 140	56/56	28 - 140			26
*Thallium	0.022/0.001[g]	0/14	BDL	0/14	BDL	0/14	BDL	2/14	0.0017	2/56	0.0017 - 0.0017	0.006	0.0017	BDL
Vanadium	0.007	0/14	BDL	1/14	0.009	2/14	0.01 - 0.025	0/14	BDL	3/56	0.009 - 0.025			0.009
Zinc	0.004	0/14	0.0068JB - 0.02JB	10/14	0.004 - 0.013	12/14	0.004 - 0.013	0/14	BDL	22/56	0.004 - 0.013			0.031
VOLATILE ORGANICS:														
1,1-Dichloroethane	0.005	0/14	BDL	0/14	BDL	0/14	BDL	1/14	0.003	1/56	0.003			BDL
*1,2-Dichloroethane	0.005	0/14	BDL	1/14	0.016	0/14	BDL	0/14	BDL	1/56	0.016	0.0027	0.0028	BDL
*1,1,2,2-Tetrachloroethane	0.005	2/14	0.0063 - 0.015	0/14	BDL	0/14	BDL	0/14	BDL	2/56	0.0063 - 0.015	0.0029	0.003	BDL
*1,1,2-Trichloroethane	0.005	1/14	0.0088	0/14	BDL	0/14	BDL	0/14	BDL	1/56	0.0088 - 0.0088	0.0026	0.0027	BDL
1,2-Dichloropropane	0.003	2/14	0.0036 - 0.0041	0/14	BDL	0/14	BDL	0/14	BDL	2/56	0.0036 - 0.0041			BDL
2-Hexanone	0.01	2/14	0.018 - 0.022	0/14	BDL	0/14	BDL	0/14	BDL	2/56	0.018 - 0.022			BDL
*Benzene	0.002	2/14	0.0024 - 0.0089	2/14	0.0049 - 0.005	2/14	0.0015 - 0.0016	1/14	0.014	7/56	0.0015 - 0.014	0.0013	0.0014	BDL
Bromoform	0.005	2/14	0.0064 - 0.008	0/14	BDL	0/14	BDL	0/14	BDL	2/56	0.0064 - 0.008			BDL
Chlorodibromomethane	0.005	1/14	0.0052	0/14	BDL	0/14	BDL	0/14	BDL	1/56	0.0052 - 0.0052			BDL

TABLE 6-1

CHEMICALS DETECTED IN GROUND WATER
Southwest Funston Landfill
Fort Riley, Kansas

		RESULTS BY (QUARTERLY) SAMPLING EPISODES:								RESULTS FOR ENTIRE DATA SET:				
		BASELINE (July 1992)		FIRST QUARTER (November 1992)		SECOND QUARTER (February 1993)		THIRD QUARTER (May 1993)						
Parameter	MDL (a)	Freq. (b)	Range (c)	Freq. (b)	Range (c)	Freq. (b)	Range (c)	Freq. (b)	Range (c)	Freq. (b)	Range (c)	Arithmetic Mean (d)	95% UCL (e)	Maximum Backgrnd. Conc. (f)
VOLATILE ORGANICS (cont'd)														
Methyl Isobutyl Ketone	0.03	2/14	0.019 - 0.022	0/14	BDL	0/14	BDL	0/14	BDL	2/56	0.019 - 0.022			BDL
Methylene Chloride	0.005	7/14	0.0062JB - 0.026JB	13/14	0.0064B2 - 0.032B2	7/14	0.01 - 0.013	3/14	0.011T - 0.014	30/56	0.0063 JB - 0.032 B2			0.021JB
Styrene	0.003	1/14	0.0031	0/14	BDL	0/14	BDL	0/14	BDL	1/56	0.0031			BDL
Trichloroethene	0.003	0/14	BDL	0/14	BDL	0/14	BDL	1/14	0.0043	1/56	0.0043			BDL
Trichlorofluoromethane	0.005	0/14	BDL	0/14	BDL	0/14	BDL	1/14	0.0021	1/56	0.0021			BDL
*Vinyl Chloride	0.01	1/14	0.018	0/14	BDL	0/14	BDL	0/14	BDL	1/56	0.018	0.0052	0.0054	BDL
Total Xylenes	0.005	1/14	0.0063 -	0/14	BDL	0/14	BDL	0/14	BDL	1/56	0.0063			BDL
*cis-1,3-Dichloropropene	0.003	2/14	0.0054 - 0.0059	0/14	BDL	0/14	BDL	0/14	BDL	2/56	0.0054 - 0.0059	0.0016	0.0017	BDL
TRPH[h]	0.5	0/14	BDL	3/14	0.002E - 0.014E	0/14	BDL	1/14	0.00074	4/56	0.00074 - 0.014E			BDL

Notes: Table does not include results from private irrigation well (see Table 6-2).
All concentrations are in mg/L (ppm).
* Indicates consituents of potential concern based on the toxicity screen of the entire date set.
(a) Method Detection Limit
(b) Number of samples in which chemical was positively detected divided by the number of samples available.
(c) For metals, the range does not include the concentration of chemicals detected in the background sample.
(d) The mean is calculated by assuming that non-detect values are equal to one-half the method detection limit, and accounts for all sampling episodes.
(e) 95% Upper Confidence Limit. The 95% Upper Confidence Limit is calculated using statistical procedures appropriate for characterizing lognormal populations (Gilbert, 1987). The UCL may be "artificially" high because of small sample size and the large standard deviation of the data set.
(f) Maximum Background Concentration. Comparison to background concentrations are applicable for inorganic constituents only. The presence of organic constituents in the background samples indicates these samples may have been collected in an area influenced by site contamination.
(g) The MDL for Thallium was 0.022 mg/L in the baseline and the first quarter sampling episodes, and was 0.001 mg/L in the second and third sampling episodes.
(h) Total Recoverable Petroleum Hydrocarbons
BDL Samples all below the detection limit.
B1 Sample concentration is estimated; concentration less than five times the method blank.
B2 Sample concentration is estimated; concentration less than ten times the method blank.
JB Sample concentration is estimated; constituent associated with blanks.
JE Sample concentration is estimated due to poor presision.
M2 Sample concentration is biased low due to low matrix spike recovery caused by the sample matrix effect.
T Sample concentration is estimated; concentration less than ten times the method blank.
E Estimated result

TABLE 6–2

CHEMICALS DETECTED IN PRIVATE IRRIGATION WELL
Southwest Funston Landfill
Fort Riley, Kansas

Parameter	Method Detection Limit	Maximum Background Concentration	Sample Concentration
TOTAL METALS:			
Aluminum	0.11	0.46	BDL
Arsenic	0.002	0.0071	0.0083
Barium	0.02	0.35	0.16
Beryllium	0.001	0.0018	0.0014
Calcium	0.074	160	67
Iron	0.045	1.7	2.3
Magnesium	0.081	26	9.8
Manganese	0.003	1	0.61
Potassium	0.13	8	6.5
Selenium	0.001	0.0021	0.0011
Sodium	0.21	21	140
Zinc	0.004	0.018JB	0.013JB
WET CHEMICAL INORGANICS:			
Bicarbonate	1	576	362
Chloride	0.2	12.8	38.2
Nitrate	0.2	4.4	12.5
Sulfate	0.2	69.1	93.4

All concentrations are in mg/L (ppm).

* Indicates constituents of potential concern.

JB Sample concentration is estimated; constituent associated with blanks.

BDL Below detection limit.

TABLE 6-3

CHEMICALS DETECTED IN SOIL BORINGS
Southwest Funston Landfill
Fort Riley, Kansas

Parameter	Frequency of Detection (a)	Method Detection Limit (b)	Range of Detected Concentrations (c)	Maximum Background Concentration
TOTAL METALS:				
Aluminum	20/20	11-14	370 - 21000	9200
Arsenic	18/20	0.3-0.8	0.5 - 7.2	3.4
Barium	20/20	3.3-7.8	17 - 760	200
Beryllium	10/20	0.2-0.4	0.2 - 2.3	0.5
Cadmium	1/20	0.6-1.1	0.6	BDL
Calcium	20/20	32-36	2100 - 170000	8800
Chromium	13/20	1.6-2	1.9 - 20	11
Cobalt	9/20	1.4-1.8	1.6 - 7.8	9.2
Copper	16/20	0.5-0.9	0.8 - 13	8.6
Iron	20/20	2.8-3.6	1300 - 21000	12000
Lead	20/20	0.2-0.8	1 - 16	13
Magnesium	20/20	27-34	200 - 5100	3000
Manganese	20/20	0.5-0.6	15 - 740	110
Nickel	10/20	2.8-3.2	4 - 30	14
Potassium	20/20	33-42	130 - 3800	2000
Selenium	2/20	0.2	0.2	BDL
Silver	2/20	0.6-0.8	1.3 - 1.5	BDL
Sodium	18/20	33-41	66 - 700	170
Thallium	2/20	12-15	17 - 21	15
Vanadium	20/20	0.8-1.2	3 - 41	21
Zinc	20/20	0.5-0.7	3.5 - 73	39
VOLATILE ORGANICS:				
Acetone	1/20	0.11-0.13	0.035	BDL
Carbon Disulfide	1/20	0.0032-0.0042	0.0042	BDL
Methyl Chloride	1/20	0.011-0.015	0.041	BDL
Methylene Chloride	1/20	0.0054-0.011	0.012	0.065J
PESTICIDES/PCBS:				
4,4'-DDE	1/20	0.0075-0.0076	0.055	BDL
Aroclor 1248	1/20	0.075-0.092	0.25 J	BDL
SEMIVOLATILE ORGANICS:				
Bis(2-ethylhexyl)phthalate	7/20	0.37-0.48	0.037 - 9.7 J	0.43
Butyl Benzyl Phthalate	1/20	0.37-0.48	1.0	BDL
ORGANICS:				
TRPH	16/20	10	10 - 470	78

All concentrations are in mg/kg (ppm).

(a) Number of samples in which chemical was positively detected divided by the number of samples available.

(b) The method detection limit of soil samples may vary with the moisture content of the sample.

(c) The range does not include the concentration of chemicals detected in the background sample.

BDL Samples are Below the Detection Limit.

J Estimated result.

TABLE 6–4

CHEMICALS DETECTED IN SURFACE WATER – KANSAS RIVER, SMOKY HILL RIVER, AND REPUBLICAN RIVER

Southwest Funston Landfill
Fort Riley, Kansas

Parameter	Frequency of Detection (a)	Method Detection Limit	Range of Detected Concentrations (b)	Maximum Site Background Concentration	Maximum Upstream Background Concentration
TOTAL METALS:					
Aluminum	4/4	0.11	0.89 – 1.4	0.62	11.47
Arsenic	4/4	0.002	0.0043JL – 0.0046JL	0.0035JL	0.023
Barium	4/4	0.02	0.160 – 0.170	0.220	ND
Calcium	4/4	0.074	78 – 88	74	ND
Iron	4/4	0.045	1.2 – 1.6	0.66	ND
Magnesium	4/4	0.081	25 – 28	22	ND
Manganese	4/4	0.003	0.28 – 0.35	0.12	1.217
Potassium	4/4	0.13	11	11	ND
Selenium	2/4	0.001	0.0011	0.0015	ND
Sodium	4/4	0.21	210 – 280	120	ND
Vanadium	1/4	0.007	0.0071	BDL	ND
Zinc	4/4	0.004	0.022 – 0.026	0.027	ND
VOLATILE ORGANICS:					
Methylene Chloride	1/4	0.005	0.012	0.016JB	ND

All concentrations are in mg/L (ppm).

BDL	Samples are Below the Detection Limit.
JL	Sample concentration is estimated due to poor precision; bias is low.
JB	Sample concentration is estimated; constituent associated with blanks.
ND	No Data
(a)	Number of samples in which chemical was positively detected divided by the number of samples available.
(b)	The range does not include the concentration of chemicals detected in the background sample.

TABLE 6-5

CHEMICALS DETECTED IN SURFACE WATER – THREEMILE CREEK
Southwest Funston Landfill
Fort Riley, Kansas

Parameter	Method Detection Limit	Maximum Background Concentration	Sample Concentration
TOTAL METALS:			
Aluminum	0.11	1.3	1.1
*Arsenic	0.002	0.0025J	0.0044J
*Barium	0.02	0.16	0.17
Calcium	0.074	94	97
Iron	0.045	0.97	1.2
Magnesium	0.081	23	23
*Manganese	0.003	0.092	0.15
Potassium	0.13	12	9.7
Sodium	0.21	65	60
Zinc	0.004	0.035	0.026J

All concentrations are in mg/L (ppm).
* Indicates constituents of potential concern.
J Sample concentration is estimated.

TABLE 6-6

CHEMICALS DETECTED IN SEDIMENTS – KANSAS RIVER, SMOKY HILL RIVER, AND REPUBLICAN RIVER

Southwest Funston Landfill
Fort Riley, Kansas

Parameter	Frequency of Detection (a)	Method Detection Limit (b)	Range of Detected Concentrations (c)	Maximum Site Background Concentration	Maximum Upstream Background Concentration
TOTAL METALS:					
Aluminum	4/4	5.6-20	450 - 1900	440	ND
Arsenic	4/4	0.3-0.4	0.8 - 1.2	0.7	ND
Barium	4/4	3.3-3.6	20 - 61	37	ND
Beryllium	0/4	0.2	NA	0.3	ND
Calcium	4/4	12-13	2800 - 10000	35000	ND
Chromium	2/4	1.6-1.8	2.2 - 2.3	BDL	7
Cobalt	2/4	1.6-1.8	1.9 - 2.7	2.2	ND
Copper	1/4	0.8-0.9	1.3	BDL	1.3
Iron	4/4	3.3-8.1	1700 - 3700	2600	17000
Lead	4/4	0.2	1.5 - 2.1	1.1	14.3
Magnesium	4/4	13-14	200 - 710	460	ND
Manganese	4/4	0.5	34JL - 130JL	92JL	200
Potassium	4/4	21-23	160 - 470	150	ND
Sodium	4/4	34-37	41 - 120	59	ND
Vanadium	4/4	1.2-1.3	3.1 - 7.6	10	ND
Zinc	4/4	0.7	4.7 - 10	5.5	143
VOLATILE ORGANICS:					
Methylene Chloride	4/4	0.0057-0.006	0.013 - 0.02JB	0.019JB	ND

All concentrations are in mg/kg (ppm).

JL Sample concentration is estimated due to poor precision and is biased low.
JB Sample concentration is estimated; constituent associated with blanks.
NA Not Applicable.
ND No Data
BDL Below Detection Limit
(a) Number of samples in which chemical was positively detected divided by the number of samples available.
(b) The method detection limit of sediment samples may vary with the moisture content of the sample.
(c) The range does not include the concentration of chemicals detected in the background sample.

TABLE 6-7

CHEMICALS DETECTED IN SEDIMENTS – THREEMILE CREEK

Southwest Funston Landfill
Fort Riley, Kansas

Parameter	Method Detection Limit (a)	Maximum Background Concentration	Sample Concentration
TOTAL METALS:			
Aluminum	5.6–20	13000	8200
•Arsenic	0.3–0.4	1.9	2.1
Barium	3.3–3.6	190	150
Beryllium	0.2	0.5	0.2
Cadmium	0.8–1	1.7	1.6
Calcium	12–13	31000	17000
Chromium	1.6–1.8	14	9.8
Cobalt	1.6–1.8	9	6.2
Copper	0.8–0.9	10	6.2
Iron	3.3–8.1	13000	9900
•Lead	0.2	1.7	5.9
Magnesium	13–14	4400	2900
Manganese	0.5	310JL	200JL
Nickel	3–3.6	15	10
Potassium	21–23	2600	1900
Sodium	34–37	200	200JR
Vanadium	1.2–1.3	22	22
Zinc	0.7	48	30

All concentrations are in mg/kg (ppm).
• Indicates constituents of potential concern.
(a) The method detection limit of sediment samples varies with the moisture content of the sample.
JR Sample concentration is estimated; constituent is associated with rinsate.
JL Sample concentration is estimated due to poor precision; bias is low.

TABLE 6–8

CHEMICALS DETECTED IN SURFACE SOILS
Southwest Funston Landfill
Fort Riley, Kansas

Parameter	Frequency of Detection (a)	Method Detection Limit	Range of Detected Concentrations (b)	Maximum Background Concentration
TOTAL METALS :				
Aluminum	7/7	NR	3200 – 5900	6300
•Antimony	2/7	2.5	5.1 – 5.8	BDL
•Arsenic	7/7	4.6	1.5 – 3.1	2.5
•Barium	7/7	NR	60 – 170	110
•Beryllium	7/7	NR	0.29 – 0.67	0.57
•Cadmium	4/7	0.45	0.53 – 2.1	0.76
Calcium	7/7	NR	8300 – 37000	16000
•Chromium	7/7	NR	5.5 – 16	7.8
•Copper	3/7	3.9	12 – 110	8
Iron	7/7	NR	4800 – 11000	7800
•Lead	7/7	NR	10 – 160	23J
Magnesium	7/7	NR	1200 – 2100	2900
•Manganese	7/7	NR	88 – 220	200
•Mercury	1/7	0.11	1.8	BDL
Nickel	6/7	3.6	4.7 – 8.4	10
Potassium	7/7	NR	810 – 1800	1800
Selenium	1/7	0.45	0.55 J	0.94J
•Silver	1/7	0.68	3.2	BDL
Sodium	7/7	NR	64 – 160	75
•Thallium	1/7	0.23	0.26	BDL
•Vanadium	7/7	NR	11 – 18	17
•Zinc	7/7	NR	27J – 250J	56J

Note: All concentrations are in mg/kg (ppm).

• Indicates consituents of potential concern.

J	Sample concentration is estimated.
NR	Detection limit not reported.
BDL	Below detection limit.
(a)	Number of samples in which the chemical was positively detected divided by the number of samples available.
(b)	The range does not include the concentration of chemicals detected in the background sample

chemical that is not a common laboratory contaminant in concentrations less than five times the amount detected in any blank were treated as non-detects (USEPA, 1989a). In this case, one-half the blank-related concentration was used as the proxy concentration.

The method used to calculate the 95 percent UCL is based on the assumption that the sample population has an approximate lognormal distribution, which is the most commonly used distribution for environmental contaminant data (Gilbert, 1987). A W-test (Gilbert, 1987) was conducted on a representative chemical from both the groundwater sample data and the soil sample data to determine if the data sets were consistent with a normal or lognormal distribution. The W-test failed to determine the distribution of the groundwater or soil sample data (i.e., the data did not seem to fit either distribution). Because neither set of data fit the normal or lognormal distribution, a lognormal distribution was assumed. Although USEPA Region VII does not have an explicit policy, this approach is consistent with current USEPA guidance in other regions (i.e., Region IV). In addition, according to USEPA guidance (USEPA, 1992d), most "complete" environmental data sets from (soil) sampling are lognormally distributed rather than normally distributed. Therefore, in most cases, it is reasonable to assume that Superfund sampling data are lognormally distributed (USEPA, 1992d). The equation used to calculate the 95 percent UCL is shown below:

$$UCL_{0.95} = \exp\left(\bar{y} + 0.5\, S_y^2 + \frac{S_y H_{0.95}}{\sqrt{n-1}}\right)$$

where:

n = sample size
$\bar{y}$ = arithmetic mean of the n transformed values of samples
S_y^2 = standard error of the mean
$H_{0.95}$ = value obtained from tables provided by Land (1975) for computing a one-sided 95 percent UCL on a lognormal mean

The 95 percent UCL calculations for constituents detected in site media are included in Appendix M. It should be noted that the 95 percent UCL values generated for some of the constituents may be higher than the maximum detected concentration in site samples. In these cases, the UCL values may be "artificially" elevated due to small sample size and/or large standard deviation of the samples in a given medium. When the 95 percent UCL value exceeds the maximum concentration detected, the maximum concentration is used in the risk characterization, per USEPA guidance (USEPA, 1992d).

Table 6-1 summarizes the analytical results for the groundwater samples collected during the four groundwater sampling events. A total of 18 volatile organic compounds, and 22 metals were detected in the samples collected from the monitoring wells installed on site.

The groundwater results collected from the private irrigation well adjacent to the landfill are presented in Table 6-2. A total of 12 metals and four wet chemical inorganic compounds were detected in the samples.

The results of the subsurface soil samples collected from the monitoring well boreholes are presented in Table 6-3. One pesticide, one PCB, four volatile organic compounds, two semi-volatile organic compounds, and 21 metals were detected in these samples. The TRPH results in soil boring samples are also presented in this table.

Table 6-4 summarizes the surface water results collected from the Kansas River located adjacent to the southern boundary of the SFL. A total of 12 metals, and one volatile organic compound were detected in the surface water samples. The surface water results for the sample collected from Threemile Creek are presented in Table 6-5. A total of 10 metals were detected.

The Kansas River sediment results are presented in Table 6-6. The sediment samples were collected in the same locations as the corresponding surface water samples. A total of one volatile organic compound and 16 metals were detected in these samples. Table 6-7 presents the results for sediments collected from Threemile Creek. Eighteen metals were detected in the sediment samples.

Surface soils were collected and analyzed on site by PRC in July 1992. A total of 114 sampling locations were selected using a randomly based grid. These soil samples were analyzed for lead, copper, and zinc by XRF. These results are field screening results, and as such are considered EPA Level 2 data (USEPA, 1987a). Because these results are only semi-quantitative in nature, ten soil samples were reanalyzed for confirmation of results using EPA Level 4 techniques. Of these ten, eight samples were located on the SFL site; one of the eight usable samples is a duplicate. For purposes of this risk assessment, these seven surface soil samples collected on site were used to estimate the metals concentrations in the landfill cap. The Level 4 analytical results for selected surface soil samples are presented in Table 6-8. A total of 22 metals were detected in these samples.

Air samples were not collected at the site. However, air exposures will be addressed in the risk assessment by using soil concentrations to estimate exposure point concentrations based on fugitive dust models (see Section 6.1.2.6).

6.1.1.4 Chemicals of Potential Concern - The chemicals of potential concern identified in the soil, surface water, groundwater, and sediments sampled at the site are identified in this section and Table 6-9. These chemicals were selected for evaluation in the baseline risk assessment based on the following criteria, in accordance with federal guidance (USEPA, 1989a):

- Comparison of chemical concentrations with naturally occurring levels

TABLE 6-9

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN
Southwest Funston Landfill
Fort Riley, Kansas

	Concentration				
Chemical	Groundwater	Soil Borings	Sediments ••	Surface Water ••	Surface Soils
Aluminum	0.11 - 0.35•	370 - 21000•	8200•	1.3•	3200 - 5900•
Antimony	0.022 - 0.031	BDL	BDL	BDL	5.1 - 5.8
Arsenic	0.002 - 0.045	0.5 - 7.2•	2.1	0.0044	1.5 - 3.1
Barium	0.068 - 2.0	17 - 760•	150•	0.17	60 - 170
Benzene	0.0015 - 0.014	BDL	BDL	BDL	BDL
Beryllium	0.001 - 0.004	0.2 - 2.3•	0.2•	BDL	0.29 - 0.67
Cadmium	0.004 - 0.005	<0.06 - 0.06•	1.6•	BDL	0.53 - 2.1
Cobalt	0.008 - 0.012•	1.6 - 7.8•	6.2•	BDL	BDL
Copper	0.004 - 0.015•	0.8 - 13•	6.2•	BDL	12 - 110
1,2-Dichloroethane	0.016 - 0.016	BDL	BDL	BDL	BDL
cis-1,3-Dichloropropene	0.0054 - 0.0059	BDL	BDL	BDL	BDL
Lead	BDL	0.9 - 16•	5.9•	BDL	10 - 160
Manganese	0.34 - 2.70	9.2 - 740•	200JL•	0.15	88 - 220
Mercury	BDL	BDL	BDL	BDL	<0.11 - 1.8
Methylene Chloride	0.0062 JB - 0.032 B2•	0.0079 JB• - 0.078 JB•	0.016JB•	0.011JB•	NA
Silver	0.003 - 0.008•	1.3 - 1.5•	BDL	BDL	<0.68 - 3.2
1,1,2,2-Tetrachloroethane	0.0063 - 0.015	BDL	BDL	BDL	BDL
Thallium	0.0017 - 0.0017	17 - 21•	BDL	BDL	<0.23 - 0.26
1,1,2-Trichloroethane	0.0088 - 0.0088	BDL	BDL	BDL	BDL
TRPH	BDL	10 - 470•	BDL	BDL	BDL
Vanadium	0.009 - 0.025	1.7 - 41•	22•	BDL	11 - 18
Vinyl Chloride	0.018 - 0.018•	BDL	BDL	BDL	BDL
Zinc	0.004JB - 0.013•	3.5 - 73•	30•	0.035•	27J - 250J

Note: All concentrations are in ppm (mg/kg or mg/L).

BDL	Below Detection Limit. Not selected as a chemical of potential concern for this media.
NA	Not analyzed.
JL	Sample concentration is estimated due to poor precision and is biased low.
JR	Sample concentration is estimated; constituent is associated with rinsate.
JBR	Sample concentration is estimated; constituent is associated with rinsate and blanks.
JB	Sample concentration is estimated; constituent associated with blanks.
JE	Sample concentration is estimated due to poor precision.
M2	Sample concentration is biased low due to matrix spike recovery caused by the matrix spike effect.
B1	Sample results are less than five times the amount detected in the blank - Result is estimated.
B2	Sample results are less than ten times the amount detected in the blank - Result is estimated.
J	Sample concentration is estimated.
•	Not selected as a chemical of concern in this medium.
••	The value is from the sample collected from Threemile Creek.

- Evaluation of measured concentrations and frequency of detection at the site
- Evaluation of essential nutrients
- Comparison of chemical concentrations with levels detected in associated blank samples
- Evaluation of data qualifiers
- Evaluation of toxicity and use of a concentration-toxicity screen
- Physical and chemical characteristics related to environmental mobility and persistence

A comparison of sample concentrations with background concentrations was made to identify the non-site-related chemicals found at or near the site, in accordance with guidance (USEPA, 1989a). Metals with maximum detected concentrations less than the maximum detected background concentration in a given medium were eliminated from consideration as chemicals of concern in accordance with USEPA Region VII policy (1992e). A discussion of the comparison of site surface water, sediment and groundwater samples to background is given in Sections 6.1.4.4.3 to 6.1.4.4.5.

Constituents detected in groundwater and surface soil were screened for potential toxicity by comparing the maximum detected concentrations in each medium to available reference doses or slope factors (IRIS, 1993) according to the concentration-toxicity screen described in guidance (USEPA, 1989a). Constituents detected in groundwater samples were eliminated as potential chemicals of concern if they failed to pass the concentration-toxicity screen. This screening procedure is used to reduce the number of chemicals considered for inclusion in the risk assessment as potential chemicals of concern. If the "risk ratio" for a chemical did not exceed one percent of the total screening risk for that media, the chemical was not considered a constituent of concern for that media. Chemicals without toxicity values were not eliminated from the risk assessment, per USEPA guidance (USEPA, 1989a). Concentration-toxicity screening tables are included in Appendix M. Chemicals selected for evaluation of human health exposure and risk, according to medium, are presented in Table 6-9.

Constituents were eliminated as constituents of concern unless the constituent scored above one percent in the toxicity screen. Constituents which can be considered essential nutrients (such as, iron, magnesium, calcium, potassium, and sodium) are evaluated qualitatively in Section 6.1.4.5, and therefore are not identified as potential chemicals of concern in the quantitative portion of the risk assessment.

Several chemicals were detected in the blank samples. Methylene chloride, a common laboratory contaminant, was detected in the trip blanks of all media sampled and in the method blanks for soil and groundwater samples. Metals were also detected in method blanks and in the rinsate samples. Sodium was detected in the rinsate blanks for sediment and surface water samples, and zinc and sodium were detected in the soil sample method blanks.

To compile the data set to be used in the risk assessment, the concentrations of the constituents detected in the blank samples were compared to their concentrations in the site samples. A constituent recognized as a common laboratory contaminant was assumed to be present if its concentration in the environmental sample was ten times greater than its concentration in the blank sample. For those constituents not classified as common laboratory contaminants, a sample concentration five times that of the blank concentration was considered to be evidence of that constituent's presence in a sample. On the basis of this evaluation of the data, methylene chloride was deleted from the risk assessment data set for soils and sediment because it was present in the blanks, and its sample concentrations did not exceed the blank concentrations by the required margin. Some groundwater samples and a surface water sample collected contained methylene chloride that was not associated with blanks, and thus, could not be eliminated due to blank contamination. Although zinc was present in blanks and rinsates, its blank-associated samples exceeded the required margin; thus, zinc was not deleted from the risk assessment data set.

6.1.2 Exposure Assessment

The objectives of the exposure assessment are to:

- Characterize the exposure setting
- Characterize potentially exposed populations
- Identify the potential exposure pathways
- Identify exposure points and routes
- Quantify the potential exposure to site-related contaminants expected to occur.

6.1.2.1 Characterization of Exposure Setting - The physical characteristics of the site which may impact potential exposures include climate, vegetation, soil type, and hydrology. The soils of Riley and Geary counties are described in Section 3.5 of this report. Surface water hydrology is discussed in Section 3.3, geology in 3.4, and hydrogeology of the region in 3.6. The two remaining physical characteristics, climate and ecology, are summarized in Sections 3.1 and 3.8, respectively.

6.1.2.2 Potentially Exposed Populations - The SFL is located in the southern portion of Fort Riley, adjacent to the southwest corner of the Camp Funston cantonment area. The southernmost boundary of the landfill extends down to the north bank of the Kansas River, south of Huebner Road, east to an old channel of the Kansas River and resides entirely in the flood plain alluvium.

6.1.2.2.1 Site and Site Vicinity - The landfill, covering approximately 120 acres, is presently grass covered and displays little relief compared to the surrounding land surface. The landfill may have up to 2 feet (0.66 meter) of soil cover which is moderately permeable and readily flooded. The soil cover at the SFL is comprised mostly of soil obtained from the target berms at the rifle range just north of the site (DEH, 1992a). The soil potentially contains bullet fragments and heavy metals contamination.

Access to the SFL area is restricted by a locking gate on Well House Road, a short distance south of Huebner Road (see Figure 1-2) but pedestrian entry to the site may be gained by walking around the gate. The off-site area north of Well House Road was previously designated for training. However, according to the Realty Specialist from Fort Riley's Real Property Planning Department, the area north of Well House Road has not been used for training purposes since the early 1970s (Fort Riley, 1993c). Hunting was previously allowed in the area of the landfill, but has been restricted on site since 1991. The area north of Well House Road was reopened for hunting in late autumn 1992 according to the Chief of Fort Riley's Fish and Wildlife Department (Fort Riley, 1993d). This area is not within the boundaries of the landfill. However, animals that feet, nest or breed on the SFL may move north of the SFL where they may be legally hunted. In addition, animals may drink or feed in Threemile Creek and bioaccummulate contaminants through ingestion of contaminated water, plant, or animal material. The northern boundary of the SFL, based on soil gas and geophysical surveys, parallels the Well House Road and is approximately 400 feet south of the road.

The human populations potentially exposed to the chemicals of potential concern at the SFL are those persons who may come in contact with the soils, sediment, or surface water on or adjacent to the site, and those persons who may come into contact with groundwater or biota originating from the site. Due to the partial loss of soil cover material on some areas of the landfill as a result of surface erosion, burrowing and settlement, there is the potential for humans to be exposed to the landfill wastes at these locations. Due to the location and nature of the site, the most likely current human receptors for exposure to constituents detected in site surface soils are trespassing hunters using the site or hunters who catch animals that may have come in contact with the site contaminants. Regular landscaping does not occur on site, therefore, essentially no current human receptors exist who may come into repeated contact with chemicals of potential concern. Hunting is allowed in the area north of the SFL, across Well House Road; however, this area is not within the boundaries of the SFL. As stated earlier, access to the site is controlled by a locked gate on Well House Road, but pedestrian entry to the site may be gained by walking around the gate, as the site road is not fenced. However, limited access, military police patrols, high visibility of available parking, and posted signs, as well as the presence of overgrown vegetation and biological hazards such as biting and stinging insects (mosquitoes and ticks), most likely deter the more casual hunter or recreational user from spending a great deal of time on site.

The primary source of drinking water for Fort Riley, Junction City, the Riley County Rural Water District, and the towns of Keats and Ogden is the alluvial aquifer of the Republican and

Kansas rivers. Junction City and Fort Riley's water supply wells are within the Republican River floodplain, about 5 miles upstream from the SFL. Ogden's water supply wells are located within the Kansas River floodplain, approximately 2.6 miles downstream of the site. Currently, the groundwater beneath the site is not used as a potable water supply. Therefore, it is unlikely that the low levels of contamination detected in the groundwater beneath the site would have an impact on current human populations. However, because the state of Kansas considers the aquifer at the site a potential drinking water source, its future use as a drinking water aquifer will be evaluated in this assessment.

6.1.2.2.2 Current Land Use - The SFL is currently not used, except as a hunting area by trespassing hunters. The area north of Well House Road was reopened for hunting uses in November or December 1992 (Fort Riley, 1993d). However, as indicated by the geophysical and soil gas surveys performed at the site, this area is outside the presumed boundaries of the landfill, except for several small, isolated areas of magnetic anomalies.

6.1.2.2.3 Potential Alternate Future Land Uses - In developing future-use scenarios, it is assumed that no remedial actions will be undertaken. Such "no-action" scenarios also provide a baseline for the comparison of remedial alternatives in the Feasibility Study. According to interviews with Fort Riley personnel (IRP Manager, 1992), the future use of the SFL and the surrounding area is unlikely to change as long as Fort Riley remains an active military installation. However, grounds keeping may occur in the future and this exposure scenario will be incorporated. Future-use scenarios assume that future development of the site will be restricted from residential development. This is consistent with Fort Riley's Master Planning documents (Fort Riley, 1993b). Fort Riley is not currently placed or being considered for placement on the military installation closure lists. In accordance with USEPA guidance, a future residential scenario should be considered for all Superfund sites unless residential development can reasonably be ruled out (USEPA, 1991b). Residential development of the site at some future date is unlikely, because the entire area of the SFL is within the floodplain of the Kansas River. In addition, zoning laws prohibit construction on a 100-year floodplain (Fort Riley, 1993b). Therefore, a future residential scenario will not be developed for the site, although the groundwater beneath the SFL will be evaluated based on residential uses because the state of Kansas considers the aquifer beneath the site to be a potential potable water source. EPA Region VII's definition of the Reasonable Maximum Exposure (RME) for groundwater is the "hottest" well at the site. In order to obtain this data, risk calculations were performed for each well cluster enabling the most conservative approach to be taken. These data are presented in Appendix M and Section 6.1.4.3.

Current and future occupational exposures to soil, surface water, and sediments, and future residential exposures to groundwater will be calculated using 95 percent of the upper confidence level (UCL) on the arithmetic mean of the concentrations detected in site media samples, unless otherwise noted.

6.1.2.2.4 Subpopulations of Potential Concern - Sensitive subpopulations are present within a 3-mile radius of the SFL. Children, the elderly, and women of child-bearing age living nearby are considered sensitive subpopulations. Children will be evaluated as a sensitive subpopulation for the current and future Kansas River sediment/surface water recreational scenario and for the future residential pathways considered in the risk assessment.

6.1.2.3 Identification of Exposure Pathways - A complete exposure pathway has four essential components. USEPA guidance defines an exposure pathway as consisting of the following elements (USEPA, 1989a):

1. A source and mechanism of chemical release to the environment (that is a source of contamination)
2. An environmental transport medium for the released chemical (for example, groundwater or air)
3. A point of potential human or biota contact with the contaminated medium (that is an exposure point)
4. A route of exposure at the exposure point (for example, ingestion, inhalation, or dermal contact)

Without the presence of all four components, exposure cannot occur. The source of release, transport mechanisms, exposed populations, and routes and pathways of exposure to chemicals disposed of at the SFL site will be described in the following section.

The potential exists for the constituents in the groundwater, surface water, soil, and sediments to reach human target populations through several exposure routes. Potential exposure routes and potentially exposed human populations will be identified, and potential exposure intakes for each exposure scenario will be calculated. Risk due to carcinogenic and noncarcinogenic compounds at the site will be characterized in Section 6.1.4.

6.1.2.3.1 Sources and Receiving Media - The possible sources of contamination in the SFL were discussed previously in Section 4.1. These sources include wastes generated and disposed on post (domestic refuse) and sludge from wastewater treatment facilities and various other waste generators as mentioned in Section 4.1. The area north of Well House Road which was identified as possibly containing subsurface metallic debris and the former Fire Training Area northeast of the site are also potential sources. Finally, the farmland area west of the SFL and the Camp Funston area east of the SFL may also contribute to contamination in the area, though the latter's contribution is considered nominal to nonexistent based on Threemile Creek acting as a recharge and/or discharge source to the shallow aquifer system.

Five potential contaminant transport media have been identified:

- Surface water
- Sediment
- Groundwater
- Air
- Surface soil

Contaminants in the groundwater and surface water may be transported to a potential exposure point. Several VOCs were present in low concentrations in the groundwater, but were not detected in surface water. Low levels of VOCs detected in the groundwater are expected to quickly volatilize once discharged to surface water. Therefore, outdoor air exposures to volatile compounds related to surface water activities are expected to be insignificant, or are not expected to occur through everyday exposures, unless VOC concentrations in the groundwater increase.

At present, the contaminants detected in the groundwater are unlikely to contact current human receptors, but contact with constituents may occur in the future if the site is developed for residential drinking water wells. Additionally, if VOC concentrations increase in site groundwater in the future, it is possible that VOCs may "survive" transfer to the surface water of the Kansas River. However, VOC contamination in surface water is not expected to be significant because the volatile compounds detected in site media would either volatilize or become diluted once discharged to surface water.

Contaminants in the soil may be transported as dust which can be carried through the air to a potential receptor, or tracked off-site by heavy equipment, trespassers, or migratory wildlife. Contaminated sediment may be carried by surface water to a potential receptor or, together with surface water, may come into contact with a receptor directly, such as a utility worker.

6.1.2.3.2 Fate and Transport in Release Media - Physical and chemical information concerning the transport and fate of contaminants is used to identify the possible extent and magnitude of environmental contamination. The fate and transport of constituents detected in site media are discussed in Chapter 5.0 of this report.

The primary environmental transport pathways for chemicals at the SFL are through rainwater infiltration and groundwater movement. One of the primary transport pathways is via infiltration of rainwater through underlying waste and soils which may contribute to groundwater contamination. Groundwater movement toward the river, and any episodic, high river-stage event that temporarily reverses groundwater flow away from the river is the other primary transport pathways for chemicals. Surface water runoff across the landfill cover soils and the sorption of contaminants to soil particles which may result in the dispersion of contaminated airborne particulates are minor transport pathways.

6.1.2.4 Exposure Points and Exposure Routes - In this risk assessment, exposure pathways are divided according to current-use and future-use scenarios. Under the current-use scenario, exposures and risks to which on-site trespassing hunters and utility workers are or could be subject to under continued normal site use are assessed. In developing future-use scenarios, it is assumed that no remedial action will be taken, and that future residential development at the site will be restricted. Alternative development of the site is not likely, and future residential development at the site is precluded due to the presence of the floodplain. However, grounds keeping is a likely occurrence in the future.

A potential exists for constituents in the soil, sediments, surface water, and groundwater at the SFL to reach human target populations through several exposure routes. The routes of exposure which are of primary concern at this site are as follows:

- Incidental ingestion (by hand-to-mouth contact) of potentially contaminated on-site soils; inhalation of fugitive dusts from and dermal contact with the contaminated on-site soils by hunters using the SFL and (future) grounds keepers
- Ingestion, dermal exposure, and inhalation of VOCs from potentially contaminated drinking water drawn from (future) residential groundwater wells screened in the upper water bearing zone
- Dermal exposure to contaminated surface water during utility work on lines adjacent to Threemile Creek
- Dermal contact with and incidental ingestion of contaminated sediments during utility work on utility lines near Threemile Creek
- Ingestion of potentially contaminated wildlife feeding on plants growing on site (a qualitative discussion will be included), or drinking the water from Threemile Creek

The exposure routes considered for this assessment are summarized in Table 6-10. A brief discussion of the potential for exposure by each of these pathways is provided below.

6.1.2.5 <u>Summary of Exposure Pathways</u> - The following discussions summarize the exposure pathways for soil, groundwater, surface water and sediment.

6.1.2.5.1 Soil Exposures - Current and future trespassing and recreational hunters and future grounds maintenance workers at the SFL may be exposed to contaminants in the surface soils at the site. Potential exposure may occur through absorption of contaminants from the soil through the skin and from incidental ingestion of soil on the hands by individuals who smoke, drink, or eat after visiting the site. The generation of fugitive dust from surface soils is common with the use of heavy construction equipment and less common with pedestrian traffic. Fugitive dust containing adsorbed contaminants can be generated by pedestrian traffic or by vehicles on the site and result in inhalation of contaminated soil by current or future visitors. The fact that surface soils are mostly covered with grass and other vegetation should reduce soil exposures for the hunters, unless intrusive activities such as excavation occur. However, the soil pathway is evaluated for hunters and grounds keepers because, in the dry season, dust may be generated in spite of the vegetative cover on site.

The subsurface soil samples collected from the site are from depths exceeding 15 feet; therefore, potential exposures to subsurface soils less than 15 feet in depth cannot be quantified. This should not be a cause for concern, because exposures to on-site subsurface soils currently do not exist. In the event of remediation involving deep intrusive activities, such as excavation, exposure to subsurface soil contamination may need to be re-evaluated.

The 95 percent UCL on the arithmetic mean of the contaminant concentrations in the surface soils evaluated using Level 4 analytical techniques is used to quantify exposure of current and future recreational hunters on and around the SFL site. The samples with the highest detected levels of metals by XRF screening methods were submitted to the laboratory for confirmatory analysis. Therefore, the use of these confirmatory samples for the generation of the 95 percent UCL values, though limited in number, is conservative. The risks associated with these samples should be protective for potentially exposed receptors. If the 95 percent UCL exceeds the maximum detected concentration, then the maximum detected concentration will be used as the exposure point concentration.

6.1.2.5.2 Groundwater Exposures - Currently, groundwater beneath the SFL is not used as a potable water source. Fort Riley obtains its potable water from well fields approximately 5

TABLE 6-10

EXPOSURE ROUTES CONSIDERED
Southwest Funston Landfill
Fort Riley, Kansas

Time Frame	Medium	Population	Exposure Route	Exposure Route Complete?	Explanation
Current	Surface Soils	On-site Worker	Incidental Ingestion Inhalation of Fugitive Dust Dermal Contact	No No No	Currently, no one regularly works on site.
		Residential Adults and Children	Incidental Ingestion Inhalation of Fugitive Dust Dermal Contact	No No No	There are no residences located on-site, and none in the immediate area surrounding SFL.
		Trespassing Adult (Hunter)	Incidental Ingestion Inhalation of Fugitive Dust Dermal Contact	Yes Yes Yes	Current unauthorized use of SFL as a hunting site
Future		On-site Worker Residential Adults and Children	Incidental Ingestion Inhalation of Fugitive Dust Dermal Contact	No No No	Future industrial or residential development of the SFL is unlikely, because the site lies within the Kansas River floodplain, and construction is prohibited within the 50-year floodplain.
		Recreational Adult (Hunter)	Incidental Ingestion Inhalation of Fugitive Dust Dermal Contact	Yes Yes Yes	Future use of SFL as a hunting site
		Grounds Keeper Worker	Incidental Ingestion Inhalation of Fugitive Dust Dermal Contact	Yes Yes Yes	Future maintenance of SFL
Current & Future	Deep Subsurface Soils (> 16 feet)	Residential Adults & Children Occupational Adults Recreational Adults	Incidental Ingestion Inhalation of Fugitive Dust Dermal Contact	No No No	No exposures to soils at depth (> 16 feet deep).

TABLE 6–10

EXPOSURE ROUTES CONSIDERED
Southwest Funston Landfill
Fort Riley, Kansas

Time Frame	Medium	Population	Exposure Route	Exposure Route Complete ?	Explanation
Current	Ground Water	Residential Adults and Children (Off site) Occupational Adults	Ingestion of Drinking Water Inhalation of Volatiles Dermal Contact	No No No	No potable water wells currently on site. The low levels of constituents currently detected in site ground water are unlikely to affect the nearest potable water supply well.
Future		Residential Adults and Children	Ingestion of Drinking Water Inhalation of Volatiles Dermal Contact	Yes Yes Yes	Assumption: Assumes the future installation of drinking water wells on site
Current & Future	Surface Water (Threemile Creek)	Occupational Adult	Dermal Contact	Yes	Exposure to surface water may occur if utility lines located adjacent to Threemile Creek need repair.
			Incidental Ingestion	No	Recreational exposure and total body exposure to Threemile Creek's surface water does not occur and is unlikely to occur in the future.
			Inhalation of Volatiles	No	Volatile organic compounds were not detected in the surface water of Threemile Creek.
Current & Future	Sediment (Threemile Creek)	Occupational Adult	Incidental Ingestion Dermal Contact	Yes Yes	Exposure to sediment may occur if utility lines located adjacent to Threemile Creek need repair.
Current & Future	Game Animals	Hunters and Families Adults & Children	Ingestion of Game	Yes?	The route is complete only if the game animals are contaminated, which is unknown at this time.

miles upgradient from the SFL, and Ogden obtains its water supply from wells located approximately 2.6 miles northeast from the site. However, the state of Kansas considers the groundwater beneath the site as a potential potable water supply; therefore, a conservative future groundwater scenario was developed which assumes the use of the aquifer on site as a source of potable water. EPA Region VII defines RME as the "hottest" well at the site. In order to obtain this data, risk calculations were performed for each well cluster. The data are presented in Appendix M and in Section 6.1.4.3.

The 95 percent UCL on the arithmetic mean of the contaminant concentrations in the groundwater sampled from the on-site monitoring wells will be used to quantify exposure of future residential users of the aquifer beneath the SFL site. If the 95 percent UCL exceeds the maximum detected concentration, then the maximum detected concentration will be used as the exposure point concentration. The 95 percent UCL is based on all wells except the background wells (SFL92-101, SFL92-102, and SFL92-103) and the wells east of Threemile Creek (SFL92-501, SFL92-502, and SFL92-503).

Groundwater constituent concentrations were not modeled to the exposure point of the Ogden public water supply wells. As discussed in Section 3.6.2.2.6, considerable variation occurs in the groundwater gradient beneath the SFL. The cause of this variation is due to widely different fluctuations in groundwater levels due to river influx, regional variations in recharge to the aquifer, and variations in the stage of the Kansas River. A more thorough discussion of the variation in groundwater levels at the site is presented in Section 3.6.2.

With more data, constituent concentrations in the aquifer beneath the SFL could be modeled to exposure point concentrations at the nearest receptor point (i.e., the nearest downgradient potable well). Therefore, this risk assessment estimates exposures to groundwater constituents using the concentrations detected at the site, without considering attenuation due to decay, dilution, or other mechanisms. It should be noted that this approach will tend to overestimate groundwater exposures that may occur for current users of a downgradient potable water well, and therefore does not accurately reflect the potential risks to these downgradient receptors.

Groundwater exposure in this risk assessment is evaluated for ingestion of groundwater and dermal absorption of contaminants during bathing or household use. Because volatile organics were identified as contaminants of potential concern in the groundwater, inhalation of volatilized organics during bathing and household use is also evaluated as a potential exposure pathway. These potential exposure pathways will be evaluated for the future groundwater scenario presented in this risk assessment.

6.1.2.5.3 Surface Water and Sediment Exposures - Potentially contaminated surface waters and sediments may occur on site in Threemile Creek. Contaminants may be released into these media by surface runoff, soil erosion, and groundwater discharge into the surface water.

Exposure to contaminated surface water and sediments may occur through direct contact by utility workers (Threemile Creek).

Potential exposure to contaminants in Threemile Creek surface water may occur through dermal absorption during utility work activities and while wading in the channel since a water utility line crosses Threemile Creek at the site. This pathway will be included in this risk assessment. A primary concern of contaminants in sediments is that sediments provide a continual source of release. The primary exposure pathway for sediments is also through dermal absorption of contaminants, although some incidental ingestion of sediments may occur. These pathways will also be included in this risk assessment.

As discussed in Section 4.3.3, migration of constituents from the SFL is not impacting the Kansas River. The constituent concentrations detected downstream of SFL do not differ from upstream concentrations and are consistent with historical levels of metals in the Kansas River. Therefore, no exposure pathways for the Kansas River are included in this risk assessment.

6.1.2.5.4 Ingestion of Plants and Wildlife - Hunting has reportedly taken place in the past on the SFL and is currently permitted on many areas of the installation. Therefore, there is a potential for current or future receptors to ingest wildlife that may have been exposed to site contamination. The ability of contaminants to bioaccumulate in plant and animal tissue and the extent to which they may bioaccumulate varies according to the chemical and organism exposed. Site-specific data are not available to adequately address the quantitative risk to such exposures. Fishing and hunting of game birds (quail, pheasant, prairie chickens, and doves), deer, turkey, elk, and small game (rabbits and squirrels) take place on most areas of Fort Riley, excluding the multipurpose range complex when in use, the impact area, and the SFL. Although SFL is officially closed to hunters, trespassing hunters may hunt on site. In addition, game animals passing through the SFL and travelling to other areas on the installation may be hunted for sport and subsequently eaten. However, their contribution to the diet of residents is expected to be minimal because Fort Riley is used for recreational, and not subsistence, hunting and therefore, it is unlikely that a hunter would derive a major portion of his meat intake from animals frequenting the site. These pathways are not quantified in this risk assessment because there are no data available that document the body burden of contaminants in game animals (or vegetation) at the installation. A more thorough discussion of exposures of environmental receptors to site contaminants is provided in Section 6.2.

6.1.2.6 Quantification of Exposure - The next step in the exposure assessment is to quantify the magnitude, frequency, and duration of exposure for the populations and pathways selected. This step is most often conducted in two stages: first, exposure point concentrations are estimated, then pathway-specific intakes are quantified. Intake variables and exposure point concentrations are selected so that the combination of all variables results in an estimate of the reasonable maximum exposure (RME) for each pathway. The RME is the maximum exposure that is reasonably expected to occur at a site. The RME results in an exposure scenario that is both "protective and reasonable," but not the worst possible case (USEPA, 1991b). The RME is utilized to provide decision-makers with an understanding of potential exposures and provides the basis for the development of protective exposure levels (NCP, 1988). The RME for groundwater, as determined by Region VII, is the "hottest" well at the site. Therefore, risk calculations have been performed for each well cluster in order to obtain the worst case scenario.

6.1.2.6.1 Estimation of Exposure Point Concentrations - Concentrations of contaminants of concern at the exposure points identified in the previous section must be estimated in order to assess risk. Table 6-11 summarizes the pathway-specific exposure point concentrations for the pathways selected for quantitative evaluation.

Unless stated otherwise, the exposure point concentrations for all exposure pathways are based on the 95 percent UCL on the arithmetic mean of the constituent concentrations in all samples from each of the environmental media on site, respectively. Because of the uncertainty associated with any estimate of exposure concentration, the use of the 95 percent UCL exposure will provide an estimate of RMEs. In the event that the 95 percent UCL is greater than the maximum concentration, then the maximum concentration will be used as the exposure concentration.

The use of the 95 percent UCL values as exposure point concentrations for future scenarios assumes that constituent concentrations in the groundwater, surface water, soils, and sediments will be the same as those currently found in those media on site. This is an assumption which, in general, will tend to overestimate the risks from the site, especially with respect to the future residential groundwater pathways, as actual on-site drinking water well development may never occur and natural decay and degradation of contaminants may also decrease future risks. It should be noted that the groundwater concentrations of constituents may also increase in the future, depending on the source and mechanism for release at the site. However, an increase of contaminant concentrations is unlikely because the landfill has been closed for over 11 years.

The exposure point concentrations for fugitive dust emitted from surficial soils are based on the ambient air concentration of contaminant particulates less than 10 μm diameter in air. The ambient concentration of air particulates is estimated based on the Wind Erosion Model (Cowherd et al., 1985) and Simple Box Model (Hwang and Falco, 1986). The wind erosion model estimates the annual average flux rate of respirable particles and utilizes site-specific factors such as the area of contaminated surface, vegetative cover and mean annual wind speed and threshold wind speed. The models used to estimate fugitive dust emissions estimate that portion of the total respirable dust that is due to the contaminated area of concern. Meteorological data were obtained from Marshall Army Airfield.

TABLE 6-11

ESTIMATED EXPOSURE POINT CONCENTRATIONS
Southwest Funston Landfill
Fort Riley, Kansas

Medium	Land Use/Populations	Exposure Pathway	Parameter	Exposure Concentration	Comments
Surface Soils	Current & Future Land Use:				
	Hunter	Incidental Ingestion, Inhalation of Fugitive Dust	Aluminum	5900 mg/kg	Concentrations are the maximum of measured concentrations analyzed using Level 4 analytical techniques in the seven surface soil samples.
			Antimony	5.8 mg/kg	
			Arsenic	3.1 mg/kg	
			Barium	170 mg/kg	
			Beryllium	0.67 mg/kg	
			Cadmium	2.1 mg/kg	** Assumed to be trivalent chromium, based on soil pH and redox potential at the site.
			Chromium **	16 mg/kg	
	Grounds Maintenance Worker (future only)	Incidental Ingestion, Inhalation of Fugitive Dust	Copper	110 mg/kg	
			Lead	160 mg/kg	
			Manganese	220 mg/kg	
			Mercury	1.8 mg/kg	
			Silver	3.2 mg/kg	
			Thallium	0.26 mg/kg	
			Vanadium	18 mg/kg	
			Zinc	250 mg/kg	
Ground Water	Future Land Use: Residents	Ingestion of Drinking Water Dermal Contact	Antimony	0.012 mg/L	Concentrations are the 95% UCL of measured concentrations in all ground water samples collected from the monitoring wells for the site.
			Arsenic	0.019 mg/L	
			Barium	0.569 mg/L	
			Beryllium	0.0021 mg/L	
			Cadmium	0.0026 mg/L	
			Manganese	1.748 mg/L	*When the 95%UCL exceeded the maximum detected concentration, the maximum concentration is used as the exposure point concentration.
			Thallium	0.0017 mg/L *	
		Ingestion of Drinking Water Inhalation of Volatile Organics While Bathing Dermal Contact	Benzene	0.0014 mg/L	Concentrations are the 95% UCL of measured concentrations in all ground water samples collected from the monitoring wells for the site.
			cis-1,3-Dichloropropene	0.0017 mg/L	
			1,2-Dichloroethane	0.0028 mg/L	
			1,1,2,2-Tetrachloroethane	0.003 mg/L	
			1,1,2-Trichloroethane	0.0027 mg/L	
			Vinyl Chloride	0.0054 mg/L	

TABLE 6-11

ESTIMATED EXPOSURE POINT CONCENTRATIONS
Southwest Funston Landfill
Fort Riley, Kansas

Medium	Land Use/Populations	Exposure Pathway	Parameter	Exposure Concentration	Comments
	Current & Future Land Use:				
Surface Water	Threemile Creek – Utility Worker	Dermal Contact	Arsenic	0.0044 mg/L	Concentrations are equal to the concentrations detected in downstream surface water samples at Threemile Creek (TCSW02).
			Barium	0.17 mg/L	
			Manganese	0.15 mg/L	
	Current & Future Land Use:				
Sediments	Threemile Creek – Utility Worker	Incidental Ingestion Dermal Contact	Arsenic	2.1 mg/kg	Concentrations are equal to the concentrations detected in downstream sediment samples (TCS002).

Assuming a respirable particle fraction (RP) of 0.036 g/m^2-hour [default value - derived from empirical data (Cowherd et al., 1985)], an estimated vegetative cover (G) of 0.8 for the landfill, a mean annual wind speed (Um) of 4.896 m/s (PCGEMs), a threshold wind speed (Ut) of 6.25 m/s (calculated - see Appendix M), and a function value (F(x)) of 1.45 (calculated - see Appendix M), an annual average flux rate (N_{10}) of respirable particles (PM_{10}) is calculated as follows:

$$N_{10} = RP * (1-G) * (Um/Ut)^3 * F(x) = 5 \times 10^{-3} \text{ g/m}^2\text{-hour}$$

The simple box model is then applied to estimate the ambient concentration of dust in the air (PM_{10}), assuming the area of contamination (A), 4.33×10^5 m^2, is equal to the area of the SFL. Thus, the width of the area of contamination perpendicular to the prevailing wind direction (LS) is 579 m. The average wind speed in the mixing zone (V) was assumed to be equal to half of the annual wind speed, or 2.5 m/s. A mixing height (MH) of two meters (approximately equal to the average man's height) was also assumed. A conversion factor of 3600 s/hour was also incorporated. The equation of the simple box model is shown below:

$$PM_{10} = (N_{10} * A)/(LS * V * MH * 3600 \text{ s/hr}) = 2.08 \times 10^{-4} \text{g/m}^3$$

The equation below relates detected contaminant concentration in soil (CS) to the concentration of contaminants on respirable particles in the air (CA), using a conversion factor of 0.001 kg/g:

$$CA \text{ (mg/m}^3) = CS * PM_{10} * 0.001 \text{ kg/g} = CS \text{ (mg/kg)} * 2.08 \times 10^{-7}$$

6.1.2.6.2 Pathway-Specific Intake Estimates - Pathway-specific intakes are quantified by defining a series of variables that describe the exposed population, such as contact rate, exposure frequency and duration, and body weight. The specific calculation procedures and variables used to determine pathway-specific intakes are described below. These exposure variables are multiplied by the exposure point concentrations shown in Table 6-11 to yield estimates of the chemical-specific intakes for these pathways. The chemical-specific intakes are calculated individually in the Risk Calculation Tables in Appendix M.

Standard default body weights of 70 kg for an adult and 15 kg for a child, aged zero to six years, were used. Standard default exposure values were taken from the "Supplemental Guidance to the Human Health Evaluation Manual" (USEPA, 1991b), unless otherwise noted.

Incidental Ingestion of Surface Soil - The equation for determining chemical intakes from the incidental ingestion of soil is shown in Table 6-12. Based on the variables provided in the table, intakes are calculated for current and future recreational hunters and future grounds maintenance workers.

TABLE 6-12

CURRENT & FUTURE EXPOSURE:
INCIDENTAL INGESTION OF SURFACE SOILS
INGESTION INTAKES
Southwest Funston Landfill
Fort Riley, Kansas

$$\text{INGESTION INTAKE (a)} = \frac{C * FI * IR * EF * ED * CF}{BW * AT}$$

Where:
C = Concentration of constituent in surface soil, mg/kg
FI = Fraction Ingested from source, unitless
IR = Ingestion Rate, mg/day
EF = Exposure Frequency, days/year
ED = Exposure Duration, years
CF = Conversion Factor, kg/10^6 mg
BW = Body Weight, kg
AT = Averaging Time, days

	Incidental Ingestion of Surface Soil	
Exposure Variable	Hunter	(Future) Grounds Maintenance Worker
FI	100%[b]	100%[b]
IR	100[f]	480[c]
EF	50[d]	10[e]
ED	30[c]	25[c]
CF	10^{-6}	10^{-6}
BW	70[c]	70[c]
AT (Noncarcinogen)	10,950[c]	9,125[c]
AT (Carcinogen)	25,550[c]	25,550[c]

PATHWAY-SPECIFIC INTAKES:

Incidental Ingestion of Surface Soil (current & future):

Hunter (Noncarcinogens): C (mg/kg) * 1.96E-07 kg/kg-day

Hunter (Carcinogens): C (mg/kg) * 8.39E-08 kg/kg-day

Incidental Ingestion of Surface Soil (future):

Grounds Maintenance Worker (Noncarcinogens): C (mg/kg) * 1.88E-07 kg/kg-day

Grounds Maintenance Worker (Carcinogens): C (mg/kg) * 6.71E-08 kg/kg-day

(a) Chemical-specific intakes are calculated in the risk calculation tables (Appendix M).
(b) USEPA, 1989a
(c) USEPA, 1991b
(d) Chief, Land Management, Fort Riley Fish and Wildlife Department/Natural Resources (personal communication), 1992; KDWP, 1988; KDWP, 1991; KDWP, 1992
(e) Turf Specialist (personal communication), Master Lawn and Landscaping, 1993.
(f) Calabrese et al., 1987 (as cited in USEPA, 1989b); USEPA, 1991c.

According to Fort Riley's Fish and Wildlife Administrator, Natural Resources (DEH, 1993c), the game animals hunted in the vicinity of SFL are primarily white-tailed deer (archery and firearm), bobwhite quail, rabbits, and squirrel. In order to estimate the number of days a hunter may hunt in the area of the SFL, the Kansas Department of Wildlife and Parks hunter activity surveys were reviewed (KDWP, 1988; KDWP, 1991; and KDWP, 1992). These reports present in tabular form information obtained through random surveys of permitted hunters in Kansas (resident and non-resident) for each of the game animals hunted. The maximum number of season days per hunter reported for each of the species hunted in the SFL area are listed below:

Quail	7.05
Squirrels	6.02
Cottontails	6.5
Deer (firearms)	12.0
(archery)	18.4
Total:	49.97

Thus, for the purpose of the risk assessment, the number of days hunted per year (or exposure frequency) was assumed to be 50 days per year, over a period of 30 years (default for residential exposure duration).

A current occupational scenario was not developed for the landfill, because currently no workers regularly occupy the site. Grass and weed growth on the SFL site is currently controlled by periodic burning of the vegetative cover; this burning does not appear to occur at regularly planned intervals (DEH, 1993e). However, in the future, the need for maintenance and rehabilitation of the existing ground cover may arise. Thus, a future grounds maintenance worker scenario is included in this assessment. According to landscaping companies in the Fort Riley area, maintenance of a plot of land as large as the SFL would require approximately two weeks (10 days) of work annually (Master Lawn and Landscaping, 1993). That is, it would require ten days of work per year to mow or bush hog an area as large and overgrown as the SFL. Therefore, the grounds keeper is assumed to be on site for eight hours daily for these ten days over a period of 25 years (default for occupational exposure duration).

An incidental soil ingestion rate of 100 mg/day is used for the on-site hunter. This value represents the upper-bound of a range suggested by Calabrese et al. (1987) [as cited in USEPA, 1989b] for an adult's inadvertent soil ingestion. A 100 mg per day soil ingestion rate is also suggested by USEPA for use in developing soil remediation goals (USEPA, 1991c). According to Attachment B in USEPA's supplemental guidance entitled "Standard Default Exposure Factors" (USEPA, 1991b), an upper-bound soil ingestion rate of 480 mg/day has been estimated for soil ingestion that occurs during yardwork, and may be used to estimate ingestion by someone engaged in construction or landscaping. The future grounds maintenance worker evaluated in this risk assessment mows or bush-hogs the SFL site while riding on a tractor or similar motorized vehicle; the on-site hunter evaluated merely travels across the surface of the landfill. Therefore, neither of the receptors evaluated in this risk assessment have gross contact with or exposure to site soils (that is, neither person digs in the soil at the site). However, because the activities of the future grounds maintenance worker are more likely to generate dust from site soils than the hunter's activities, a soil ingestion value of 480 mg/day (the USEPA upper-bound soil ingestion value) is used to develop the future grounds maintenance worker's intake.

Chemical intakes were not calculated for receptors working adjacent to the SFL, because these workers do not have direct contact with contaminated site media. A future residential scenario was also not developed because the location of the SFL in the Kansas River floodplain precludes future residential development of the site. According to Fort Riley's Master Planning, in Kansas, construction is prohibited within a 50-year flood zone, although construction of docks and levees may be permitted (Fort Riley, 1993b).

Inhalation of Fugitive Dusts Generated from Surface Soils - The chemical intakes for inhalation of fugitive dusts by current and future recreational hunters and future grounds maintenance workers are calculated using the equation in Table 6-13. The inhalation rate of 2.5 m^3/hour (moderate activity, adult) (USEPA, 1989b) and an exposure frequency and duration of 50 days/year for 30 years were assumed for the recreational exposure. The hunters are assumed to be on site for a total of eight hours each day (exposure time). Likewise, a 2.5 m^3/hour inhalation rate for eight-hour work days was assumed for the grounds maintenance worker. An exposure frequency of 10 days/year for 25 years was also used in the equation.

Fugitive dust exposures to off-site employees working in areas adjacent to the SFL are expected to be no more than those experienced by the on-site hunter.

Dermal Contact with Surface Soils - The chemical intake equation for this pathway for current and future recreational hunters and future grounds maintenance workers is presented in Table 6-14. A surface area of 2,020 cm^2 (hands and head) is assumed for the hunter, while a surface area of 3,160 cm^2 (lower arms, hands, and head) is assumed for the grounds maintenance worker. Surface area values are the 50th percentile values for an adult male (USEPA, 1989b). Exposure duration, time and frequency are the same as described above.

A soil adherence factor of 1.0 mg/cm^3 (USEPA, 1992b) and a conservative absorption factor of 100 percent (USEPA, 1992c) is used for both receptors.

Ingestion of Groundwater - The (future) intakes for the ingestion of groundwater are shown in Table 6-15. The calculations are based on the assumption that people live at one residence for 30 years. Receptors are assumed to consume two liters of water from the contaminated aquifer daily at a frequency of 350 days per year. The exposure frequency value assumes a two-week period away from the home each year (USEPA, 1991b).

TABLE 6–13

CURRENT & FUTURE EXPOSURE:
INHALATION OF FUGITIVE DUST GENERATED FROM SURFACE SOILS
INHALATION INTAKES
Southwest Funston Landfill
Fort Riley, Kansas

$$\text{INHALATION INTAKE (a)} = \frac{C * IR * EF * ET * ED * CF}{BW * AT}$$

Where:

C = Concentration of constituent in surface soil, mg/kg
IR = Inhalation Rate, m^3/hr
EF = Exposure Frequency, days/year
ET = Exposure time, hrs/day
ED = Exposure Duration, years
CF = Conversion Factor from Cowherd Model[(b)], kg/m^3
BW = Body Weight, kg
AT = Averaging Time, days

Exposure Variable	Inhalation of Fugitive Dust Hunter	 (Future) Grounds Maintenance Worker
IR	2.5[c]	2.5[c]
EF	50[d]	10[e]
ET	8[f]	8[e]
ED	30[f]	25[f]
CF	2.08E–07[b]	2.08E–07[b]
BW	70[f]	70[f]
AT (Noncarcinogen)	10,950[f]	9,125[f]
AT (Carcinogen)	25,550[f]	25,550[f]

PATHWAY–SPECIFIC INTAKES:

Inhalation of Fugitive Dust (current & future):

Hunter (Noncarcinogens):	C (mg/kg) * 8.13E–09 kg/kg–day
Hunter (Carcinogens):	C (mg/kg) * 3.49E–09 kg/kg–day

Inhalation of Fugitive Dust (future):

Grounds Maintenance Worker (Noncarcinogens):	C (mg/kg) * 1.63E–09 kg/kg–day
Grounds Maintenance Worker (Carcinogens):	C (mg/kg) * 5.81E–10 kg/kg–day

(a) Chemical–specific intakes are calculated in the risk calculation tables (Appendix M)
(b) Cowherd et al, 1985 (see Appendix M)
(c) USEPA, 1989b
(d) Fort Riley, 1993a; KDWP, 1988; KDWP, 1991; KDWP, 1992
(e) Master Lawn and Landscaping, 1993
(f) USEPA, 1991b

TABLE 6-14
CURRENT AND FUTURE EXPOSURE
DERMAL CONTACT WITH SURFACE SOILS
DERMAL INTAKES
Southwest Funston Landfill
Fort Riley, Kansas

$$\text{DERMAL INTAKE (a)} = \frac{C * SA * AF * ABS * EF * ED * CF}{BW * AT}$$

Where:
C = Concentration of constituent in surface soil, mg/kg
SA = Surface Area of exposed skin, cm^2/day
AF = Soil to skin Adherance Factor, mg/cm^2
ABS = Absorption Factor (unitless)
EF = Exposure Frequency, days/year
ED = Exposure Duration, years
BW = Body Weight, kg
AT = Averaging Time, days
CF = Conversion Factor, 1E-06 kg/mg

Exposure Variable		Dermal Contact with Surface Soils	
		Hunter	(Future) Grounds Maintenance Worker
SA		2,020[b]	3,160[c]
AF		1[d]	1[d]
ABS		100%[e]	100%[e]
EF		50[f]	10[g]
ED		30[h]	25[h]
CF		1E-06	1E-06
BW		70[h]	70[h]
AT	(Noncarcinogen)	10950[h]	9,125[h]
AT	(Carcinogen)	25550[h]	25,500[h]

PATHWAY-SPECIFIC INTAKES:

Dermal Exposure to Surface Soils (current and future):

Hunter (Noncarcinogens):	= C (mg/kg) * 3.95E-06 kg/kg-day
Hunter (Carcinogens):	= C (mg/kg) * 1.69E-06 kg/kg-day

Dermal Exposure to Surface Soils (future):

Grounds Maintenance Worker (Noncarcinogens):	= C (mg/kg) * 1.24E-06 kg/kg-day
Grounds Maintenance Worker (Carcinogens):	= C (mg/kg) * 4.42E-07 kg/kg-day

(a) Chemical-specific intakes are calculated in the risk calculation tables (Appendix M).
(b) USEPA, 1989b (head and hands)
(c) USEPA, 1989b (lower arms, hands, and head)
(d) USEPA, 1992b
(e) USEPA, 1992c
(f) Fort Riley, 1993a; KDWP, 1988; KDWP, 1991; KDWP, 1992
(g) Master Lawn and Landscaping, 1992
(h) USEPA, 1991b

TABLE 6-15

FUTURE (OFF-SITE) RESIDENTIAL EXPOSURE: INGESTION OF GROUND WATER INGESTION INTAKES

Southwest Funston Landfill
Fort Riley, Kansas

$$\text{INGESTION INTAKE (a)} = \frac{C * IR * EF * ED}{BW * AT}$$

Where:
C = Concentration of constituent in ground water, mg/L
IR = Ingestion Rate, L/day
EF = Exposure Frequency, days/year
ED = Exposure Duration, years
BW = Body Weight, kg
AT = Averaging Time, days

Exposure Variable	Ingestion of Ground Water	
	Adult	Child
IR	2^b	2^b
EF	350^b	350^b
ED	$30\ (24)^c$	6^b
BW	70^c	15^b
AT (Noncarcinogen)	$10{,}950^b$	$2{,}190^b$
AT (Carcinogen)	$25{,}550^b$	NA

PATHWAY-SPECIFIC INTAKES:

Ingestion of Ground Water (future):

(Off-site) Residential Adult (Noncarcinogens)[c]:	C (mg/kg) * 4.75E-02 L/day-kg
(Off-site) Residential Adult (Carcinogens)[c]:	C (mg/kg) * 2.04E-02 L/day-kg
(Off-site) Residential Child (Noncarcinogens):	C (mg/kg) * 1.28E-01 L/day-kg

(a) Chemical-specific intakes are calculated in the risk calculation tables (Appendix M).

(b) USEPA, 1991b

(c) The equation for estimating the adults intake is divided into two parts [1] a six-year exposure duration for young children which accounts for the period of lowest body weight (15kg); and [2] a 24-year exposure for older children and adults which accounts for a higher body weight (70 kg). The equation used follows:

$$\text{Intake} = \frac{\dfrac{C^* IR_{ADULT} * EF_{ADULT} * ED_{ADULT}}{BW_{ADULT}} + \dfrac{C^* IR_{CHILD} * EF_{CHILD} * ED_{CHILD}}{BW_{CHILD}}}{AT_{ADULT}}$$

The adult ED value of 24 years is for "adult" component of total ED, or 30 years (6+ 24 = 30)

Inhalation of Volatiles During Showers - The chemical intakes for the inhalation of volatiles during showers are calculated using the equation shown in Table 6-16. A shower or bath length of 12 minutes, once daily, which is the 90th percentile for bathing duration (USEPA, 1992b), is assumed for exposed receptors. Standard default exposure frequencies and duration (350 days per year for 30 years) are also used in the equation.

Chemical-specific inhalation exposure to VOCs are estimated using an equation derived by Andelman (1990) [as cited in USEPA, 1991c] that defines the relationship between the concentration of a contaminant in household water and the average concentration of the volatilized contaminant in air. All uses of household water (i.e., showering, laundering, dishwashing) are considered in the derivation of the equation (USEPA, 1991c). The equation uses a default "volatilization" constant (K), an upper-bound value of 0.0005 x 1000 L/m^3. In deriving the equation and the volatilization constant K, Andelman made a number of assumptions, as follows:

- the volume of water used in a residence for a family of four is 720 L/day;
- the volume of the household dwelling is 150,000 L;
- the air exchange rate is 0.25 m^3/hr; and
- half of the concentration of each volatile chemical in water will be transferred to air by all water uses in the household.

Dermal Exposure to Groundwater - The equation for calculating future residential dermal contact to groundwater during bathing and other household activities is shown in Table 6-17. Surface area values of 19,400 cm^2 and 8,660 cm^2, representing the 50th percentile values for an adult male and a child, respectively, are used in the calculation (USEPA, 1989b). A shower or bath duration of 12 minutes once daily, is assumed for exposed receptors (USEPA, 1992b). Standard default exposure frequencies and durations (350 days per year for 30 years or 6 years for a child) were also used in the calculation. The permeability constant is based on a chemical-specific permeability coefficient for constituents in water (USEPA, 1992b).

Dermal Exposure to Surface Water - The equation for determining chemical intakes from dermal contact during utility work to surface waters is presented in Table 6-18. Based upon interviews with Fort Riley personnel (DEH, 1993d), one utility (water) line runs through the landfill near Threemile Creek. According to Fort Riley DEH employees working in the Exterior Utility Section of the Structures Branch, the estimated repair time for a leaking utility line is approximately four hours; while the estimated time to replace a utility line is approximately two eight-hour days (DEH, 1993a; DEH, 1993b). Both individuals stated that a reasonable estimate of the life expectancy of a utility line was approximately 20 to 30 years; a line would probably need replacement after this time period, especially if numerous leaks or breaks occurred. In addition, both individuals stated that they would expect no more than one or two leaks during

TABLE 6-16
FUTURE (OFF-SITE) RESIDENTIAL EXPOSURE
INHALATION OF AIRBORNE (VAPOR PHASE) CHEMICALS IN HOUSEHOLD POTABLE WATER
INHALATION INTAKES
Southwest Funston Landfill
Fort Riley, Kansas

INGESTION INTAKE (a) $= \dfrac{C * K * IR * EF * ED}{BW * AT}$

Where:
C = Concentration in ground water, mg/L
K = Volatilization Factor, L/m^3
IR = Daily Inhalation Rate, m^3/day
EF = Exposure Frequency, days/year
ED = Exposure Duration, years
BW = Body Weight, kg
AT = Averaging Time, days

Exposure Variable	Inhalation of Vapors (Whole House Scenario)	
	Adult	Child
K	0.5^{b}	0.5^{b}
IR	20^{c}	20^{c}
EF	350^{c}	350^{c}
ED	$30(24)^{c,d}$	6^{c}
BW	70^{c}	15^{c}
AT (Noncarcinogen)	$10{,}950^{c}$	$2{,}190^{c}$
AT (Carcinogen)	$25{,}550^{c}$	NA

PATHWAY-SPECIFIC INTAKES:

Inhalation of Volatiles (future):

(Off-site) Residential Adult (Noncarcinogens)^{d} = C (mg/L) * 2.37E-01 L/kg-day
(Off-site) Residential Adult (Carcinogens)^{d} = C (mg/L) * 1.02E-01 L/kg-day
(Off-site) Residential Child (Noncarcinogens) = C (mg/L) * 6.39E-01 L/kg-day

(a) Chemical-specific intakes are calculated in the risk calculation tables (Appendix M).

(b) Andelman, 1990; as cited by USEPA, 1991c

(c) USEPA, 1991b

(d) The equation for estimating the adults intake divided into two parts: 1) a six-year exposure duration for young children which accounts for the period of lowest body weight (15kg); and 2) a 24-year exposure for older children and adults which accounts for a higher body weight (70kg). The equation used follows:

$$\text{Intake} = \frac{\dfrac{C * IR_{\text{ADULT}} * EF_{\text{ADULT}} * ED_{\text{ADULT}} * K}{BW_{\text{ADULT}}} + \dfrac{C * IR_{\text{CHILD}} * EF_{\text{CHILD}} * ED_{\text{CHILD}} * K}{BW_{\text{CHILD}}}}{AT_{\text{ADULT}}}$$

The Adult ED value of 24 years is for "adult" component of total ED, or 30 years (6 + 24 = 30)

TABLE 6–17

FUTURE (OFF–SITE) RESIDENTIAL EXPOSURE: DERMAL EXPOSURE TO GROUND WATER DERMAL INTAKES

Southwest Funston Landfill
Fort Riley, Kansas

$$\text{DERMAL INTAKE (a)} = \frac{C * SA * PC * ET * EF * ED * CF}{BW * AT}$$

Where:
C = Concentration of constituent in ground water, mg/L
SA = Surface Area of exposed skin, cm^2
PC = Permeability Constant, cm/hour
ET = Exposure Time, hours/day
EF = Exposure Frequency, days/year
ED = Exposure Duration, years
CF = Conversion Factor, $1L/10^3\ cm^3$
BW = Body Weight, kg
AT = Averaging Time, days

Exposure Variable	Dermal Exposure to Ground Water Adult	Child
SA	19,400[b]	8,660[b]
PC	*** chemical specific ***	
ET	0.2[c]	0.2[c]
EF	350[d]	350[d]
ED	30(24)[d, e]	6[d]
CF	10^{-3}	10^{-3}
BW	70[d]	15[d]
AT (Noncarcinogen)	10,950[d]	2,190[d]
AT (Carcinogen)	25,550[d]	NA

PATHWAY–SPECIFIC INTAKES:

Dermal Exposure to Ground Water (future):

(Off–Site) Residential Adult (Noncarcinogens)[e]:	C (mg/L) * PC(cm/hr) * 6.47E–02 L–hr/cm–kg–day
(Off–Site) Residential Adult (Carcinogens)[e]:	C (mg/L) * PC(cm/hr) * 2.77E–02 L–hr/cm–kg–day
(Off–Site) Residential Child (Noncarcinogens):	C (mg/L) * PC(cm/hr) * 1.11E–01 L–hr/cm–kg–day

(a) Chemical–specific intakes are calculated in the risk calculation tables (Appendix M)
(b) USEPA, 1989b (whole body surface area–50th percentile)
(c) USEPA, 1992b
(d) USEPA, 1991b
(e) The equation for estimating the adult's intake is divided into two parts: 1) a six–year exposure duration for young children which accounts for the period of lowest body weight (15 kg); and 2) a 24–year exposure for older children and adults which accounts for a higher body weight (70kg). The equation used follows:

$$\text{Intake} = \frac{\dfrac{C* PC *SA_{ADULT} *ET_{ADULT} *EF_{ADULT} *ED_{ADULT} *CF}{BW_{ADULT}} + \dfrac{C* PC *SA_{CHILD} *ET_{CHILD} *EF_{CHILD} *ED_{CHILD} *CF}{BW_{CHILD}}}{AT_{ADULT}}$$

The Adult ED value of 24 years for "adult" component of total ED, or 30 years (6 + 24 = 30)

TABLE 6-18

FUTURE OCCUPATIONAL EXPOSURE (UTILITY WORKER): DERMAL EXPOSURE TO SURFACE WATER- THREEMILE CREEK
DERMAL INTAKES
Southwest Funston Landfill
Fort Riley, Kansas

$$\text{DERMAL INTAKE (a)} = \frac{C * SA * PC * ET * EF * ED * CF}{BW * AT}$$

Where:
C = Concentration of constituent in surface water, mg/L
SA = Surface Area of exposed skin, cm^2
PC = Permeability Constant, cm/hour
ET = Exposure Time, hours/day
EF = Exposure Frequency, days/year
ED = Exposure Duration, years
CF = Conversion Factor, $1L/10^3\ cm^3$
BW = Body Weight, kg
AT = Averaging Time, days

Exposure Variable	Dermal Exposure to Surface Water Utility Worker
SA	5,170[b]
PC	0.001 (metals)[c]
ET	8[d]
EF	0.44[e]
ED	25[d]
CF	10^{-3}
BW	70[d]
AT (Noncarcinogen)	9,125[d]
AT (Carcinogen)	25,550[d]

PATHWAY-SPECIFIC INTAKES:

Dermal Exposure to Surface Water (future):

Utility Worker (Noncarcinogens):	C (mg/L) *	7.12E-07 L/kg-day
Utility Worker (Carcinogens):	C (mg/L) *	2.54E-07 L/kg-day

(a) Chemical-specific intakes are calculated in the risk calculation tables (Appendix M)
(b) USEPA, 1989b (lower arms, lower legs, hands, and feet)
(c) USEPA, 1992b
(d) USEPA, 1991b
(e) Conservative estimation, based on DEH, 1993a; DEH, 1993b; and DEH, 1993d.

that 20- to 30-year time period. The two men interviewed give slightly different estimates for the number of men needed to completely replace a broken/leaking line. One stated that four men would need two days to make a replacement, while the other stated that a crew of up to three men would require two days to make the replacement.

Based on these interviews, the future utility worker's exposure frequency is estimated to be approximately 0.44 eight-hour days yearly for 25 years. The rationale used to arrive at this exposure frequency follows.

Since the life expectancy of a utility line is 20 to 30 years, it is reasonable to believe a line will be completely replaced during the 25-year time period used to estimate occupational exposures. In addition, since no more than two leaks or breaks are expected in 20 to 30 years, a conservative estimate of the number of leaks in the receptor's exposure duration of 25 years would be 1 in 10 years, or approximately 3 leaks in 25 years. To conservatively estimate exposure time, it is assumed that the line present in the area of concern would need both replacement and repair during a 25-year period.

In the other occupational scenario developed in this risk assessment, it is assumed that one individual will repeatedly contact contaminated media, instead of a crew of individuals, or several different employees rotating through job tasks. Therefore, the following exposure frequency is estimated:

1 (line in SFL area) * 2 (8-hour days to replace line) * 4 (man crew) = 8 man-days
1 (lines in SFL area) * 0.5 (8-hour day for repair) * 3 breaks (in 25 years) * 2 (men) = 3 man-days

TOTAL = 8 + 3 = 11 man-days in twenty-five years or **0.44 8-hour days/year**

This scenario assumes total replacement of utility lines and three breaks in a 25-year period; it should be noted that repair work of this magnitude may not occur at the site. It should also be noted that this scenario is conservative in that it assumes that utilities are repaired by a lone individual, instead of two to three individuals. Therefore, this scenario essentially doubles the exposure a single individual may receive in the given time period.

A surface area value of 5,170 cm^2, the 50th percentile value of an adult male's lower arms, lower legs, hands, and feet, is also used in the equation (USEPA, 1989b).

In the occupational scenarios, the dermal permeability constant is based on a chemical-specific permeability coefficient for constituents in water (USEPA, 1992b).

Dermal Contact with Sediments - The equations for determining chemical intakes from dermal contact with sediments is shown in Table 6-19. Based on the variables provided in this table, an intake was calculated for occupational exposure, utility repair activities at Threemile Creek, (current and future exposure for occupational receptors are assumed to be equal).

TABLE 6–19

FUTURE OCCUPATIONAL EXPOSURE (UTILITY WORKER): DERMAL EXPOSURE TO SEDIMENTS – THREEMILE CREEK DERMAL INTAKES

Southwest Funston Landfill
Fort Riley, Kansas

$$\text{DERMAL INTAKE (a)} = \frac{C * SA * AF * ABS * EF * ED * CF}{BW * AT}$$

Where:

C = Concentration of constituent in sediment, mg/kg
SA = Surface Area of exposed skin, cm^2/event
AF = Sediment to skin Adherence Factor, mg/cm^2
ABS = Absorption Factor, unitless
EF = Exposure Frequency, days/year
ED = Exposure Duration, years
CF = Conversion Factor, $kg/10^6$ mg
BW = Body Weight, kg
AT = Averaging Time, days

Exposure Variable	Dermal Exposure to Sediment Utility Worker
SA	3,160[b]
AF	1[c]
ABS	100%[d]
EF	0.44[e]
ED	25[f]
CF	10^{-6}
BW	70[f]
AT (Noncarcinogen)	9,125[f]
AT (Carcinogen)	25,550[f]

PATHWAY–SPECIFIC INTAKES:

Dermal Exposure to Sediment (future):

Utility Worker (Noncarcinogens):	C (mg/kg) *	5.44E–08 kg/kg–day
Utility Worker (Carcinogens):	C (mg/kg) *	1.94E–08 kg/kg–day

(a) Chemical–specific intakes are calculated in the risk calculation tables (Appendix M).
(b) USEPA, 1989b (50th percentile surface area values for an adult male: head, hands, forearms)
(c) USEPA, 1992b
(d) USEPA, 1992c
(e) Conservative estimation based on DEH, 1993a; DEH, 1993b; and DEH, 1993d.
(f) USEPA, 1991b

For the occupational scenario, an exposed surface area of 3,160 cm^2 is assumed (50th percentile surface area of head, hands, and forearms, USEPA 1989b). The exposure duration, frequency, and time for the occupational receptor is the same as described above in the surface water scenario.

A sediment adherence factor of 1.0 mg/cm^3 (USEPA, 1992b) and a conservative absorption factor of 100 percent (USEPA, 1992c) was assumed for all receptors.

Incidental Ingestion of Sediments - The equation for determining chemical intakes from the incidental ingestion of soil is shown in Table 6-20. Based on the variables provided in this table, an intake was calculated for occupational exposure, utility repair activities in Threemile Creek, (current and future exposure for occupational receptors are assumed to be equal).

The exposure duration, frequency, and time for the occupational receptors are the same as described in the surface water scenario above. In addition, the worker is assumed to ingest 480 mg of sediment daily, which is the upper-bound value used for incidental ingestion of soil (USEPA, 1991b).

6.1.2.7 Summary of Exposure Assessment - Eighteen potential exposure pathways were quantified in this assessment, including six current exposure pathways and twelve future pathways. The pathways quantified include:

Current Land Uses - Occupational Scenarios

1. Dermal contact with surface water
2. Dermal contact with sediments
3. Incidental ingestion of sediments

Current Land Uses - Trespassing Hunter Scenarios

4. Incidental ingestion of soil
5. Inhalation of fugitive dust
6. Dermal contact with soil

Future Land Uses - Occupational Scenarios

7. Dermal contact with surface water
8. Dermal contact with sediments
9. Incidental ingestion of sediments
10. Incidental ingestion of soil
11. Inhalation of fugitive dust
12. Dermal contact with soil

TABLE 6-20

FUTURE OCCUPATIONAL EXPOSURE (UTILITY WORKER): INCIDENTAL INGESTION OF SEDIMENTS – THREEMILE CREEK INGESTION INTAKES

Southwest Funston Landfill
Fort Riley, Kansas

INGESTION INTAKE (a) = $\frac{C * FI * IR * EF * ED * CF}{BW * AT}$

Where:

C = Concentration of constituent in sediment, mg/kg
FI = Fraction Ingested from source, unitless
IR = Ingestion Rate, mg/day
EF = Exposure Frequency, days/year
ED = Exposure Duration, years
CF = Conversion Factor, kg/10^6 mg
BW = Body Weight, kg
AT = Averaging Time, days

Exposure Variable	Incidental Ingestion of Sediment Utility Worker
FI	100%
IR	480[b]
EF	0.44[c]
ED	25[b]
CF	10^{-6}
BW	70[b]
AT (Noncarcinogen)	9,125[b]
AT (Carcinogen)	25,550[b]

PATHWAY-SPECIFIC INTAKES:

Incidental Ingestion of Sediment (future):

Utility Worker (Noncarcinogens):	C (mg/kg) * 8.27E-09 kg/kg-day
Utility Worker (Carcinogens):	C (mg/kg) * 2.95E-09 kg/kg-day

(a) Chemical-specific intakes are calculated in the risk calculation tables (Appendix M).
(b) USEPA, 1991b
(c) Conservative estimation based on DEH, 1993a; DEH, 1993b; and DEH, 1993d.

Future Land Uses - Recreational Hunter Scenarios
13. Incidental ingestion of soil
14. Inhalation of fugitive dust
15. Dermal contact with soil

Future Land Uses - Groundwater Scenario
16. Ingestion of drinking water
17. Inhalation of volatiles during bathing and household water use
18. Dermal contact while showering

Based on this summary of exposures, the reasonable maximum exposure (RME) that an individual at the site may be expected to encounter is as follows:

- Current RME receptor - a utility worker who also hunts on or near the SFL.
- Future RME receptor - a grounds maintenance worker who lives near the SFL (and obtains groundwater from the "hottest" well at the site for household use and drinking water) and uses the SFL area for hunting.

The current RME includes a utility worker since there is no residential exposure currently on-site. The personnel with the maximum exposure would be a utility worker on-site who also hunts on or near the site. There are no other occupational exposures on-site. The future RME includes a grounds maintenance worker (instead of a utility worker) because the estimated exposures are greater.

Exposure point concentrations for each of these pathways were determined based on the results of surface water, sediment, soil, and groundwater sampling events from sampling locations on site. The exposure point concentrations are multiplied by pathway-specific intake assumptions to yield quantitative estimates of chemical intakes for each pathway. Chemical-specific intake estimates are presented by pathway in Appendix M.

6.1.2.8 Uncertainties - A number of assumptions are required in developing quantitative estimates of chemical intakes. A certain amount of uncertainty is inherent in all assumptions. Table 6-21 summarizes the major assumptions associated with this exposure assessment and their inherent uncertainties. As shown, most of the assumptions will lead to an overestimate of the potential risks. This is consistent with the RME approach of this exposure assessment.

6.1.3 Toxicity Assessment

The toxicity assessment is an integral part of the preliminary risk evaluation process. First, a comparison of site concentrations to regulatory requirements, standards, and criteria is made.

TABLE 6–21

EVALUATION OF UNCERTAINTIES
Southwest Funston Landfill
Fort Riley, Kansas

Assumption	Potential Effect on Exposure May Overestimate	 May Underestimate
Environmental Sampling and Analysis:		
Exposure point concentration based on four rounds of sampling for ground water and one round of sampling for all other media	X	X
Probability of insufficient samples taken to characterize the environmental media being evaluated especially with respect to currently available surface soil data	X	X
Systematic or random errors in chemical analysis may yield erroneous data	X	X
Proxy concentrations assigned as one–half the method detection limit	X	X
Fate and Transport of Constituents:		
Use of a box model to estimate concentrations of contaminants in fugitive dust	X	X
No degradation or dispersion of contaminants assumed for estimating future exposure point concentrations	X	
Constituents detected in ground water at site will not impact existing potable water wells in vicinity		X
Exposure Pathways and Parameters:		
Future residential water well development on Southwest Funston Landfill	X	
Standard exposure parameters may not be representative of the actual exposed population	X	X
Future use of aquifer beneath SFL as drinking water source	X	
Intake by all pathways is assumed to be constant over the exposure duration	X	X
Current and future hunters exposed to fugitive dust on a daily basis	X	
Future residential users of the aquifer beneath the SFL exposed on a daily basis	X	
Current RME receptor works on the SFL and hunts on or near the site	X	
Future RME receptor obtains drinking water from the site and uses the SFL for hunting	X	

State and federal regulations, rules, guidelines, and criteria are compared to site concentrations in a sampled media. This comparison serves as a qualitative guide and points out media which may be serving as potential sources of risk.

In addition, quantitative reference values describing the toxicity of the constituents of concern are evaluated. Toxicity values such as Reference Dose or Reference Concentration (RfD/RfC) and Carcinogen Slope Factor (CSF) are based primarily on human and animal studies with supporting evidence from pharmacokinetics, mutagenicity, and chemical structure studies. The following sections will describe toxicity values used to evaluate current and potential exposures associated with the current and future exposed populations at the SFL.

Several constituents that have the potential for causing adverse human health effects have been found in the environmental media at the site. This section presents the available guidelines and standards which have been established by the USEPA for the chemicals of potential concern at the site. Additionally, a short description of the toxic effects of each chemical of concern is presented in Appendix N.

6.1.3.1 Summary of Potential ARARs - The potential chemical-specific ARARs and To Be Considered (TBC) requirements which apply for the chemicals and exposures at this site are summarized in this section.

6.1.3.1.1 Drinking Water Standards - The National Primary Drinking Water Regulations established by the USEPA provide MCLs and Maximum Contaminant Level Goals (MCLGs) for a number of constituents. By definition, the MCLGs equal to zero are non-enforceable health goals, while the MCLs are the enforceable standards which must be set as close to the MCLGs as feasible. Non-zero MCLGs are also considered ARARs for groundwater. The MCLs combine health effects data on specific chemicals with other concerns, such as analytical detection limits, treatment technology, and economic impact. Relevant state water regulations which set state MCLs for constituents may be more stringent than federal MCLs.

The receptor population's total environmental exposure to a specific chemical is considered in developing the MCL, which attempts to set lifetime limits at the lowest practicable level to reduce the amount of toxicants contributed by drinking water. An intake of two liters of water per day is assumed in developing MCLs. The MCLs are relevant for constituents in the groundwater at the site because the State of Kansas considers the aquifer beneath the site a potential potable water supply. Applicable state and federal MCLs for the chemicals of potential concern are provided in Table 6-22.

TABLE 6-22

REGULATORY AND GUIDANCE CRITERIA FOR GROUNDWATER
Southwest Funston Landfill
Fort Riley, Kansas

Parameter	Exposure Point Concentration [A] (mg/L)	Maximum Detected Concentration (mg/L)	Federal Maximum Contaminant Level [B] (mg/L)	Federal Maximum Contaminant Level Goal [B] (mg/L)	Kansas Maximum Contaminant Level [C] (mg/L)	Kansas Action Level [D] (mg/L)	Kansas Notification Level [D] (mg/L)	Alternate Kansas Action Level [D] (mg/L)	Alternate Kansas Notification Level [D] (mg/L)
Antimony	0.012	0.031	$\boxed{0.006}$ F	$\boxed{0.006}$ F	--	0.143	--	--	--
Arsenic	0.019	0.045	0.05	$\boxed{0}$	0.05	0.05	--	--	--
Barium	0.569	2.0	2 E	2 E	$\boxed{1}$	$\boxed{1}$	--	--	--
Benzene	0.0014	0.014	$\boxed{0.005}$	$\boxed{0}$	--	$\boxed{0.005}$	$\boxed{0.0005}$	--	--
Beryllium	0.0021	0.004	0.004 F	0.004 F	--	$\boxed{0.00013}$	--	--	--
Cadmium	0.0026	0.005	0.005	0.005	0.01	0.005	--	--	--
1,2-Dichloroethane	0.0028	0.016	$\boxed{0.005}$	$\boxed{0}$	--	$\boxed{0.005}$	$\boxed{0.0005}$	--	--
cis-1,3-Dichloropropene	0.0017	0.0059	--	--	--	$\boxed{0.002}$	$\boxed{0.0002}$	--	--
Manganese	1.748	2.7	$\boxed{0.05}$ S	$\boxed{0.2}$ F	--	$\boxed{0.05}$	--	--	--
1,1,2,2-Tetrachloroethane	0.003	0.015	--	--	--	$\boxed{0.0017}$	$\boxed{0.00017}$	--	--
Thallium	0.0017	0.0017	0.002	$\boxed{0.0005}$	--	0.013	--	--	--
1,1,2-Trichloroethane	0.0027	0.088	$\boxed{0.005}$	$\boxed{0.003}$	--	$\boxed{0.0061}$	$\boxed{0.00061}$	--	--
Vinyl Chloride	0.0054	0.018	$\boxed{0.002}$	$\boxed{0}$	--	$\boxed{0.002}$	$\boxed{0.0002}$	--	--

Boxed values indicate exceedence of regulatory or guidance criteria

S – Secondary MCL

P – Proposed MCL/MCLG

T – Value is for total chromium.

TT – Treatment technology – Action Level is value stated.

A – The 95% UCL (or maximum detected concentration if 95 % UCL > maximum concentration) of concentrations detected in ground water samples.

B – Maximum Contaminant Levels and Maximum Contaminant Level Goals (40 CFR 141 Subpart B)

C – Kansas Drinking Water Rules (KAR 28.15), last amended 1 May, 1988.

D – KDHE Memorandum, dated 5 December, 1988; Revised Groundwater Contaminant Cleanup Target Concentraions for Aluminum and Selenium.

E – National Public Drinking Water Rules for 38 Inorganic and Synthetic Organic Chemicals (January, 1991), Phase II Fact Sheet.

F – Drinking Water Regulations and Health Advisories, USEPA Office of Water, December 1992.

-- No guidance value available

In addition to MCLs, the state of Kansas has developed Kansas Action Levels (KALs), Kansas Notification Levels (KNLs), Alternate Kansas Action Levels (AKALs), and Alternate Kansas Notification Levels (AKNLs). The KNL or AKNL is used to constitute administrative confirmation that groundwater contamination exists. The KAL or AKAL is applied to represent the level at which long-term exposure to contaminant concentrations is unacceptable.
The KNL/KAL apply to fresh and usable water aquifers in the state; whereas, the AKNL/AKAL apply to alluvial aquifers and/or specific aquifers which surface through springs or seeps to become contributors to the surface water of the state (KDHE, 1988). Discussions with the KDHE (KDHE, 1992) indicate that the state of Kansas failed to meet the federally mandated deadline for completing revisions to the drinking water regulations and health advisories. Therefore, by default, the state is required to enforce the federally established MCLs.

The KALS, KNLs, AKALs, and AKNLs for constituents detected in the groundwater samples are included in Table 6-22 as TBCs. The AKALs and AKNLs were not available for most of these constituents. In general, the KNL values are one-tenth the KAL values.

The state also has a water antidegradation policy as follows. No degradation of water quality by artificial sources is allowed that could result in harmful effects on populations of any threatened or endangered species of aquatic life or wildlife in a critical habitat. The state antidegradation policy also states that "if existing surface water quality is better than applicable water quality criteria given in these regulations, water quality shall not be lowered unless it has been determined that the change is justified as a result of important social and economic development" (KAR, 1987).

6.1.3.1.2 Ambient Water Quality Criteria - The USEPA has developed AWQC for constituents in surface waters. The AWQC for the protection of aquatic organisms are derived based on two criteria: (1) acute criterion representing the maximum concentrations permissible at any time, and (2) chronic criterion representing the maximum permissible concentration averaged over a 24-hour time period.

The AWQC for the protection of human health accounts for ingestion of contaminated water and/or for the ingestion of contaminated organisms in surface waters (USEPA, 1987b). The AWQC for the protection of human health from the ingestion of water and organisms assumes a daily intake of two liters of water and 6.5 grams of fish. Ambient concentrations corresponding to several incremental lifetime cancer risk levels have been estimated for constituents exhibiting carcinogenic and/or mutagenic effects in laboratory tests and are, therefore, suspected of being carcinogenic to humans. The ambient or background concentrations which may result in one excess cancer per one million persons (risk = 1×10^{-6}) are presented as AWQC for constituents known or suspected to be carcinogens.

The state of Kansas incorporates the federal AWQC for the protection of aquatic life as the State Water Quality Standards by reference (KAR, 1987). Table 6-23 presents the potential ARARs and TBCs for the constituents detected in the site's surface water. These criteria are not entirely applicable to near-site surface water (for example, Threemile Creek) because the use of this surface water source for recreational activities or a domestic water supply is not feasible. Threemile Creek provides a limited aquatic habitat. However, recreational use of Threemile Creek is very unlikely due to its limited size and the presence of more desirable recreational streams in the near vicinity. In addition, neither Threemile Creek nor the Kansas River are used as a potable water supply. Therefore, the AWQC for the protection of human health are not entirely applicable to Threemile Creek or the Kansas River in the vicinity of the SFL.

The creek averages approximately 15 feet in width and 3 feet in depth. During the site reconnaissance, benthic macroinvertebrates were observed at each sampling station in Threemile Creek; it was also apparent that the creek supports aquatic life including shiner, minnow, and sunfish communities. Therefore, the AWQC for the protection of aquatic life are applicable.

6.1.3.1.3 Soil and Sediment Criteria - Currently under CERCLA regulations, no guidelines exist for allowable soil concentrations. In the proposed RCRA Subpart S regulations (Federal Register, 1990), Corrective Action Levels (CALs) have been developed which are health-based criteria serving as an indication of whether a corrective measure is required. The RCRA CALs for carcinogens are calculated based on CSFs. The calculation of lifetime (carcinogenic) soil criteria assumes that 0.1 grams of soil are ingested per day by a 70 kilogram (kg) person for a lifetime of 70 years (Federal Register, 1990). The CALs for systemic toxicants are calculated based on RfDs and are an estimate of the daily exposure an individual, including sensitive individuals, can experience without appreciable risk of health effects during a lifetime. The calculation of these criteria assumes that 0.2 grams of soil are ingested per day by a 15 kg child for a five-year period (1 to 6 years of age). The concentrations of constituents detected in the site's surface soil samples are compared to the proposed RCRA CALs in Table 6-24.

The National Oceanic and Atmospheric Administration (NOAA) has developed Effects Range concentrations which are non-enforceable guidance criteria for sediments (NOAA, 1990). These concentrations were derived from data on the potential of these chemicals to cause adverse biological effects in coastal marine and estuarine environments. The Effects Range - Low (ER-L) is the lower 10 percentile of concentrations with detectable adverse effects. The Effects Range - Median (ER-M) is the corresponding median concentration. The NOAA criteria are not strictly applicable to the site because they were developed for estuarine and marine environments, but they may be used as an indication of the general health of the ecosystem. The NOAA sediment criteria values are presented in Section 6.2 and are used as a basis for the environmental risk evaluation.

TABLE 6–23

REGULATORY AND GUIDANCE CRITERIA FOR SURFACE WATER
Southwest Funston Landfill
Fort Riley, Kansas

Parameter	Maximum Concentration Detected (mg/L) Threemile Creek	FEDERAL AMBIENT WATER QUALITY CRITERIA (mg/L)**				KANSAS STATE WATER QUALITY STANDARDS*** C For the Protection of Aquatic Life: (mg/L)
		For the Protection of Aquatic Life:		For the Protection of Human Health: (consumption of)		
		Acute	Chronic	Water & Fish	Fish only	
Aluminum	BB	--	--	--	--	--
Arsenic, pentavalent	0.0044^{T}	0.85^{A}	0.048^{A}	$\boxed{0.0022^{B}}$	0.0175^{B}	--
Arsenic, trivalent	0.0044^{T}	0.36	0.19	$\boxed{0.0022^{B}}$	0.0175^{B}	--
Barium	0.17	--	--	1	--	--
Manganese	0.15	--	--	$\boxed{0.05}$	$\boxed{0.1}$	--
Methylene Chloride	ND	--	--	--	--	--

Boxes indicate an exceedence of regulatory or guidance criteria
A – Insufficient data to develop criteria. Value presented is lowest observed effect level.
B – Human health criteria for carcinogens reported for three risk levels. Value presented in this table is the 10^{-6} risk level.
BB – Below background.
C – The State of Kansas has incorporated the Federal AWQC for the protection of aquatic life as the State Water Quality Standards by reference.
T – Valence of metal was not established; concentration listed in table is for total metal(s).
Sources: **Quality Criteria for Water – 1986. EPA 440/5–86.001, 1 May, 1987.
***Kansas Water Quality Standards (KAR 28.16.28), 1 May, 1987.

TABLE 6-24

COMPARISON OF CONSTITUENTS DETECTED IN SURFACE SOIL SAMPLES TO RCRA SOIL ACTION LEVELS

Southwest Funston Landfill
Fort Riley, Kansas

Parameter	Exposure Point Concentration[a] (Surface Soils) (mg/kg)	RCRA Soil Action Level[b] (mg/kg)
Aluminum	5900	30*
Antimony	5.8	30
Arsenic	3.1	80
Barium	170	4000
Beryllium	0.67	$\boxed{0.2}$
Cadmium	2.1	40
Chromium	16	400[c]
Copper	110	--
Lead	160	500-1000[d]
Manganese	220	--
Mercury	1.8	200
Silver	3.2	200
Thallium	0.26	7[e]
Vanadium	18	--
Zinc	250	--

Boxes indicate an exceedance of regulatory or guidance criteria.

-- No available soil action level

* Value is for aluminum phosphide.

[a] The maximum of detected concentrations in ths site samples.

[b] RCRA Action Levels – Federal Register, Vol. 55, No. 145, 27 July 1990. Pages 30798–30884. Corrective Action for Solid Waste Managements Facilities, Proposed Rule.

[c] Value is for hexavalent chromium.

[d] Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites. Memorandum from H. Longest and B. Diamond to EPA Regions. OSWER Directive No. 9355.4-02. September 7, 1989.

[e] Value is for thallium acetate.

6.1.3.2 Comparison of Exposure Point Concentrations to ARARs - The exposure point concentrations of the constituents of concern in the environmental media sampled for the SFL were compared to the ARARs for each medium. The Kansas MCLs are based on the federal MCLs, which are either the same or more conservative. Therefore, all discussions of comparisons to MCLs will refer to federal MCLs. The results of the comparisons are presented in Tables 6-22 through 6-24 and are discussed below.

6.1.3.2.1 Groundwater - Table 6-22 presents a comparison of the maximum detected concentrations and the exposure point concentrations for constituents of concern in groundwater to the available state and federal regulatory and guidance criteria. Please note that this comparison is based on actual detected concentrations at the SFL (where the groundwater is not currently used as a potable water supply), and not estimated or "modeled" concentrations to the nearest exposure point. Section 6.1.2.5.2 provides a more detailed discussion regarding the difficulty in modeling with current data.

As shown in Table 6-22, the exposure point concentrations and the maximum detected concentrations of antimony and vinyl chloride exceed both their Federal MCLs and MCLGs. The maximum detected concentrations of benzene, 1,2-dichloroethane, and 1,1,2-trichloroethane also exceed their respective Federal MCLs and Federal MCLGs. Both the exposure point concentration and the maximum detected concentration of thallium (0.0017 and 0.0017) exceed the Federal MCLG of 0.0005. The maximum detected concentration for barium of 2.0 mg/L exceeds the Kansas MCL and KAL of 1 mg/L. Both the exposure point concentration and the maximum detected concentration of 1,1,2,2-tetrachloroethane, and vinyl chloride exceed their KALs and their KNLs. The exposure point concentrations of 1,1,2-trichloroethane, benzene, cis-1,3-dichloropropene and 1,2-dichloroethane exceed their respective KNLs. The maximum detected concentrations for these constituents exceed both their KNLs (as above) and their KALs. Both the exposure point concentration of 0.0021 mg/L and maximum detected concentration 0.004 mg/L for beryllium exceed the KAL of 0.00013 mg/L.

It should be noted that the practical quantitation limit (PQL) for vinyl chloride is an order of magnitude above the MCL, as previously stated in Section 6.1. Therefore, the laboratory reports any result between 0.002 mg/L and 0.01 mg/L as an estimated result. It should also be noted that the PQL for antimony of 0.022 mg/L is greater than the Federal MCL of 0.006 mg/L. The exposure point concentrations for vinyl chloride and antimony listed in the previous paragraphs are based on two and three (non-estimated) data points, respectively, so the exceedance mentioned here is valid, but may be underestimated. The underestimation may result from using one-half the detection limit as proxy for non-detect concentrations. Similarly for the baseline and first quarter monitoring results the PQL for thallium of 0.022 mg/L exceeds the Federal MCL of 0.002 mg/L.

Both the maximum detected concentration (2.7 mg/L) and the exposure point concentration (1.748 mg/L) for manganese exceed the secondary MCL established by the federal government (0.05 mg/L). Secondary MCLs are used to define the aesthetic quality of drinking water and are not enforceable standards. However, it should be noted that the maximum detected concentration for manganese (2.7 mg/L) is consistent with concentrations of manganese in alluvial wells in the Kansas River Valley. Naturally occurring manganese concentrations ranging from 0.15 to 2.8 have been documented previously (Fader, 1974). There are currently no federal MCLs for cis-1,3-dichloro-propene and 1,1,2,2-tetrachloroethane.

6.1.3.2.2 Surface Water - The maximum detected concentrations for contaminants of concern in surface water were compared to AWQC for the protection of human health for the ingestion of water and fish and to the AWQC for the (chronic and acute) protection of aquatic life. The results are presented in Table 6-23. Manganese and arsenic concentrations in the surface water samples collected from Threemile Creek exceed the AWQC for the protection of human health (see Table 6-23). It should be noted that the maximum detected surface water concentrations for arsenic and manganese in Threemile Creek are well within the range of concentrations for these constituents detected upstream of SFL in the Kansas River (see Table 6-4 and Appendix C). Therefore, the concentrations detected in Threemile Creek may be naturally occurring levels for these constituents in surface waters of the Kansas River drainage basin. However, these constituents are included in this risk assessment because there were no upstream data available for Threemile Creek. There are no current regulatory criteria for aluminum or methylene chloride.

6.1.3.2.3 Surface Soils - The maximum detected concentrations for contaminants of concern in surface soil were compared to RCRA CALs for soil. The comparisons are presented in Table 6-24. With the exception of beryllium, the exposure point concentrations of all metals detected in surface soils are present in concentrations below available CALs. The exposure point concentration of beryllium, 0.67 mg/kg, exceeds the RCRA CAL of 0.2 mg/kg. There are no RCRA action levels for copper, manganese, vanadium, or zinc.

6.1.3.2.4 Sediments - The maximum detected concentration for contaminants of concern in sediments were compared to the NOAA criteria for sediments. The comparisons are presented and discussed in Section 6.2.2 (Table 6-35). The maximum detected concentrations of all metals detected in sediments are present in concentrations below available NOAA criteria. There are no NOAA criteria for aluminum, barium, beryllium, calcium, cobalt, iron, magnesium, manganese, potassium, sodium, vanadium and TRPH. The NOAA criteria are discussed in more detail in Section 6.2.2.2.

6.1.3.3 Toxicity Values for Noncarcinogenic and Carcinogenic Effects - The USEPA has developed toxicity values which reflect the magnitude of the adverse noncarcinogenic and carcinogenic effects from exposure to specific chemicals. Toxicity values for the chemicals of potential concern at this site are presented in this section.

6.1.3.3.1 Noncarcinogenic Effects - Chemicals that give rise to toxic endpoints other than cancer and gene mutations are often referred to as "systemic toxicants" because of their effects on the function of various organ systems. Chemicals considered to be carcinogenic can also exhibit systemic toxicity effects. For many noncarcinogenic effects, protective mechanisms (that is exposure or dose thresholds) are believed to exist that must be overcome before an adverse effect is manifested. This characteristic distinguishes systemic toxicants from carcinogens and mutagens which are often treated as acting without a distinct threshold. As a result, a range of exposure exists from zero to some finite value that can be tolerated with essentially no chance of the organism expressing adverse effects. In developing toxicity values for evaluating noncarcinogenic effects, the standard approach is to identify the upper bound of this tolerance range or threshold and to establish the toxicity values based on this threshold.

The toxicity value most often used in evaluating noncarcinogenic effects is a reference dose (RfD; expressed in units of mg/kg-day) for oral or dermal exposure or a reference concentration (RfC; expressed in units of mg/m^3) for inhalation exposure. Various types of RfDs/RfCs are available, depending on the exposure route of concern (oral or inhalation), the critical effect of the chemical (developmental or other), and the length of exposure being evaluated (chronic or subchronic).

A chronic RfD/RfC is defined as an estimate of a daily exposure level for the human population that is likely to be without appreciable risk of deleterious effects during a lifetime. Chronic RfDs/RfCs are specifically developed to be protective for long-term exposures, for example, seven years to a lifetime (70 years). All exposures, except childhood exposures, in this risk evaluation are assumed to be long-term.

Childhood exposures (such as the recreational child) in this risk assessment are evaluated using subchronic RfD$_{sc}$/RfC$_{sc}$. By definition, a subchronic RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a portion of a lifetime (USEPA, 1989a). For sites evaluated under the Superfund program, the subchronic RfD$_{sc}$/RfC$_{sc}$ is used for exposures lasting from two weeks to seven years. Since the recreational child being evaluated in this risk assessment is six years old, the use of a subchronic RfD$_{sc}$/RfC$_{sc}$ is appropriate. Subchronic RfD$_{sc}$/RfC$_{sc}$ values are obtained from the Health Effects Assessment Summary Tables (HEAST, 1992). In most cases, the subchronic RfD$_{sc}$/RfC$_{sc}$ values listed in HEAST for the constituents of concern are equivalent to the chronic values. However, the following exceptions exist, and therefore are used in evaluating childhood exposures in this risk assessment:

Constituent	Subchronic RfD_{sc} (mg/kg/day)	Chronic RfD (mg/kg/day)
cis-1,3-Dichloropropene	ORAL - 0.003	ORAL - 0.0003
Thallium	ORAL - 0.0009	ORAL - 0.00009
1,1,2-Trichloroethane	ORAL - 0.04	ORAL - 0.004
Zinc	ORAL - 0.2	ORAL - 0.3

The chronic RfDs/RfCs for the chemicals of concern at this site are presented in Table 6-25. As stated earlier, noncarcinogenic toxicity values for the inhalation route are often expressed as RfCs, in units of mg/m^3. Prior to input in Table 6-25, RfCs were converted to RfDs using standard default values, as follows:

$$\text{RfC (mg/m}^3\text{)} * \frac{20\ \text{m}^3}{\text{day}} * \frac{1}{70\ \text{kg}} = \text{RfD (mg/kg-day)}$$

The inhalation rate of 20 m^3/day and body weight of 70 kg are USEPA standard default values for an average adult male (USEPA, 1991b).

6.1.3.3.2 Carcinogenic Effects - Carcinogenesis, unlike many noncarcinogenic health effects, is generally thought to be a nonthreshold effect. In other words, USEPA assumes that a small number of molecular events can cause changes in a single cell that can lead to uncontrolled cellular growth. This hypothesized mechanism for carcinogenesis is referred to as "nonthreshold," because there is believed to be essentially no level of exposure to such a chemical that does not pose a finite probability of generating a carcinogenic response.

To evaluate carcinogenic effects, USEPA uses a two-part evaluation in which the chemical is first assigned a weight-of-evidence classification, then a Carcinogenic Slope Factor (CSF) is calculated. These indices can be derived for either oral or inhalation exposures. The weight-of-evidence classification is based on an evaluation of the available data to determine the likelihood that the chemical is a human carcinogen. Chemicals with the strongest evidence of human carcinogenicity are denoted with Class A, B1, or B2, while chemicals with less supporting evidence are classified as C or D. The slope factor quantitatively defines the relationship between the dose and the response. The slope factor is generally expressed as a plausible upper-bound estimate of the probability of response occurring per unit of chemical. The carcinogenic slope factors for the chemicals of potential concern at this site are presented in Table 6-26.

6.1.3.4 <u>Toxicity Assessment of Dermal Exposures</u> - Dermal intakes associated with groundwater and surface water exposures were adjusted to absorbed dose estimates by assuming

TABLE 6-25

TOXICITY VALUES FOR CHRONIC NONCARCINOGENIC EFFECTS
Southwest Funston Landfill
Fort Riley, Kansas

Parameter	Chronic RfD[a] (mg/kg-day)	Confidence Level[b]	Critical Effect	Uncertainty Factor[c]	Source
Oral Route:					
Aluminum[e]					
Antimony	4.0E-04	low	Affects longevity, blood glucose, and cholesterol	1000	IRIS
Arsenic	3.0E-04	medium	Hyperpigmentation, keratosis, vascular complications	3	IRIS
Barium	7.0E-02	medium	Increased blood pressure	3	IRIS
Benzene	no data				
Beryllium	5.0E-03	low	No adverse effects	100	IRIS
Cadmium	1.0E-03 (food) 5.0E-04 (water)	high	Significant proteinuria	10	IRIS
Chromium[d]	1.0E+00	low	No effects observed	100	IRIS
Cobalt	pending				
Copper	1.3E+00		Gastrointestinal system irritation		HEAST
1,2-Dichloroethane	no data				
cis-1,3-Dichloropropene	3.0E-04	low	Increased relative kidney weight in rats	10000	IRIS
Lead	no data				
Manganese	1.0E-01 (food) 5.0E-03 (water)				IRIS, HEAST
Mercury	3.0E-04				HEAST
Methylene chloride	6.0E-02	medium	Liver toxicity	100	IRIS
Silver	5.0E-03	low	Argyria	3	IRIS
1,1,2,2-Tetrachloroethane	no data				
Thallium (acetate)	9.0E-05	low	Increased levels of liver enzymes (SGOT & LDH)	3000	IRIS
1,1,2-Trichloroethane	4.0E-03	medium	Clinical serum chemistry	1000	IRIS
TRPH[e]					
Vanadium	pending (7.0E-03)		None observed	100	IRIS(HEAST)
Vinyl Chloride	no data				
Zinc	3.0E-01	medium	47% decrease in erythrocyte superoxide dismutase (ESOD) concentration in females after ten weeks of zinc exposure	3	IRIS

NOTES:
(Values in parentheses are from HEAST, and are used in the absence of a current IRIS value)
Pending – Under review by an EPA work group
Withdrawn – Withdrawn (from IRIS) as a result of Further review
Pending – Under review by an EPA work group
a – Inhalation RfCs are converted to RfDs as follows: RfC(mg/m^3) * 20 m^3/day * 1/70 kg = RfD (mg/kg-day)
b – Confidence Level (i.e., high, medium, or low) as reported in IRIS
c – Uncertainty Factors (UF) are assigned by USEPA in multiples of 10 based on the following limitations in the database used to develop the Rfc/RfD;
A – Animal to human extrapolation (UF of 10) S – Extrapolation from a subchronic NOAEL instead of a chronic NOAEL (UF of 10)
H – Variations in human sensitivity (UF of 10) L – Extrapolation from a LOAEL to a NOAEL (UF of 10)
d – Value is for trivalent chromium
e – IRIS or HEAST listing not available for this chemical

Source: IRIS = Integrated Risk Information System (6/93)
HEAST = Health Effects Assessment Summary Tables (FY – 1992 Annual)

TABLE 6-25

TOXICITY VALUES FOR CHRONIC NONCARCINOGENIC EFFECTS
Southwest Funston Landfill
Fort Riley, Kansas

Parameter	Chronic RfD[a] (mg/kg-day)	Confidence Level[b]	Critical Effect	Uncertainty Factor[c]	Source
Inhalation Route:					
Aluminum[e]					
Antimony	no data				
Arsenic	no data				
Barium	pending (1.4E-04)		Fetotoxicity		IRIS (HEAST)
Benzene	no data				
Beryllium	no data				
Cadmium	pending				
Chromium[d]	pending				
Cobalt	no data				
Copper	no data				
1,2-Dichloroethane	no data				
cis-1,3-Dichloropropene	5.7E-03	high	Affects nasal tissue	30	IRIS
Lead	no data				
Manganese	1.1E-04	medium	Increased prevalence of respiratory symptoms and psychomotor disturbances	300	IRIS
Mercury	8.6E-05			30	HEAST
Methylene chloride	pending (8.6E-01)		Liver toxicity	100	IRIS (HEAST)
Silver	no data				
1,1,2,2-Tetrachloroethane	no data				
Thallium (acetate)	no data				
1,1,2-Trichloroethane	no data				
TRPH[e]					
Vanadium	no data				
Vinyl Chloride	no data				
Zinc	no data				

NOTES:
(Values in parentheses are from HEAST, and are used in the absence of a current IRIS value)
Pending – Under review by an EPA work group
Withdrawn – Withdrawn (from IRIS) as a result of Further review
Pending – Under review by an EPA work group
a – Inhalation RfCs are converted to RfDs as follows: RfC(mg/m^3) * 20 m^3/day * 1/70 kg = RfD (mg/kg-day)
b – Confidence Level (i.e., high, medium, or low) as reported in IRIS
c – Uncertainty Factors (UF) are assigned by USEPA in multiples of 10 based on the following limitations in the database used to develop the Rfc/RfD;
A – Animal to human extrapolation (UF of 10) S – Extrapolation from a subchronic NOAEL instead of a chronic NOAEL (UF of 10)
H – Variations in human sensitivity (UF of 10) L – Extrapolation from a Loael to a Noael (UF of 10)
d – Value is for trivalent chromium
e – IRIS or HEAST listing not available for this chemical

Source: IRIS = Integrated Risk Information System (6/93)
HEAST = Health Effects Assessment Summary Tables (FY – 1992 Annual)

TABLE 6-26

TOXICITY VALUES FOR POTENTIAL CARCINOGENIC EFFECTS

Southwest Funston Landfill
Fort Riley, Kansas

Parameter	Slope Factor (kg-day/mg)	Weight of Evidence[d]	Type of Cancer	Source
Oral Route:				
Aluminum[b]	- - -			
Antimony	no data			
Arsenic	1.8E+00	A	Skin cancer	EPA
Barium	no data			
Benzene	2.9E-02	A	Nonlymphocytic leukemia	IRIS
Beryllium	4.3E+00	B2	Lung cancer via inhalation (rats, monkeys); Osteosarcomas via I.V. and intramedullary injection	IRIS
Cadmium	no data	B1		IRIS
Chromium[c]	pending			
Cobalt	no data			
Copper	no data	D		IRIS
1,2-Dichloroethane	9.1E-02	B2	Several tumor types in rats and mice and lung papillomas in mice	IRIS
cis-1,3-Dichloropropene	1.8E-01	B2	Several tumor types in rats and mice	IRIS
Lead	no data	B2		
Manganese	no data			
Mercury	no data			
Methylene chloride	7.5E-03	B2	Increased incidence of heptocellular neoplasms and alveolar/ bronchiolar neoplasms	IRIS
Silver	no data			
1,1,2,2-Tetrachloroethane	2.0E-01	C	Hepatocellular carcinomas in mice	IRIS
Thallium (acetate)	no data			
1,1,2-Trichloroethane	5.7E-02	C	Hepatocellular carcinomas and pheochroacytomas in mice	IRIS
TRPH[b]	- - -			
Vanadium	no data			
Vinyl Chloride	1.9E-00	A	Lung and liver tumors in rats	IRIS/HEAST
Zinc	no data	D		

NOTES:

No Data - No value listed in reference
(Values listed in parentheses are from HEAST, and are used in the absence of current IRIS values)
Pending - Under review by an EPA work group
(a) Slope factors provided in terms of unit risk are converted prior to input to this table as follows:
for oral route: UNIT RISK (L/ug) * 1,000 ug/mg * day/2 L * 70 kg = CSF(kg-day/mg)
for inhalation route: UNIT RISK (m^3/ug) * 1,000 ug/mg * day/20 m^3 * 70 kg = CSF(kg-day/mg)
(b) IRIS or HEAST listing not available for this chemical
(c) Value is for trivalent chromium
(d) Weight of Evidence Classification:
A - Human Carcinogen
B1 - Probable human carcinogen; limited human data available
B2 - Probable human carcinogen; inadequate or no evidence in humans
C - Possible human carcinogen
D - Not classifiable as to human carcinogenicity

Source: IRIS = Integrated Risk Information System (6/93)
HEAST = Health Effects Assessment Summary Tables (FY - 1992 Annual)
EPA = Memorandum to Assisstant Administrators. Recommended Agency Policy on the Carcinogenicity Risk Associated with the Ingestion of Inorganic Arsenic. USEPA, Office of the Administrator, Washington, D.C. June 21, 1988.

TABLE 6-26

TOXICITY VALUES FOR POTENTIAL CARCINOGENIC EFFECTS
Southwest Funston Landfill
Fort Riley, Kansas

Parameter	Slope Factor (kg-day/mg)	Weight of Evidence[d]	Type of Cancer	Source
Inhalation Route:				
Aluminum[b]	---			
Antimony	no data			
Arsenic	1.5E+01	A	Lung cancer	IRIS
Barium	no data			
Benzene	2.9E-02	A	Nonlymphatic leukemia	IRIS
Beryllium	8.4E+00	B_2	Lung cancer via inhalation (rats,monkeys); osteosarcomas via I.V. and intramedullary injection (rabbits)	IRIS
Cadmium	6.3E+00	B_1	Carcinogenic in mice by various routes	IRIS
Chromium[c]	pending			IRIS
Cobalt	no data			
Copper	---			
1,2-Dichloroethane	9.1E-02	B_2	Several tumor types in rats and mice and lung papillomas in mice	IRIS
cis-1,3-Dichloropropene	no data	B_2		
Lead	no data	B_2		
Manganese	no data			
Mercury	no data			
Methylene chloride	1.6E-03	B_2	Increased incidence of heptocellular neoplasms and alveolar/ bronchiolar neoplasms	IRIS
Silver	no data			
1,1,2,2-Tetrachloroethane	2.0E-01	C	Hepatocellular carcinomas in mice	IRIS
Thallium (acetate)	no data			
1,1,2-Trichloroethane	5.7E-02	C	Hepatocellular carcinomas and pheochroacytomas in mice	IRIS
TRPH[b]	---			
Vanadium	no data			
Vinyl Chloride	3.0E-01	A	Lung and liver tumors in rats	IRIS/HEAST
Zinc	---	D		IRIS

NOTES:

No Data - No value listed in reference
(Values listed in parentheses are from HEAST, and are used in the absence of current IRIS values)
Pending - Under review by an EPA work group
(a) Slope factors provided in terms of unit risk are converted prior to input to this table as follows:
for oral route: UNIT RISK (L/ug) * 1,000 ug/mg * day/2 L * 70 kg = CSF(kg-day/mg)
for inhalation route: UNIT RISK (m^3/ug) * 1,000 ug/mg * day/20 m^3 * 70 kg = CSF(kg-day/mg)
(b) IRIS or HEAST listing not available for this chemical
(c) Value is for trivalent chromium
(d) Weight of Evidence Classification:
A - Human Carcinogen
B1 - Probable human carcinogen; limited human data available
B2 - Probable human carcinogen; inadequate or no evidence in humans
C - Possible human carcinogen
D - Not classifiable as to human carcinogenicity

Source: IRIS = Integrated Risk Information System (6/93)
HEAST = Health Effects Assessment Summary Tables (FY - 1992 Annual)
EPA = Memorandum to Assistant Administrators. Recommended Agency Policy on the Carcinogenicity Risk Associated with the Ingestion of Inorganic Arsenic. USEPA, Office of the Administrator, Washington, D.C. June 21, 1988.

that the contaminants permeate skin at chemical-specific permeability rates (USEPA, 1992b). Permeability constants for constituents detected in aqueous media are listed on the Risk Characterization Tables in Appendix M. Chemical-specific permeability constants are not currently available for constituents detected in soil and sediment media; therefore, dermal intakes for these media are not adjusted to absorbed doses by using permeation rates.

No RfDs or CSFs have been derived for dermal absorption. According to USEPA guidance, risks associated with dermal exposures may be evaluated with Oral Absorbed Dose RfDs or Oral Absorbed Slope Factors after dermal exposures are converted to their respective absorbed dose (USEPA, 1992b). However, in accordance with USEPA Region VII guidance (USEPA, 1992c), oral RfDs and CSFs were not adjusted by oral absorption rates (i.e., the default absorbance factor used in Region VII is 100 percent). The constituents are assumed to be completely absorbed through the skin. Thus, bioavailability is assumed to be equal to that received from an oral dose. This is a conservative assessment process because the majority of constituents detected at the site are not highly lipid soluble and thus, are not readily absorbed through intact skin.

6.1.4 Risk Characterization

The risk characterization integrates the results of the exposure and toxicity assessments into quantitative and qualitative expressions of risk. To characterize potential noncarcinogenic effects, comparisons are made between the estimated chemical intakes and the RfDs/RfCs for those chemicals; to characterize potential carcinogenic effects, estimated chemical intakes are multiplied by the chemical-specific slope factors to yield chemical-specific dose-response information.

6.1.4.1 Noncarcinogenic Effects Characterization - Noncarcinogenic effects are characterized by comparing the estimated chemical intakes to the appropriate RfD/RfC value. The RfD/RfC value is, by definition, an estimate of a daily exposure level for the human population that is likely to be without appreciable risk of deleterious effects during a lifetime. Therefore, when the estimated chronic daily intake of a chemical exceeds the appropriate RfD/RfC, there may be a concern for potential noncancer effects from exposure to that chemical. The ratio of the chronic daily intake to the chronic RfD/RfC is referred to as the "hazard quotient." The sum of the hazard quotients for each chemical in a specific pathway is termed the "hazard index." It is important to note that the hazard quotient does not represent a statistical probability; a ratio of 0.01 does not mean that there is a one in one hundred chance of the effect occurring. Rather, a hazard quotient greater than 1.0 indicates that the "threshold" for that chemical has been exceeded. The chemical-specific hazard quotient calculations are presented, by pathway, in Appendix M.

The USEPA assumes additivity of effects in evaluating noncarcinogenic effects from a mixture of chemicals. The chemical-specific hazard quotients are summed to yield an overall pathway hazard index; pathway hazard indices are then summed to yield a total risk for each relevant population. Table 6-27 presents a summary of the chronic hazard index estimates for exposed adults and children by pathway.

The following sections will discuss the risk of noncarcinogenic effects for current and future exposed populations, by media and exposure pathway.

6.1.4.1.1 Current Noncarcinogenic Risk - Currently exposed populations include recreational adults and children and occupational adults only. The media-specific risks, by pathway, are presented as follows.

Surface Soils - The calculated hazard indices for noncarcinogenic effects of exposure of current trespassing adults (for example, hunters) to surface soil by incidental ingestion, dermal contact, and inhalation of fugitive dust are below the departure point of 1.0. Based on current site-specific data, there is no unacceptable noncarcinogenic risk from exposure to surface soil for trespassing hunters by these pathways.

Hazard quotients for off-site workers' (at Camp Funston) exposure to surface soils were not calculated because these receptors do not have direct exposure to site (SFL) soils. Any exposure due to site surface soils should be no more than that experienced by the on-site hunter because the off-site workers have no dermal contact with SFL soils, have less exposure to fugitive dust, and negligible exposure via incidental ingestion. Since the hazard indices calculated for the trespassing hunter are at least one order of magnitude below 1.0, the hazard index for an off-site worker should also be less than 1.0.

Subsurface Soils - Hazard quotients for on-site hunters' and utility workers' exposure to subsurface soils were not calculated because these receptors do not have direct exposure to deep subsurface soil. Any risk due to exposure resulting from utility excavation work would probably be in soils up to 10 feet deep; these risks cannot be estimated because no data exist for soils of this depth. The subsurface soil samples collected at the SFL ranged between 16 and 64 feet below ground surface.

Groundwater - Noncarcinogenic risk due to current exposures to groundwater was not calculated because there are no potable water supply wells are currently operational on the SFL site.

Surface Water - The chronic hazard indices for dermal exposure to Threemile Creek surface water during utility work fall below the departure point of 1.0 for occupational adults. Therefore, based on current site data, no evidence exists of potentially unacceptable risks to persons exposed to Threemile Creek surface water.

TABLE 6-27

SUMMARY OF NONCARCINOGENIC RISKS, CURRENT AND FUTURE
Southwest Funston Landfill
Fort Riley, Kansas

Receptors	Surface Soil Expsoures			Ground Water Exposures			Surface Water Expsoures	Sediment Exposures		Totals for Each Receptor (a)
	Ingestion	Inhalation	Dermal	Ingestion	Inhalation	Dermal	Dermal	Ingestion	Dermal	
Current Population:										
trespassing hunter	0.009	0.030	0.19	NA	NA	NA	NA	NA	NA	0.23
utility worker (Threemile Creek)	NA	NA	NA	NA	NA	NA	<0.001	<0.001	<0.001	0.001
Future Population:										
recreational hunter	0.009	0.030	0.19	NA	NA	NA	NA	NA	NA	0.23
grounds maintenance worker	0.008	0.005	0.059	NA	NA	NA	NA	NA	NA	0.07
utility worker (Threemile Creek)	NA	NA	NA	NA	NA	NA	<0.001	<0.001	<0.001	0.001
(offsite) residential adult	NA	NA	NA	26	0.07	0.03	NA	NA	NA	26
(offsite) residential child	NA	NA	NA	54	0.19	0.05	NA	NA	NA	54

Boxed values indicate an exceedance of acceptable risk levels.
NA – Not applicable; pathway not evaluated.

(a) Possible RME receptors for the SFL site, and the total potential risk associated with the receptors' exposures, follow:

- Current RME Receptor – A utility worker (HI = 0.001) who also hunts (HI= 0.23) on or near the SFL site
  TOTAL NONCARCINOGENIC RISK ESTIMATED 0.2

- Future RME Receptor – A grounds maintenance worker (HI = 0.07) living near SFL and using the groundwater ("hottest" well) beneath the site as a potable water supply (HI= 80; see Table 6-29), who also hunts (HI=0.23) on or near the SFL site.
  TOTAL NONCARCINOGENIC RISK ESTIMATED 80

TABLE 6–27

SUMMARY OF NONCARCINOGENIC RISKS, CURRENT AND FUTURE
Southwest Funston Landfill
Fort Riley, Kansas

Current & Future Surface Soil Exposures

Hunter

Ingestion		*	Inhalation		*	Dermal		*
FI =	100%	a	--			SA =	2,020 cm^2	e
IR_S =	100 mg/day	j	IR_A =	2.5 m^3/hr	e	AF =	1 mg/cm^2	f
EF =	50 day/yr	c	ET =	8 hr/day	b	EF =	50 day/yr	c
ED =	30 yr	b	EF =	50 day/yr	c	ED =	30 yr	b
BW =	70 kg	b	ED =	30 yr	b	BW =	70 kg	b
AT =	10,950 day	b	BW =	70 kg	b	AT =	10,950 day	b
			AT =	10,950 day	b	ABS=	100%	g

Future Surface Soil Exposures

Grounds Maintenance Worker

Ingestion		*	Inhalation		*	Dermal		*
FI =	100%	a	--			SA =	3,160 cm^2	e
IR_S =	480 mg/day	b	IR_A =	2.5 m^3/hr	e	AF =	1 mg/cm^2	f
EF =	10 day/yr	d	ET =	8 hr/day	b	EF =	10 day/yr	d
ED =	25 yr	b	EF =	10 day/yr	d	ED =	25 yr	b
BW =	70 kg	b	ED =	25 yr	b	BW =	70 kg	b
AT =	9,125 day	b	BW =	70 kg	b	AT =	9,125 day	b
			AT =	9,125 day	b	ABS=	100%	g

Current & Future Surface Water Exposures

Utility Worker

Dermal		*
SA =	5,170 cm^2	e
ET_W=	8 hr/day	b
EF =	3 day/yr	i
ED =	25 yr	b
BW =	70 kg	b
AT =	9,125 day	b

Current & Future Sediment Exposures

Utility Worker

Ingestion		*	Dermal		*
FI =	100%	a	SA =	3,160 cm^2	e
IR_S =	480 mg/day	b	AF =	1 mg/cm^2	f
EF =	0.44 day/yr	i	EF =	0.44 day/yr	i
ED =	25 yr	b	ED =	25 yr	b
BW =	70 kg	b	BW =	70 kg	b
AT =	9,125 day	b	AT =	9,125 day	b
			ABS=	100%	g

Future Groundwater Exposures

Residential Adult

Ingestion		*	Inhalation		*	Dermal		*
IR_G =	2 L/day	b	IR_A =	20 m^3/day	b	SA =	19,400 cm^2	e
EF =	350 day/yr	b	EF =	350 day/yr	c	EF =	350 day/yr	b
ED =	30 yr	b	ED =	30 yr	c	ED =	30 yr	b
BW =	70 kg	b	BW =	70 kg	c	BW =	70 kg	b
AT =	10,950 day	b	AT =	10,950 day	c	AT =	10,950 day	b
			ET_S=	0.2 hr/day	c	ET_S=	0.2 hr/day	f
			K =	0.5 L/m^3	h			

Residential Child

Ingestion		*	Inhalation		*	Dermal		*
IR_G =	2 L/day	b	IR_A =	20 m^3/day	b	SA =	8,660 cm^2	e
EF =	350 day/yr	b	EF =	350 day/yr	c	EF =	350 day/yr	b
ED =	6 yr	b	ED =	6 yr	c	ED =	6 yr	b
BW =	15 kg	b	BW =	15 kg	c	BW =	15 kg	b
AT =	2,190 day	b	AT =	2,190 day	c	AT =	2,190 day	b
			ET_S=	0.2 hr/day	c	ET_S=	0.2 hr/day	f
			K =	0.5 L/m^3	h			

KEY FOR ACRONYMS

FI –	Fraction Ingested from Source	ABS –	Absorption Factor
IR_S –	Ingestion Rate of Soil/Sediment	ET_S –	Exposure Time in Shower
IR_A –	Inhalation Rate of Air	ET_W –	Exposure Time in Surface Water
IR_G –	Ingestion Rate of Groundwater	EF –	Exposure Frequncy
SA –	Surface Area of Exposed Skin	ED –	Exposure Duration
K –	Volatilization factor	BW –	Body Weight
AF –	Soil-to-Skin Adherence Factor	AT –	Averaging Time

* NOTES:

a – USEPA, 1989a
b – USEPA, 1991b
c – Fort Riley, 1993a; KDWP, 1988; KDWP, 1991; KDWP, 1992.
d – Master Lawn and Landscaping, 1993.
e – USEPA, 1989b
f – USEPA, 1992b
g – USEPA, 1992c
h – Andelman, 1990; as cited by USEPA, 1991c.
i – Conservative estimationbased on DEH, 1993a and DEH, 1993b; and DEH, 1993d.
j – Calabrese et al. 1987(as cited in USEPA, 1989b); USEPA, 1991c.
k – West et al., 1989.

No volatile organics were detected in any of the surface water samples for exposure from inhalation. Therefore, no hazard index was calculated for exposure by this pathway.

Sediments - The hazard indices for exposure of current occupational adults to Threemile Creek sediments by incidental ingestion and dermal contact fall below the departure point of 1.0. Therefore, potentially unacceptable noncarcinogenic risks from exposure to sediments are not currently present.

6.1.4.1.2 Future Noncarcinogenic Risk - Future potentially exposed populations include occupational receptors (utility workers and grounds maintenance workers), recreational adults (hunters), and off-site residents (adults and children) who may use the groundwater beneath the site as a potable water supply. The media-specific risks, by pathway, are presented as follows.

Surface Soils - The calculated hazard indices for noncarcinogenic effects of exposure of future occupational adults (grounds maintenance workers) and future recreational adults (hunters) to surface soil by incidental ingestion, dermal contact, and inhalation of fugitive dust are below the standard point of departure of 1.0. Based on current site-specific data, and assuming no increase in constituent concentrations, there are no projected unacceptable systemic risks from exposure to surface soil through these pathways.

Hazard quotients for off-site workers' (at Camp Funston) exposure to surface soils were not calculated because these receptors do not have direct exposure to site (SFL) soils. Any exposure due to site soils should be no more than that experienced by the on-site hunter or on-site grounds maintenance worker, because off-site receptors would have no direct dermal exposure, negligible incidental ingestion exposure, and lesser fugitive dust exposure than the on-site receptors.

Hazard quotients for on-site residents' exposure to surface soils were not calculated because the future development of the SFL for residential use is precluded because the SFL site lies entirely within the floodplain of the Kansas River.

Subsurface Soils - Hazard quotients for future on-site hunters' and grounds keepers' exposure to subsurface soils were not calculated because these receptors do not have direct exposure to deep subsurface soil. Subsurface soil samples at the SFL were collected from depths ranging between 16 and 64 feet below ground surface. Subsurface soil exposures to utility workers would most likely be to soils 10 feet deep or less. These risks cannot be estimated because no data exist for subsurface soils of this depth.

Groundwater - The hazard indices for future exposure to groundwater by ingestion of drinking water by residential adults and children are 26 and 54, respectively; both exceed the departure point of 1.0. The risk is primarily attributed to the presence of manganese and, to a lesser extent, antimony and arsenic in the groundwater. Arsenic was detected in 47 of 56 wells. The maximum concentration detected (0.045 mg/L) was below the MCL (0.05 mg/L). Manganese was detected in all 56 wells, with a 95 percent UCL concentration (1.7 mg/L) greater than the secondary MCL of 0.05 mg/L. Secondary MCLs are used to define the aesthetic quality of drinking water and are not enforceable standards. As discussed previously, the manganese concentrations detected at SFL are consistent with naturally occurring concentrations in alluvial wells of the Kansas River valley (Fader, 1974). Therefore, the manganese in the groundwater at SFL may not be site-related.

The estimate of risk for this pathway is conservative, as it is based on the assumption that potable water wells will be installed and used as a residential water supply in the future. As stated earlier, the future development of the SFL site for this use is not likely to occur. In addition, the groundwater scenario presented in this risk assessment assumes all of the drinking water ingested in a given day comes from the contaminated source and that the constituent concentrations currently present in site groundwater will reach residential groundwater users unchanged.

The hazard indices calculated for future exposure to groundwater by inhalation of volatile organics did not exceed the departure point of 1.0, with an HI of 0.07 for adults and 0.2 for children. This indicates that there should not be cause for concern due to inhalation exposures to groundwater based on current site-specific data. It should be noted that all estimations of risk due to groundwater are based on the actual concentrations detected in the site's aquifer. Further study is needed before an accurate "modeling" of groundwater constituent concentrations to the nearest exposure point can be accomplished. If constituent concentrations were able to be modeled to the nearest potable water well, they would probably decrease as a result of dilution, decay, and other forms of attenuation. Therefore, the risks estimated here for groundwater exposures are likely to be overestimated.

The hazard index calculated for future exposure to groundwater by dermal contact during showering falls below the standard departure point of 1.0. Therefore, no projected unacceptable systemic risks exist due to exposure to groundwater by this pathway.

<u>Surface Water</u> - The chronic hazard index is less than 1.0 for dermal exposure to Threemile Creek surface water during utility repair work for occupational receptors. Therefore, based on current site data, there is no evidence of potentially unacceptable systemic risks to persons who may be exposed to Threemile Creek surface water during utility repair.

No volatile organics were detected in surface water samples collected from the site. Therefore, no hazard index was calculated for exposure to surface water by inhalation.

<u>Sediments</u> - The hazard indices for exposure of future occupational adults to Threemile Creek sediments by incidental ingestion and dermal contact fall below the departure point of 1.0. Therefore, based on current site-specific data, potentially unacceptable noncarcinogenic risks from exposure to sediments are not present.

6.1.4.2 Carcinogenic Risk Characterization - Risks from potential carcinogens are estimated as probabilities of excess cancers as a result of exposure to chemicals from the site. The carcinogenic slope factor correlates estimated total chronic daily intake directly to incremental cancer risk. The results of the risk characterization are expressed as upper-bound estimates of the potential carcinogenic risk for each exposure point. Chemical-specific cancer risks are estimated by multiplying the slope factor by the chronic daily intake estimates. Chemical-specific risk calculations are presented by pathway in Appendix M.

To assess the overall potential for cancer effects posed by the mixture of chemicals present at the site, USEPA assumes additivity. Therefore, cancer risks are estimated for each chemical, then the chemical-specific risks are summed to yield an estimate of the overall pathway-specific cancer risk. Table 6-28 provides a summary of the cancer risk estimates for each receptor population by pathway.

Carcinogenic risks for children are not calculated, because carcinogenic risk is determined from chronic exposures (>7 years) to site constituents. Therefore, the calculation of carcinogenic risk for 6-year-old children is not performed, given their length of exposure. USEPA assumes carcinogenesis is a nonthreshold event which can result from a single exposure to a carcinogen. Therefore, where appropriate, time-weighted averages of intake were estimated to account for differing intake rates between child and adult receptors. These time-weighted averages were used to estimate residential adult exposure to carcinogens over a lifetime.

The National Contingency Plan defines acceptable exposure levels as concentration levels that represent an excess upper bound lifetime cancer risk within the range of 1×10^{-4} to 1×10^{-6}. This corresponds to one excess cancer in a population of ten thousand to one excess cancer in a population of one million. The risk of carcinogenic effects for current and future exposed populations, by media and exposure pathway, will be discussed in the following sections.

6.1.4.2.1 Current Carcinogenic Risk - The current risks from exposure to carcinogens present at the SFL were evaluated for recreational (hunters and fishermen) and occupational (utility worker) adult populations. The media-specific carcinogenic risks, by pathway, are presented below.

Surface Soils - The calculated carcinogenic risks for the current trespassing hunter's exposure to surface soil by dermal contact is within the NCP risk range of 1×10^{-4} to 1×10^{-6}, while the carcinogenic risk for the trespassing hunter's exposure to surface soil by incidental ingestion and inhalation of fugitive dust is below the NCP cancer risk range. Based on current conditions at the site, there is no unacceptable carcinogenic risk from exposure to surface soil for trespassing hunters by these exposure pathways.

TABLE 6-28

SUMMARY OF CARCINOGENIC RISKS, CURRENT AND FUTURE
Southwest Funston Landfill
Fort Riley, Kansas

Receptors	Surface Soil Exposures			Ground Water Exposures			Surface Water Exposures	Sediment Exposures		Totals for Each Receptor (a)
	Ingestion	Inhalation	Dermal	Ingestion	Inhalation	Dermal	Dermal	Ingestion	Dermal	
Current Population:										
trespassing hunter	7×10^{-7}	2×10^{-7}	$\boxed{1 \times 10^{-5}}$	NA	NA	NA	NA	NA	NA	$\boxed{1 \times 10^{-5}}$
utility worker (Threemile Creek)	NA	NA	NA	NA	NA	NA	2×10^{-9}	1×10^{-8}	7×10^{-8}	8×10^{-8}
Future Population:										
recreational hunter	7×10^{-7}	2×10^{-7}	$\boxed{1 \times 10^{-5}}$	NA	NA	NA	NA	NA	NA	$\boxed{1 \times 10^{-5}}$
grounds maintenance worker	6×10^{-7}	4×10^{-8}	$\boxed{4 \times 10^{-6}}$	NA	NA	NA	NA	NA	NA	$\boxed{5 \times 10^{-6}}$
utility worker (Threemile Creek)	NA	NA	NA	NA	NA	NA	2×10^{-9}	1×10^{-8}	7×10^{-8}	8×10^{-8}
(offsite) residential adult	NA	NA	NA	$\boxed{\boxed{1 \times 10^{-3}}}$	$\boxed{\boxed{3 \times 10^{-4}}}$	$\boxed{4 \times 10^{-6}}$	NA	NA	NA	$\boxed{\boxed{1 \times 10^{-3}}}$

Double boxed values indicate an exceedance of the NCP carcinogenic risk range (cancer risk > 1×10^{-4}); single boxed values indicate carcinogenic risk within the NCP risk range (1×10^{-6} to 1×10^{-4}).
NA – Not applicable; pathway not evaluated.

(a) Possible RME receptors for the SFL site, and the total potential risk associated with the receptors' exposures, follow:

- Current RME Receptor – A utility worker (cancer risk = 8×10^{-8}) who also hunts (cancer risk = 1×10^{-5}) on or near the SFL site.
  TOTAL CANCER RISK ESTIMATED = $\boxed{1 \times 10^{-5}}$
- Future RME Receptor – A grounds maintenance worker (cancer risk = 5×10^{-6}) living near SFL and using the groundwater ("hottest well") beneath the site as a potable water supply (cancer risk = 3×10^{-3}; see Table 6-29) who also hunts (cancer risk = 1×10^{-5}) on or near the SFL site
  TOTAL CANCER RISK ESTIMATED = $\boxed{\boxed{3 \times 10^{-3}}}$

TABLE 6–28

SUMMARY OF CARCINOGENIC RISKS, CURRENT AND FUTURE
Southwest Funston Landfill
Fort Riley, Kansas

Current & Future Surface Soil Exposures
Hunter

Ingestion		*	Inhalation		*	Dermal		*
FI =	100%	a	--			SA =	2,020 cm^2	e
IR_S =	100 mg/day	j	IR_A =	2.5 m^3/hr	e	AF =	1 mg/cm^2	f
EF =	50 day/yr	c	EF =	50 day/yr	c	EF =	50 day/yr	c
ED =	30 yr	b	ET =	8 hr/day	b	ED =	30 yr	b
BW =	70 kg	b	ED =	30 yr	b	BW =	70 kg	b
AT =	25,550 day	b	BW =	70 kg	b	AT =	25,550 day	b
			AT =	25,550 day	b	ABS=	100%	g

Current & Future Surface Water Exposures
Utility Worker

Dermal		*
SA =	5,170 cm^2	e
ET_W=	8 hr/day	b
EF =	0.44 day/yr	i
ED =	25 yr	b
BW =	70 kg	b
AT =	25,550 day	b

Current & Future Sediment Exposures
Utility Worker

Ingestion		*	Dermal		*
FI =	100%	a	SA =	3,160 cm^2	e
IR_S =	480 mg/day	b	AF =	1 mg/cm^2	f
EF =	0.44 day/yr	i	EF =	0.44 day/yr	i
ED =	25 yr	b	ED =	25 yr	b
BW =	70 kg	b	BW =	70 kg	b
AT =	25,550 day	b	AT =	25,550 day	b
			ABS=	100%	g

Future Groundwater Exposures
Residential Adult

Ingestion		*	Inhalation		*	Dermal		*
IR_G =	2 L/day	b	IR_A =	20 m^3/day	b	SA =	19,400 cm^2	e
EF =	350 day/yr	b	EF =	350 day/yr	c	EF =	350 day/yr	b
ED =	30 yr	b	ED =	30 yr	c	ED =	30 yr	b
BW =	70 kg	b	BW =	70 kg	c	BW =	70 kg	b
AT =	25,550 day	b	AT =	25,550 day	c	AT =	25,550 day	b
			ET_S=	0.2 hr/day	c	ET_S=	0.2 hr/day	f
			K =	0.5 L/m^3	h			

Future Surface Soil Exposures
Grounds Maintenance Worker

Ingestion		*	Inhalation		*	Dermal		*
FI =	100%	a	--			SA =	3,160 cm^2	e
IR_S =	480 mg/day	b	IR_A =	2.5 m^3/hr	e	AF =	1 mg/cm^2	f
EF =	10 day/yr	d	ET =	8 hr/day	b	EF =	10 day/yr	d
ED =	25 yr	b	EF =	10 day/yr	d	ED =	25 yr	b
BW =	70 kg	b	ED =	25 yr	b	BW =	70 kg	b
AT =	25,550 day	b	BW =	70 kg	b	AT =	25,550 day	b
			AT =	25,550 day	b	ABS=	100%	g

KEY FOR ACRONYMS

FI–	Fraction Ingested from Source
IR_S –	Ingestion Rate of Soil/Sediment
IR_A –	Inhalation Rate of Air
IR_G –	Ingestion Rate of Groundwater
SA –	Surface Area of Exposed Skin
K –	Volatilization Factor
AF –	Soil–to–Skin Adherence Factor
ABS –	Absorption Factor
ET_S –	Exposure Time in Shower
ET_W –	Exposure Time in Surface Water
EF –	Exposure Frequncy
ED –	Exposure Duration
BW –	Body Weight
AT –	Averaging Time

* NOTES:

a – USEPA, 1989a
b – USEPA, 1991b
c – Fort Riley, 1993a; KDWP, 1988; KDWP, 1991; KDWP,1992.
d – Master Lawn and Landscaping, 1993.
e – USEPA, 1989b
f – USEPA, 1992b
g – USEPA, 1992c
h – Andelman, 1990; as cited by USEPA, 1991c.
i – Conservative estimation based on DEH, 1993a; DEH, 1993b; and DEH, 1993d.
j – Calabrese et al. 1987 (as cited in USEPA, 1989b); USEPA, 1991c.

Current carcinogenic risks for off-site workers' (at Camp Funston) exposure to surface soils were not calculated because these receptors do not have direct exposure to site (SFL) soils. Any exposure due to site surface soils should be no more than that experienced by the on-site hunter.

Subsurface Soils - Carcinogenic risks for on-site hunters' and utility workers' exposure to subsurface soils were not calculated. On-site hunters do not have direct exposure to deep (>16 feet) subsurface soil. Any utility workers performing work on site are expected to have exposure to subsurface soils up to 10 feet deep. Since the subsurface soil data at SFL is from samples collected from depths of 16 to 64 feet, the risk to these latter receptors cannot be quantified.

Groundwater - Carcinogenic risk due to current exposure to groundwater is not calculated because there are no potable water supply wells currently in operation on the SFL site, and the nearest potable well is more than two miles away.

Surface Water - The carcinogenic risks to occupational adults from Threemile Creek surface waters fall below the NCP range of 1 x 10^{-4} to 1 x 10^{-6}. Because no volatile organics were detected in any of the surface water samples collected at the site, there is no quantitative estimate of carcinogenic risk from current exposure to surface water through inhalation.

Sediments - The risk of exposure to current occupational adults at Threemile Creek through incidental ingestion and dermal contact with sediment fall below the NCP cancer risk range of 1 x 10^{-4} to 1 x 10^{-6}. Therefore, there are no unacceptable estimated carcinogenic risks associated with sediment exposures at the SFL site.

6.1.4.2.2 Future Carcinogenic Risk - Future risk to carcinogens present at the SFL site were evaluated for recreational, occupational, and off-site residential adult populations. The media-specific carcinogenic risks, by pathway, are presented below.

Surface Soils - The calculated carcinogenic risks for future exposure of recreational adults (hunters) to surface soil by dermal contact is within the NCP range of 1 x 10^{-6} to 1 x 10^{-4}, while the estimated risk due to incidental ingestion and inhalation of fugitive dust are below the NCP range. In addition, the calculated risk for the grounds maintenance worker's exposure to surface soils via dermal contact falls within the NCP risk range, while this receptor's estimated risks due to exposure to surface soils through incidental ingestion and inhalation of fugitive dust fall below the NCP range of 1 x 10^{-6} to 1 x 10^{-4}. Based on current site-specific data, no unacceptable carcinogenic risk exists from exposure to surface soil by this pathway.

Future carcinogenic risks for off-site workers' (at Camp Funston) exposure to surface soils were not calculated because these receptors do not have direct exposure to site (SFL) soils, and any exposures due to surface soils of the SFL should be no more than that experienced by the on-site hunter.

Subsurface Soils - Future carcinogenic risks for on-site hunters' and utility and grounds keeper workers' exposure to subsurface soils were not calculated because these receptors will not have direct exposure to deep subsurface soil. Any risk due to exposure resulting from utility excavation work would probably be in soils up to 10 feet deep; these risks cannot be estimated because there is no data for soils of this depth. The subsurface soil samples collected at the SFL were from depths of 16 to 64 feet below ground surface.

Groundwater - The estimated carcinogenic risk to off-site residential adults from the potential use of on-site groundwater as drinking water exceeds the NCP cancer risk range (cancer risks of 1×10^{-3} for ingestion of groundwater; and 3×10^{-4} for inhalation of VOCs in groundwater). This risk is attributed primarily to the presence of beryllium, arsenic, vinyl chloride and 1,1,2,2-tetrachloroethane in the groundwater samples. Beryllium and arsenic were detected in 47 of the 56 samples and were detected at maximum concentrations of 0.004 mg/L and 0.045 mg/L, respectively. Neither beryllium nor arsenic maximum detected concentrations exceed Federal MCLs. Vinyl chloride was detected in just 1 of the 56 samples at a concentration of 0.018 mg/L; its MCL is 0.002 mg/L. 1,1,2,2-tetrachloroethane was detected in just 2 of 56 samples at concentrations of 0.0063 mg/L and 0.015 mg/L. There is no federal or state MCL for 1,1,2,2-tetrachloroethane; the KAL is 0.0017 mg/L.

Conservative intake estimates were used to calculate exposure by this pathway; it was assumed that 100 percent of an individual's drinking water comes from the groundwater on site. The risk estimates are also based on the assumption that potable water wells will be installed on site and the aquifer beneath the site will be used for a residential water supply in the future. Furthermore, this calculated risk does not account for the natural degradation processes and attenuation of chemical constituent concentrations that may occur with time or with distance from the site. It should be noted that all estimates of carcinogenic risks due to groundwater exposures are based on the concentrations of constituents detected at the site, rather than at the nearest exposure point, and therefore are overestimations of risk. Further study is needed before an accurate and justifiable modeling effort can be made. Modeled concentrations at an off-site exposure point would probably be less than the concentrations detected in site samples. Therefore, the risks estimated here are most likely overestimations of actual groundwater exposures.

As stated earlier, future residential development of the SFL site is precluded, as the entire site lies within the Kansas River floodplain. Therefore, it is unlikely a private well will be developed on the SFL at a future date. And, because publicly supplied water is currently available to residents, the assumption that site groundwater may be consumed as drinking water conservatively overestimates the risk for this pathway.

The calculated carcinogenic risk due to dermal contact with groundwater falls within the NCP range of 1 x 10^{-4} to 1 x 10^{-6}. Based on site-specific data, there is no unacceptable carcinogenic risk from exposure to groundwater for future residential adults by this last pathway.

Surface Water - The carcinogenic risks to occupational adults from Threemile Creek through dermal contact with surface water fall below the NCP risk range of 1 x 10^{-6} to 1 x 10^{-4}. No volatile organics were detected in site surface water samples, so there is no quantitative estimate of carcinogenic risk from future exposure to surface water through inhalation.

Sediments - The risks of exposure to future occupational adults by both dermal contact with stream sediments and by incidental ingestion from Threemile Creek fall below the NCP cancer risk range. Therefore, based on current site-specific knowledge, there is no unacceptable carcinogenic risk associated with sediment exposures in Threemile Creek.

6.1.4.3 Risk Due to Future Exposure to Groundwater in Well Clusters - Quarterly groundwater monitoring results from the seven well clusters at SFL were used to calculate risk for future groundwater users. These risk calculations are provided in Appendix M and summarized in Table 6-29. The objective of this analysis was to address USEPA Region VII's policy that risks due to contaminated groundwater should be based on the well that exhibits the greatest risk. Risk was calculated assuming that the maximum detected concentrations in the wells were the exposure point concentrations. The potential risk was calculated for ingestion of water, inhalation of volatilized constituents, and dermal absorption of constituents in groundwater by adults and children.

The estimated risks due to ingestion of groundwater were highest for wells Series 300 (SFL92-301, 302, and 303) and 600 (SFL92-601, -602, and -603). The carcinogenic risk levels were 2 x 10^{-3} for these well clusters. The risk due to noncarcinogenic exposure to adults and children by the inhalation pathway was acceptable for all wells except SFL92-801 and SFL92-802. The inhalation risk due to constituents in these wells was at the criterion level of 1 for adult noncarcinogenic exposure, and above the criterion of 1 for child noncarcinogenic exposure. The estimated risk due to exposure to carcinogens via dermal absorption was within the NCP cancer risk range of 1 x 10^{-4} to 1 x 10^{-6} for the Series 200, 300, and 800 wells. The estimated risk for this exposure was 2 x 10^{-6} for each of these well clusters.

Exposure route risks are summed to yield a total risk for the groundwater pathway for each well series. The total risks exceed criteria levels for adult noncarcinogenic and carcinogenic risk and for noncarcinogenic risk to children for every well series. Criteria levels for the total risk are exceeded primarily because of ingestion of groundwater by adults and children, and secondarily due to inhalation of constituents by adults. The well clusters that result in the highest estimated excess risk levels are wells SFL92-301, SFL92-302, and SFL92-303 and SFL92-601, SFL92-

TABLE 6–29

SUMMARY OF FUTURE GROUNDWATER RISKS FOR GROUND WATER PATHWAYS
Southwest Funston Landfill
Fort Riley, Kansas

Exposure Route	Background Series 100	Series 200	Series 300	Series 400	Series 600	Series 700	Series 800	Overall Site Risk (95 % UCL)
Ingestion								
Adults Noncarcinogenic	1E+01	3E+01	2E+01	2E+01	3E+01	2E+01	2E+01	3E+01
Children – Noncarcinogenic	3E+01	8E+01	6E+01	6E+01	8E+01	4E+01	4E+01	5E+01
Carcinogenic	3E–04	7E–04	2E–03	2E–06	2E–03	6E–04	6E–04	1E–03
Inhalation								
Adults Noncarcinogenic	NA	3E–03	4E–03	3E–03	3E–03	3E–03	1E+00	7E–02
Children – Noncarcinogenic	NA	9E–03	1E–02	7E–03	9E–03	8E–03	3E+00	2E–01
Carcinogenic	NA	2E–06	2E–06	2E–06	7E–04	2E–06	5E–04	3E–04
Dermal								
Adults Noncarcinogenic	2E–02	4E–02	3E–02	3E–02	4E–02	2E–02	3E–02	3E–02
Children – Noncarcinogenic	3E–02	7E–02	5E–02	6E–02	7E–02	4E–02	4E–02	5E–02
Carcinogenic	3E–07	1E–06	2E–06	9E–09	9E–06	8E–07	2E–06	4E–06
Total Risk								
Adults Noncarcinogenic	1E+01	3E+01	2E+01	2E+01	3E+01	2E+01	2E+01	3E+01
Children – Noncarcinogenic	3E+01	8E+01	6E+01	6E+01	8E+01	4E+01	4E+01	5E+01
Carcinogenic	3E–04	7E–04	2E–03	4E–06	3E–03	6E–04	1E–03	1E–03

Note: "Series 100" includes wells SFL92–101, 102, and 103; "Series 200" includes wells SFL92–201 and 203; and so forth.
NA = Not Applicable, no volatile chemicals of concern.

602, and SFL92-603 for carcinogenic risk. Wells SFL92-201 and -203 and SFL92-601, SFL92-602, and -603 are the wells with the highest estimated noncarcinogenic risk.

The chemical that contributes most to excess cancer risk due to groundwater ingestion is arsenic in the Series 200, 300, 600, and 800 wells. Vinyl chloride is also a major contributor to excess risk in the Series 600 wells. Antimony contributes to excess cancer risk in the Series 700 wells. The major chemical contributor to excess noncarcinogenic risk is manganese, especially for future groundwater ingestion. Adult carcinogenic risk due to inhalation of volatile compounds is primarily due to methylene chloride in well Series 200, 300, and 400, and vinyl chloride in Series 600. For dermal exposure, carcinogenic risk is primarily due to arsenic in Series 300 and 800.

Risk estimates from each well series for each exposure route were also summed to yield an overall site risk for that exposure route. Overall groundwater site risks are discussed in detail in Sections 6.1.4.1 and 6.1.4.2.

6.1.4.4 Risk Due to Background Concentrations of Site Constituents - Naturally occurring concentrations are concentrations of chemicals that are present under ambient conditions and that have not been increased by anthropogenic (i.e., human-caused) sources. In some cases, the background concentrations of constituents may present a significant risk. This risk due to background may be an important site characteristic to those exposed.

In order to assess the risk due to background at the SFL, the noncarcinogenic and carcinogenic risks due to the naturally-occurring ("background") levels of metals detected in site media from wells SFL92-101, -102, and -103 are characterized. This risk characterization is accomplished in the same manner as described in earlier sections (Sections 6.1.4.1 and 6.1.4.2), using the exposure scenarios identified in Section 6.1.2. The difference in this process is that a chemical's maximum site-specific background concentration is used as the exposure point concentration in the characterization of risk, instead of the 95 percent upper confidence limit of concentrations detected, where possible, in site samples.

The results of the analysis of risk due to site-specific background are presented in the following paragraphs. The detailed background risk calculations are provided in Appendix M. A summary of these results is presented in Table 6-30. A qualitative discussion is presented in Section 6.1.4.4.3 which addresses concentrations of naturally occurring constituents found in background wells, other than the site-specific background wells.

6.1.4.4.1 Noncarcinogenic Risk Due to Background - A hazard index greater than 1.0 was calculated for future adult (HI=10) and child (HI=25) residents using on-site groundwater from

TABLE 6-30

RISK DUE TO BACKGROUND
(SUMMARY OF NONCARCINOGENIC RISKS, CURRENT AND FUTURE)
Southwest Funston Landfill
Fort Riley, Kansas

Receptors	Surface Soil Exposures			Ground Water Exposures			Surface Water Exposures	Sediment Exposures		Totals for Each Receptor
	Ingestion	Inhalation	Dermal	Ingestion	Inhalation	Dermal	Dermal	Ingestion	Dermal	
Current Population:										
trespassing hunter	0.003	0.006	0.067	NA	NA	NA	NA	NA	NA	0.076
utility worker (Threemile Creek)	NA	NA	NA	NA	NA	NA	<0.001	<0.001	0.004	0.004
Future Population:										
recreational hunter	0.003	0.006	0.067	NA	NA	NA	NA	NA	NA	0.076
grounds maintenance worker	0.003	0.004	0.021	NA	NA	NA	NA	NA	NA	0.028
utility worker (Threemile Creek)	NA	NA	NA	NA	NA	NA	<0.001	<0.001	0.004	0.004
(offsite) residential adult	NA	NA	NA	$\boxed{10}$	NA	0.012	NA	NA	NA	$\boxed{10}$
(offsite) residential child	NA	NA	NA	$\boxed{25}$	NA	0.024	NA	NA	NA	$\boxed{25}$

Boxed values indicate an exceedance of acceptable risk levels.
NA – Not applicable; pathway not evaluated.

TABLE 6–30
RISK DUE TO BACKGROUND
(SUMMARY OF CARCINOGENIC RISKS, CURRENT AND FUTURE)
Southwest Funston Landfill
Fort Riley, Kansas

Receptors	Surface Soil Exposures			Ground Water Exposures			Surface Water Exposures	Sediment Exposures		Totals for Each Receptor
	Ingestion	Inhalation	Dermal	Ingestion	Inhalation	Dermal	Dermal	Ingestion	Dermal	
Current Population:										
trespassing hunter	6×10^{-7}	2×10^{-7}	$\boxed{1 \times 10^{-5}}$	NA	NA	NA	NA	NA	NA	$\boxed{1 \times 10^{-5}}$
utility worker (Threemile Creek)	NA	NA	NA	NA	NA	NA	1×10^{-9}	2×10^{-8}	1×10^{-7}	1×10^{-7}
Future Population:										
recreational hunter	6×10^{-7}	2×10^{-7}	$\boxed{1 \times 10^{-5}}$	NA	NA	NA	NA	NA	NA	$\boxed{1 \times 10^{-5}}$
grounds maintenance worker	5×10^{-7}	3×10^{-8}	$\boxed{3 \times 10^{-6}}$	NA	NA	NA	NA	NA	NA	$\boxed{4 \times 10^{-6}}$
utility worker (Threemile Creek)	NA	NA	NA	NA	NA	NA	1×10^{-9}	2×10^{-8}	1×10^{-7}	1×10^{-7}
(offsite) residential adult	NA	NA	NA	$\boxed{\boxed{5 \times 10^{-4}}}$	NA	7×10^{-7}	NA	NA	NA	$\boxed{\boxed{5 \times 10^{-4}}}$

Double boxed values indicate an exceedance of the NCP carcinogenic risk range (cancer risk > 1×10^{-4}); single boxed values indicate carcinogenic risk within the NCP risk range (1×10^{-6} to 1×10^{-4}).
NA – Not applicable; pathway not evaluated.

the background wells as drinking water. In this case, the majority of the risk is due to naturally occurring background concentrations of manganese and, to a lesser extent, arsenic in site media. For the future adult ingesting site groundwater, background levels of arsenic and manganese contribute HIs of 1 and 9, respectively, while arsenic and manganese background levels contribute HIs of 4 and 20, respectively, for the future child ingesting groundwater.

As stated earlier, the hazard indices for groundwater ingestion exposures are calculated using conservative assumptions which may have resulted in significantly increased estimations of risks to these receptors (see Sections 6.1.4.1.2 and 6.1.4.2.2 - Groundwater).

6.1.4.4.2 Carcinogenic Risk Due to Background - Background carcinogenic risks greater than the point of departure for determining remediation goals in the absence of ARARs (1 x 10^{-6}), but still within the risk range of exposure levels set forth by the National Contingency Plan (cancer risk = 1 x 10^{-6} to 1 x 10^{-4}), were calculated for the following receptors and exposures:

Receptor	Exposure / Media	Cancer Risk
Current Trespassing Hunter	Dermal Contact - Surface Soil	1 x 10^{-5}
Future Grounds Maintenance Worker	Dermal Contact - Surface Soil	3 x 10^{-6}
Future Recreational Hunter	Dermal Contact - Surface Soil	1 x 10^{-5}

As stated earlier, the National Contingency Plan (NCP) defines acceptable exposure levels as concentration levels that result in an excess upper bound lifetime cancer risk of 1 x 10^{-6} to 1 x 10^{-4}, which corresponds to one excess cancer in a population of one million people to one excess cancer case in ten thousand people. The risks presented above fall within the range identified by the NCP.

Only one pathway identified for the site exceeded the NCP range for carcinogenic risk; the future (off-site) residential adult's exposure to background concentrations in groundwater through ingestion. The excess cancer risk for this receptor exceeds the acceptable range with a cancer risk equal to 5 x 10^{-4}.

6.1.4.4.3 Qualitative Discussion on Metal Concentrations in Background Groundwater Wells - A qualitative review was conducted of water testing data for the supply wells for the City of Ogden, and monitoring data from the U.S. Geological Survey (U.S.G.S). Well monitoring data were reviewed for background levels of metals. Public supply well data were reviewed for supply well numbers 2, 3, 4, 5, 7, 8, for the City of Ogden. Data were obtained for the time period from January 1971 to March 1993. According to Ogden City Hall only wells 2, 8, and 7 are still in service for Ogden (Ogden City Hall, 1993). All three are located within the city limits of Ogden. Their average depth is 58 feet and their well screens are placed in the alluvial formation. The maximum levels detected for arsenic, copper, and lead were higher in the supply wells than in the background monitoring wells (SFL92-101, SFL92-102, and SFL92-103) at SFL (Table 6-31). The concentration of arsenic in a municipal water sample from a well at 224 Riley Ave. (Ogden) was 0.01 mg/L compared to 0.0093 mg/L at the landfill.

Data was also reviewed for groundwater samples collected by the USGS from wells north of the Kansas River in Geary and Riley Counties (USGS, 1993). The wells are located in Township 12 south, Range 6 east. The maximum concentrations detected in these wells for arsenic, barium, copper, lead, manganese, selenium, and silver were higher than those detected in the SFL background wells. The maximum detected arsenic concentration was 0.03 mg/L in the USGS sample, compared to 0.0093 mg/L in SFL background wells, and the maximum detected manganese concentration was 3.7 mg/L in the USGS samples, compared to 1 mg/L in the SFL background wells. Maximum detected concentrations for the other metals of concern are shown in a Table 6-31.

Groundwater results were also reviewed for a private irrigation well near the landfill. The concentrations of chemicals detected in this well are in the same range as the concentrations in the SFL Series 100 background well. Aluminum, detected at a maximum concentration of 0.46 mg/L was slightly higher in the private well, than that detected in the SFL Series 100 background well, 0.023 mg/L. Table 6-2 summarizes the analytical results for the private irrigation well.

6.1.4.4.4 Qualitative Discussion on Metal Concentrations in Background Sediment Samples - Sediment data taken from Kansas River by SFL can be compared to background sediment data taken from upstream of SFL. These background sediment samples were taken over a two year period of 1976 to 1978 from two monitoring locations; the Smoky Hill River at Junction City and the Republican River at Clay Center (samples were taken by KDHE Office of Laboratories and Research; raw data is included in Appendix C). Both of these rivers are just upstream of where the Kansas River flows past SFL. The Smoky Hill and the Republican converge as the Kansas River upstream of the SFL.

As can be seen from the sediment data in Table 6-6, concentrations of metals detected in sediment samples taken from the Kansas River fall well within the range of metal concentrations of sediments located upstream. On this basis it would appear that the SFL is not contributing additional metals at higher concentrations to the Kansas River.

TABLE 6–31

COMPARISON OF BACKGROUND LEVELS OF METALS IN GROUND WATER, ON SITE AND OFF–SITE

Southwest Funston Landfill
Fort Riley, Kansas

Parameter	Landfill Series 100 Maximum Detected (mg/L)	Ogden City Wells Maximum Detected (mg/L)	Range of Detections (mg/L)	U.S.G.S. Wells Maximum Detected (mg/L)	Range of Detections (mg/L)
Aluminum	0.23	0.06	BDL – 0.06	NA	--
Arsenic	0.0093	0.0100	0.001 – 0.01	0.030	BDL – .030
Barium	0.37	0.2	0.08 – 0.2	0.570	100– 0.570
Beryllium	0.003	0.0030	BDL – 0.003	NA	--
Cobalt	0.01	< 0.004	BDL	NA	--
Copper	0.004	0.98	BDL – 0.98	0.070	1 – .070
Lead	0.0079	0.02	BDL – 0.02	0.038	BDL – .038
Manganese	1	0.250	0.007 – 0.25	3.700	BDL – 3.700
Selenium	0.0031	0.01	BDL – 0.01	0.009	BDL – .009
Silver	0.005	0.005	BDL – 0.005	0.010	BDL – .010
Vanadium	0.009	0.004	BDL – 0.004	NA	--
Zinc	0.031	0.059	.004 – .059	NA	--

☐ Boxed data indicates detected concentration is higher than maximum concentration detected in Southwest Funston Landfill series 100.

NA – Not Analyzed

Note: "Series 100" includes wells SFL92–101, –102, and –103.

6.1.4.4.5 Qualitative Discussion on Metal Concentrations in Background Surface Water Samples
Surface water samples were taken from two locations upstream of SFL: the Republican River below Milford Reservoir and the Smoky Hill River at Enterprise. These data can be compared to surface water samples analyzed from the Kansas River flowing past SFL. The upstream surface water data was collected over a nineteen year period of 1974 to 1993. The upstream data were obtained from the EPA's STORET system and are included in Appendix C of this report.

Data for the three main constituents of concern in surface water, arsenic, aluminum and manganese, are summarized in Table 6-4. As shown in this table, the surface water data for the section of the Kansas River flowing past SFL are well within the range of metal concentrations detected from the two upstream points. Therefore, SFL does not appear to be increasing the metal concentrations found in the Kansas River.

Since there is evidence that both Kansas River surface water and sediment samples contain lower concentrations of metals than do such samples from upstream, exposure pathways for these media are not considered in this baseline risk assessment.

6.1.4.5 Risk Due to Essential Nutrients - An essential nutrient is a chemical or compound that must be ingested from an outside source (e.g., in food) because it cannot be synthesized by the human body at a rate sufficient to meet its needs. The major functions of essential nutrients are to supply energy, promote growth, repair body tissues, and regulate body processes. Nutrients essential for one species may not be essential for another. Examples of human essential nutrients include iron, magnesium, calcium, potassium, and sodium (Guthrie, 1983).

According to guidance (USEPA, 1989a), chemicals that are essential nutrients may be eliminated from the baseline risk assessment if they meet the following criteria:

- The chemical is an essential human nutrient.
- The chemical is present at low concentrations (i.e., only slightly elevated above naturally occurring levels).
- The chemical is toxic only at very high doses (i.e., much higher than those that could be associated with contact at the site).

In this section, a separate qualitative analysis is performed that compares the estimate intake of the essential nutrients detected in site media to recommended daily allowances (RDAs), estimated safe and adequate daily dietary intakes, and other recommended intake values. The RDAs are the recommended daily allowances or levels of nutrients, and are set at levels high enough to meet the needs of essentially all healthy people (Guthrie, 1983). As such, RDAs may exceed the amount needed by many people, and failure to achieve this level does not necessarily indicate that an individual is deficient in the nutrient (Guthrie, 1983). Conversely, exceedances of RDAs do not necessarily imply toxicity or adverse effects. Safe and adequate intakes are established for nutrients with insufficient scientific evidence to establish an RDA (Margen, 1992).

Table 6-32 provides the results of the comparative analysis. The 95 percent upper confidence limit for each essential nutrient detected in site groundwater, soil, and sediment is multiplied by the exposure intake factors defined earlier in Section 6.1.2 and presented in Tables 6-12 through 6-20, to estimate an average daily nutrient intake. It should be noted that RDA values are expressed in units of mg/day, and the intakes developed in Section 6.1.2 are expressed in units of mg/kg-day. Therefore, the average daily nutrient intakes are also multiplied by the body weight for each receptor of concern, so the body weight term in the estimated intake is eliminated, and the RDA values can be directly compared to the estimated intakes.

As shown in Table 6-32, the following essential nutrients do not exceed the RDAs and thus are eliminated as chemicals of concern: calcium, copper, magnesium, potassium, sodium, and zinc. Estimated daily intakes for iron (approximately 120 mg per day for adults and 69 for children) exceed the RDA of 10 mg daily for adults and children using on-site groundwater as drinking water. It should be noted that the RDAs are recommendations, and not requirements; therefore, exceedances of the RDAs are not, by definition, toxic or unacceptable. Acute toxicity to iron occurs after the ingestion of more than 500 mg of iron or 2.5 grams of iron sulfate (Klaassen et al, 1986). In addition, the presence of iron in drinking water tends to give the water a disagreeable taste and odor, so it is unlikely that residential users of the groundwater would consume enough water to receive a toxic dose. Therefore, although the iron levels that could be ingested from site groundwater exceed the recommended daily allowance, these levels are not thought high enough to be a cause for concern, and iron is also eliminated as a chemical of concern in the risk assessment.

6.1.5 Summary and Uncertainties of the Baseline Risk Assessment

The Baseline Risk Assessment at SFL indicates that there may be a concern for potential risk to human health, based on some of the exposure scenarios developed in the baseline risk assessment.

A hazard index greater than 1.0 was calculated for the following receptors and exposure pathways. As shown below, even if the risk contributed from site-specific background levels of metals is accounted for, the estimated risks remain above the standard point of departure (HI=1.0).

TABLE 6-32

RECOMMENDED DIETARY INTAKE (RDA) COMPARISON FOR ESSENTIAL NUTRIENTS
Southwest Funston Landfill
Fort Riley, Kansas

Parameter	95% Upper Confidence Limit	Adult Intake Factor[a]	Child Intake Factor[a]	Adult Estimated Intake[a] (mg/day)	Child Estimated Intake[a] (mg/day)	RDA Adult[b] (mg/day)	RDA Child[b] (mg/day)
GROUND WATER - MONITORING WELLS (mg/L):							
Residents:							
Calcium	1.78E+02	4.75E-02	1.28E-01	5.92E+02	3.42E+02	8.00E+02	8.00E+02
Iron	3.60E+01	4.75E-02	1.28E-01	1.20E+02	6.91E+01	1.00E+01	1.00E+01
Magnesium	3.27E+01	4.75E-02	1.28E-01	1.09E+02	6.28E+01	3.50E+02	1.20E+02
Potassium	1.04E+01	4.75E-02	1.28E-01	3.46E+01	2.00E+01	3.00E+03 (c)	3.00E+03 (c)
Sodium	7.90E+01	4.75E-02	1.28E-01	2.63E+02	1.52E+02	2.40E+03 (c)	2.40E+03 (c)
Zinc	8.56E-03	4.75E-02	1.28E-01	2.85E-02	1.64E-02	1.50E+00	1.00E+01
GROUND WATER - PRIVATE IRRIGATION WELL (mg/L):							
Residents:							
Sodium	1.40E+02	4.75E-02	1.28E-01	4.66E+02	2.69E+02	2.40E+03 (c)	2.40E+03 (c)
SURFACE SOILS (mg/kg):							
Hunter:							
Calcium	5.97E+04	1.96E-07	---	8.19E-01	---	8.00E+02	8.00E+02
Copper	4.59E+00	1.96E-07	---	6.30E-05	---	3.00E+00 (d)	1.50E+00 (d)
Iron	8.76E+03	1.96E-07	---	1.20E-01	---	1.00E+01	1.00E+01
Magnesium	1.56E+03	1.96E-07	---	2.14E-02	---	3.50E+02	1.20E+02
Potassium	8.01E+02	1.96E-07	---	1.10E-02	---	3.00E+03 (c)	3.00E+03 (c)
Sodium	2.51E+02	1.96E-07	---	3.44E-03	---	2.40E+03 (c)	2.40E+03 (c)
Zinc	1.80E+01	1.96E-07	---	2.47E-04	---	1.50E+01	1.00E+01
Grounds Maintenance Worker:							
Calcium	5.97E+04	1.88E-07	---	7.86E-01	---	8.00E+02	8.00E+02
Copper	4.59E+00	1.88E-07	---	6.04E-05	---	3.00E+00 (d)	1.50E+00 (d)
Iron	8.76E+03	1.88E-07	---	1.15E-01	---	1.00E+01	1.00E+01
Magnesium	1.56E+03	1.88E-07	---	2.05E-02	---	3.50E+02	1.20E+02
Potassium	8.01E+02	1.88E-07	---	1.05E-02	---	3.00E+03 (c)	3.00E+03 (c)
Sodium	2.51E+02	1.88E-07	---	3.30E-03	---	2.40E+03 (c)	2.40E+03 (c)
Zinc	1.80E+01	1.88E-07	---	2.37E-04	---	1.50E+01	1.00E+01
SEDIMENTS - THREEMILE CREEK (mg/kg):							
Occupational:							
Calcium	4.78E+04	8.27E-09	---	2.77E-02	---	8.00E+02	8.00E+02
Copper	8.02E+00	8.27E-09	---	4.64E-06	---	3.00E+00 (d)	1.50E+00 (d)
Iron	5.60E+03	8.27E-09	---	3.24E-03	---	1.00E+01	1.00E+01
Magnesium	4.92E+03	8.27E-09	---	2.85E-03	---	3.50E+02	1.20E+02
Potassium	1.61E+03	8.27E-09	---	9.32E-04	---	3.00E+03 (c)	3.00E+03 (c)
Sodium	2.80E+02	8.27E-09	---	1.62E-04	---	2.40E+03 (c)	2.40E+03 (c)
Zinc	1.85E+01	8.27E-09	---	1.07E-05	---	1.50E+00	1.00E+01

Intakes are taken from Tables 6-12 to 6-20 for recreational, residential, and/or occupational exposures for all media except surface water.

Boxed values indicate an exceedence of recommended value

(a) Adult and Child estimated intakes are obtained by multiplying the exposure point concentration by the intake factor and the body weight (70 kg for adults and 15 kg for children).

(b) Recommended Dietary Allowance (RDA). The allowances listed (average daily intakes over time) are intended to provide for individual variations among most persons living in the United States under usual environmental stresses.

(c) Other Recommended Intakes. These nutrients have no RDA or Estimated Safe and Adequate Daily Dietary Intake. The daily recomendations listed in this table are based on guidelines established by various health organizations and experts.

(d) Estimated Safe and Adequate Daily Dietary Intakes of Selected Minerals. Because there is little information on which to base allowances, these values were not listed in the main table of RDAs. The RDA values listed here is the maximum value presented in the range of recommended intake..

Source: "Wellness Encyclopedia of Food and Nutrition" by Sheldon Margen; University of California at Berkeley Wellness Letter. 1992

Receptor	Exposure Pathway - Medium	HI	Adjusted HI*
Off-Site Residential			
Future Adult	Ingestion of groundwater	26	16
Future Child	Ingestion of groundwater	54	29

*Adjusted HI accounts for risk due to background

As stated earlier, estimation of risks due to groundwater exposures is likely to be overestimated, in part because the exposure point concentrations used to evaluate potential risk were not modeled to the nearest exposure point. The uncertainties associated with the risks estimated for these exposure pathways are discussed in more detail in the uncertainties section of this summary.

Cancer risk estimates were calculated for two receptors that exceed the upper limit of the NCP risk range of 1 x 10^{-6} to 1 x 10^{-4}, as follows:

Receptor	Exposure Pathway - Medium	Adjusted Risk*	Cancer Risk
Off-Site Residential			
Future Adult	Ingestion of groundwater	5 x 10^{-4}	1 x 10^{-3}
Future Adult	Inhalation of VOCs from groundwater	3 x 10^{-4}	3 x 10^{-4}

*Adjusted risk accounts for the risk due to background.

As stated earlier, these estimated risks are based on conservative exposure assumptions and, therefore, may be overestimated. The uncertainties associated with the risks calculated are discussed in more detail at the end of this section. It is important to note that when the risk due to background concentrations of metals are accounted for, the estimated carcinogenic risks remain above the upper limit of the NCP range of 1 x 10^{-4} to 1 x 10^{-6}.

In addition, cancer risk estimates were calculated that exceed the standard point of departure, but are within the risk range identified by the NCP (1 x 10^{-6} to 1 x 10^{-4}). A list of these risks, by receptor and pathway, follows:

Receptor	Exposure Pathway - Medium	Adjusted Risk*	Cancer Risk
Current			
Trespassing Hunter	Dermal Contact - Surface Soil	3×10^{-6}	1×10^{-5}
Future			
Recreational Hunter	Dermal Contact - Surface Soil	3×10^{-6}	1×10^{-5}
(Off-Site) Residential Adult	Dermal Contact - Groundwater	3×10^{-6}	4×10^{-6}
Grounds Maintenance Worker	Dermal Contact - Surface Soil	7×10^{-7}	4×10^{-6}

* Adjusted risk accounts for risk due to background.

Uncertainties

The following, based on assumptions made and existing data gaps, identify and attempt to characterize the uncertainties associated with the Baseline Risk Assessment results:

- Toxicity values are not available for several constituents of concern, and therefore, the risk due to these constituents was not quantified. Thus, the overall noncarcinogenic and carcinogenic risks calculated for a particular pathway of interest at the site may be underestimated.

- Chemical-specific absorption factors are not currently available to convert dermal intakes into dermal absorbed doses for constituents detected in soil and sediment media. The use of these factors, if they were indeed available, in calculating risks due to dermal exposures to soil and sediment may have resulted in significantly reduced risk estimations via these pathways.

- In accordance with USEPA Region VII guidance (USEPA, 1992c), when calculating risks due to dermal exposures, oral toxicity values were not adjusted by oral absorption rates. The default dermal absorbance factor used in Region VII is 100 percent; the constituents are assumed to be completely absorbed through the skin. Thus, the bioavailability of a constituent via dermal exposure is assumed to be equal to that received from an oral dose. This assessment process tends to overestimate risks associated with dermal exposures and may, in particular, greatly overestimate dermal risks due to constituents that are non-lipid soluble (i.e., metals).

- The assumption of the exclusive use of the groundwater beneath the site for a future potable water source is unlikely because a public supply of potable water is readily available nearby. Zoning laws prohibit construction in a 100-year floodplain, so residential development (and associated private well installation) is precluded on the SFL site. However, because the aquifer beneath the site is classified as a usable aquifer by the state of Kansas, a potable water use scenario is presented.

- The assumption that exposure to constituents in surface soils was evaluated fully using the PRC data. These data were generated for use in determining metals concentrations in the landfill cover; the samples were not analyzed for organic compounds. Thus, if organic compounds exist in the surface soils in toxic concentrations, the risk due to exposure of surface soils may be underestimated. However, since the results of the CLP analysis for the highest "hits" from the XRF screening were used in the risk assessment, the results are biased high in terms of characterizing surficial soil concentrations across the entire landfill. This will result in a conservative approach for determining risk which will overestimate the potential risks.

- In evaluating risks due to chromium exposure, all chromium detected on site was assumed to be trivalent chromium (the less toxic species). The justification for the use of trivalent chromium instead of hexavalent chromium (the more toxic species) is given in Appendix Mg. Calculations for the site show that trivalent chromium is the predominant chromium species on site.

- The noncarcinogenic and carcinogenic risks calculated for future exposures to groundwater are based on the concentrations of constituents detected at the site. Constituent concentrations were not modeled to the nearest potential exposure point (i.e., the nearest potable water well), because further study is needed before an accurate and justifiable modeling effort can be made. Modeled concentrations at an off-site exposure point would most likely be less than the concentrations detected in site samples. Therefore, the risks estimated for future groundwater pathways in this risk assessment may be overestimated.

- In accordance with USEPA Region VII guidance (USEPA, 1992e), metals with maximum detected concentrations greater than the site-specific maximum background concentration in a given medium were identified as chemicals of concern, provided they "passed" the concentration-toxicity screen described in Section 6.1.1.4. As stated in Section 4.2.2.3.2, variances less than 25 percent in sample concentrations for a particular constituent may be the result of the analytical uncertainty inherent in the analytical methodology. Therefore, metals that have been identified as chemicals of concern using USEPA Regional VII guidance may be, in fact, within the range of naturally-occurring background and may not be attributable to the site.

- In evaluating risks from future exposures to site media, the assumption was made that future constituent concentrations will remain the same as current concentrations. Dilution, decay, degradation, and attenuation of constituents occurs naturally over time, and site contaminants would thus present a reduced risk in future scenarios.

This risk assessment should not be viewed as an absolute quantitative measure of the risk to public health presented by site-specific contaminants. The assumptions and inherent uncertainties in the risk assessment process do not allow this level of confidence. This risk assessment provides a conservative indication of the potential for risk due to exposure to site-specific chemicals and should help guide the management of the site to reduce that potential risks to acceptable levels.

6.2 ECOLOGICAL RISK ASSESSMENT

The Ecological Risk Assessment for the SFL was conducted in accordance with the guidance provided in the "Risk Assessment Guidance for Superfund, Vol. II - Environmental Evaluation Manual" (USEPA, 1989c). The objectives of the environmental assessment are to:

1. Determine the uses of nearby natural resources (land, air, water, and biota);
2. Identify potential environmental impacts
3. Assess the significance of any environmental impacts

In this ecological risk assessment, potential receptors present in the vicinity of the SFL and the potential pathways by which these receptors might be exposed to chemicals of concern present in surface soils, surface water, and sediments were evaluated. Potential risks to environmental receptors arising from exposure to site constituents were characterized.

The ecological risk assessment is comprised of the following tasks:

- Ecological receptor identification
- Exposure pathway evaluation
- Selection of relevant exposures
- Toxicity assessment and identification of ARARs
- Risk characterization

6.2.1 Exposure Assessment

The exposure assessment involves identification of potential ecological receptors and potential exposure pathways, as discussed below.

6.2.1.1 Potential Ecological Receptors - This section presents the potential ecological receptors that may be affected by contamination present at the SFL site. Most of this information is taken from the "Survey of Threatened and Endangered Species on Fort Riley Military Reservation" conducted by the U.S. Fish and Wildlife Service (February, 1992) and a Law Wildlife Assessment Walkover site visit performed in September 1992. The U.S. Fish and Wildlife Service report is provided in Appendix R.

6.2.1.1.1 Terrestrial Vegetation - Fort Riley is within the Flint Hills region of the Central Plains. The ecological region is known as a tall grass prairie. Terrestrial systems associated with the SFL and surrounding area consisted of two major habitat types: grassland/prairie habitats and riverain habitats. The grassland/prairie habitats include various grass species including:

- Switchgrass (*Panicum virginatum*)
- Indian grass (*Sorgastrum nutans*)
- Thistle (*Canduus hataus*)
- Johnson grass (*Sorghum halepense*)
- Sunflower (*Helianthus* sp.)

Vegetation typically noted in riverain and densely vegetated drainage habitats in the Fort Riley area include cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), box elder (*Acer negundo*), and hackberry (*Celtis occidentalis*) as canopy cover and dominated by redbud (*Cercis canadensis*), dogwood (*Cornus* sp.), greenbrier (*Smilax* sp.), poison ivy (*Rhus radicans*), Virginia creeper (*Parthenocissus quinquefolia*), and seedling overstory species.

The SFL site consists primarily of cleared areas, vegetated by grasses and other herbaceous vegetation intermixed with non-vegetated areas. Wooded areas are scattered throughout the site, and parts of the site can be classified as riparian woodland and bottomland.

6.2.1.1.2 Terrestrial Wildlife - The animal community frequenting the general area of the site includes many species of birds (doves, starlings, pigeons, wild turkey, and songbirds), insects, small mammals (bats, snakes, skunks, raccoons, possums, rabbits, squirrels, and other rodents), and larger mammals (deer, occasional bobcat). The areas around and downgradient of the SFL may provide suitable habitats for most of the above species. A variety of animals inhabiting areas adjacent to the landfill may pass through the area during hunting/foraging activities. Habitats suitable for the above species include grasslands and the riverain woodlands. Herbivores and prairie dwellers which will utilize the grasslands include rabbits, rodents, snakes, and skunks while squirrels will predominantly utilize the cottonwoods and oaks of the woodland habitat. All other species mentioned above will utilize both habitats for foraging and normal daily activities at the SFL.

6.2.1.1.3 Endangered Species - As previously discussed, a recent survey conducted by the U.S. Fish and Wildlife Service (1992) provided much of the necessary background information regarding the potential for threatened and endangered species on site. Nine federally listed threatened and endangered species along with twelve federal Category 2 candidate species and an additional six state-listed threatened species could potentially occur on Fort Riley (USFWS, 1992; KDWP, 1993; IRP, 1992). Category 2 candidate species are those which the U.S. Fish and Wildlife Service is seeking additional information regarding their biological status to determine if listing of these species is warranted. A listing of the threatened and endangered species known to occur in the Fort Riley area, along with their typical habitats, is provided in Table 6-33.

6.2.1.1.4 Aquatic Species - Threemile Creek provides a limited aquatic habitat. The creek averages approximately 15 feet in width and 3 feet deep. The creek is partly to mostly shaded and most of the shoreline supports vegetation. Stream-banks are relatively unstable and stream sediments throughout much of the creek consists primarily of silt, mud/muck, sand, and organic material. Benthic macroinvertebrates were observed at each station on Threemile Creek. Although no *in-situ* water quality monitoring was conducted, it was apparent that Threemile Creek supports aquatic life, including shiner, minnow, and sunfish varieties of fish (Appendix R).

6.2.1.2 <u>Potential Exposure Pathways</u> -

<u>Terrestrial Life Forms</u> - Terrestrial plants may be exposed to constituents of potential concern present in surficial soils through root uptake. Terrestrial wildlife may be exposed to constituents present in surficial soils through dermal contact, inhalation, or incidental ingestion as a result of burrowing activities, ingestion of contaminated foodstuffs, and preening activities. Additionally, terrestrial animals may be exposed to constituents present in surface waters and sediments by drinking from the surface water present in the Kansas River, Threemile Creek or ditches with incidental ingestion of disturbed sediments. Exposure of those animals at the upper end of the food chain may be augmented as a result of biomagnification and bioaccumulation. Generally, metals sorb to organic or particulate matter (i.e., sediments and soil). As metals are the constituents of concern for each of the media at the SFL site, the bioaccumulation and biomagnification of metals by organisms at the SFL site for food chain exposures is the greatest concern. All of the metals detected in the media of the SFL have published bioconcentration factor values of greater than 100 (see Tables 5-1 and 5-2) indicating the potential for these constituents to bioaccumulate in SFL organisms.

<u>Aquatic Life Forms</u> - Any aquatic life forms present in surface water adjacent to the site (i.e., Threemile Creek) may be exposed to chemical constituents in surface sediments and waters.

TABLE 6–33

ENDANGERED AND THREATENED SPECIES (AND ASSOCIATED HABITATS) COMMON TO FORT RILEY AREA
Southwest Funston Landfill
Fort Riley, Kansas

SPECIES	HABITAT
Piping Plover (FT, ST)	Open unvegetated beach or sandbar
Least Tern (FE, SE)	Sparsely vegetated sandbars in a wide channel with good visibility
Bald Eagle (FE, SE)	Near water bodies (rivers, lakes, etc.) utilizing riparian forest; recorded sitings
Peregrine Falcon (FE, SE)	Large river or waterfowl management areas, cropland, meadows and prairies, river bottoms, marshes, and lakes. Siting by Natural Resource personnel near Manhattan Airport
Whooping Crane (FE, SE)	Wetland, riverine base sandbars, shallow water, slow river flow
Eskimo Curlew (FE, SE)	Wet meadows, fields, pastures, drier parts of salt and brackish marshes
Western Prairie Fringed Orchid (FT)	Tallgrass prairie and sedge meadow (fire adapted)
Prairie Mole Cricket* #	Tallgrass prairie, ungrazed or unmowed native tallgrass with silt–sandy loam soils
Regal Fritillary Butterfly* #	Prairie meadows (wet), moist tallgrass prairie, virgin grassland where violets act as host plants
Sturgeon Chub* (ST)	Areas of shallow strong currents and gravel bottoms, turbulent areas where shallow water flows across sandbars
Texas Horned Lizard*	Dry–flat areas with sandy, loamy, or rocky surfaces with little vegetation
Loggerhead Shrike* # (FT)	Grassland or shrubby fields with scattered woody vegetation for perching and nesting
Long–billed Curlew	Great Plains grasslands, marshes, mud flats, sandbars
White–faced Ibis* (ST)	Small ponds with stands of cattail or bulrush
Western Snowy Plover* (ST)	Unvegetated riverine
Eastern Spotted Skunk* (ST)	Open level cultivated farmland, upland sites with preference for fallen logs and brushpiles
Eastern Hognose Snake (ST)	Suitable habitat present along river, undated reported sitings
Topeka Shiner* (ST)	Turbulent areas in rivers where shallow water flows across sand bars
American Burying Beetle # (FE, SE)	Tallgrass prairie, ungrazed or unmowed native tallgrass with silt–sandy loam soils
Black Tern*	Wetland areas
Henslow's Sparrow* #	Native grassland with few trees
Hairy False Mallow* #	Rocky outcrops and dry areas in prairies

Sources: Fort Riley, 1992; Kansas Threatened and Endangered Species Listing (10/15/92).
Underlined species are known to occur on Fort Riley.
* Candidate species for federal endangerment listing.
# Species with suitable habitat at the SFL site.
FE – Federally endangered SE – State endangered
FT – Federally threatened ST – State threatened

Benthic organisms can be in direct contact with constituents present in sediments. Additional exposure may occur with the ingestion of contaminated foodstuffs according to their position in the food chain. Organic compounds with high lipid solubility (for example, pesticides) and metals may become progressively accumulated at higher trophic levels in aquatic food chains due to processes of bioaccumulation and biomagnification. The potential for each constituent detected at the site to bioconcentrate in organisms is indicated in Tables 5-1 and 5-2.

6.2.1.3 Selection of Relevant Exposures - Chemical constituents identified in surficial soil, surface water, and sediment samples collected in Threemile Creek and the Kansas River are listed in Tables 6-8, 6-4 and 6-5, and 6-6 and 6-7, respectively. Metals were the only constituents of concern in sediments and surface waters and the only constituents tested for in surface soils.

Terrestrial organisms may be exposed to metals through dermal contact and incidental ingestion of contaminated soils. Site animals may also be potentially exposed to constituents in surficial soils through inhalation of fugitive dusts. Terrestrial organisms may also be exposed to metals by drinking surface waters and incidentally ingesting contaminated sediments. Finally, terrestrial organisms at the upper end of the food chain may additionally be exposed to metals through consumption of lower life forms. These compounds are easily absorbed and demonstrate a tendency to accumulate in fatty tissues.

Aquatic organisms may be exposed to constituents in surface waters and sediments. Sediments may serve as a continuing source of contaminants in the surface water features. Although larger species of fish are unlikely to reside in the surface waters adjacent to the site, any aquatic forms present in the surface waters may potentially be exposed to the metals detected. Also, aquatic life may be exposed to metals detected in sediments through the consumption of lower life forms.

Bioconcentration is an important mechanism for exposure for environmental receptors. Higher organisms may be exposed to these contaminants via food chain exposures, through the consumption of surface water or lower (benthic) aquatic organisms that live in the sediment. Terrestrial animals foraging near the site may also be exposed to constituents in surface water or sediments in the same manner. This may be significant, because bald eagles (an endangered species) have been noticed in areas that border the site. Since eagles are opportunistic hunters, it is not unreasonable to assume they may pass through the SFL area, and if the opportunity exists, feed on amphibians or other small aquatic organisms that may be present in Threemile Creek. However, more suitable habitat and foraging areas (i.e., Kansas River) exist for eagles and other raptors in a much greater abundance than the SFL site.

6.2.2 Toxicity Assessment and Risk Characterization

This section considers the ARARs as a basis for determining which contaminants detected in surface waters, sediments, and soils may pose a risk to environmental receptors.

6.2.2.1 Surface Water - Potential ARARs for protection of aquatic life in surface water include AWQC and state of Kansas Ambient Water Criteria. AWQC for protection of aquatic life were established under the Clean Water Act. These criteria are not rules, but do represent guidance on the environmental effects of pollutants which can be used to derive regulatory requirements. The state of Kansas incorporates the federal AWQC by reference. Relevant state and federal surface water criteria are shown in Table 6-34. Water quality criteria are used for comparison with Threemile Creek surface water data because the surface water from Threemile Creek discharges into the Kansas River.

Chloride and iron concentrations from Threemile Creek exceeded the AWQC for the protection of aquatic life. There are no current aquatic life regulatory criteria for aluminum, barium, bicarbonate, calcium, magnesium, manganese, methylene chloride, nitrate, potassium, sodium, sulfate, total organic carbon, or vanadium.

As aquatic life in Threemile Creek may be limited, the impact of the exceedance in ARARs is expected to be limited under current conditions. However, the surface water may have a potential impact on aquatic life and terrestrial species drinking from surface water features.

6.2.2.2 Sediments - The NOAA has developed Effects Range Concentrations which are non-enforceable guidance concentrations for sediments. These concentrations were derived from data on the potential of these chemicals to cause adverse biological effects in costal marine and estuarine environments. Effects threshold range concentrations are defined as those concentrations at which effects may be perceived in an organism due to exposure to the constituent of concern. These values are presented in Table 6-35 and are used as a basis for the ecological risk evaluation.

As shown in Table 6-35, two effects-based values, the Effects Range - Low (ER-L) and the Effects Range - Median (ER-M), are usually determined for a given constituent, using a method (Klapow and Lewis, 1979 as cited in NOAA, 1990) similar to that used in establishing marine quality standards for the State of California (NOAA, 1990). This method involves a three-step approach. First, currently available information (studies and reports) which contain estimates of chemical sediment concentrations associated with adverse biological effects are assembled and reviewed. Next, a range is established for a particular constituent, based upon a preponderance of evidence, which reflects the concentrations at which biological effects are noted. Lastly, this

TABLE 6-34

REGULATORY AND GUIDANCE CRITERIA FOR SURFACE WATER
SOUTHWEST FUNSTON LANDFILL
Fort Riley, Kansas

Parameter	Maximum Concentration Detected (mg/L)	FEDERAL AMBIENT WATER QUALITY CRITERIA (mg/L)* For the Protection of Aquatic Life:		KANSAS STATE WATER QUALITY STANDARDS** [c] For the Protection of Aquatic Life: (mg/L)
	Threemile Creek	Freshwater Acute	Freshwater Chronic	
Aluminum	1.1	--	--	--
Arsenic, pentavalent	0.0044	0.85 [a]	0.048 [a]	--
Arsenic, trivalent	0.0044	0.36	0.19	--
Barium	0.17	--	--	--
Bicarbonate	280	--	--	--
Calcium	97	--	--	--
Chloride, inorganic	$\boxed{58}$	0.019	0.011	--
Iron	$\boxed{1.2}$	--	1	--
Magnesium	23	--	--	--
Methylene chloride	ND	--	--	--
Manganese	0.15	--	--	--
Nitrate	5	--	--	--
Potassium	9.7	--	--	--
Selenium	ND	0.28	0.035	--
Sodium	65	--	--	--
Sulfate	93	--	--	--
Total Organic Carbon	7	--	--	--
Vanadium	ND	--	--	--
Zinc	0.026	0.120	0.110	--

Boxed values indicate an exceedence of regulatory or guidance criteria.
a – Insufficient data to develop criteria. Value presented is lowest observed effect level.
b – Human health criteria for carcinogens reported for three risk levels. Value presented in this table is the 10^{-6} risk level.
c – The State of Kansas has incorporated the Federal AWQC for the protection of aquatic llife as the State Water Quality Standards by reference.
d – Hardness Dependent Criteria (100 mg/l used).
ND – Indicates not detected.
T – Valence of metal was not established; concentration listed in table is for total metal(s).
Sources: *Quality Criteria for Water – 1986. EPA 440/5–86.001, 1 May, 1987.
**Kansas Water Quality Standards (KAR 28.16.28), 1 May, 1987.

TABLE 6-35

NOAA CRITERIA FOR SEDIMENTS
Southwest Funston Landfill
Fort Riley, Kansas

Chemical	Maximum Detected Concentration Kansas River	Maximum Detected Concentration Threemile Creek	ER-L Concentration (a)	ER-M Concentration (b)	ER-L : ER-M Ratio (c)	Overall Apparent Effects Threshold (d)	Degree of Confidence (e)
METALS (mg/kg):							
Aluminum	1900	8200	NA	NA	NA	NA	NA
Arsenic	1.2	2.1	33	85	2.6	50	Low/Moderate
Barium	61	150	NA	NA	NA	NA	NA
Beryllium	0.3	0.2	NA	NA	NA	NA	NA
Cadmium	ND	1.6	5	9	1.8	5	High/High
Calcium	10000	17000	NA	NA	NA	NA	NA
Chromium	2.3	9.8	80	145	1.8	No	Moderate/Moderate
Cobalt	2.7	9	NA	NA	NA	NA	NA
Copper	1.3	6.2	70	390	5.6	300	High/High
Iron	3700	9900	NA	NA	NA	NA	NA
Lead	2.1	5.9	35	110	3.1	300	Moderate/High
Magnesium	710	2900	NA	NA	NA	NA	NA
Manganese	130	200	NA	NA	NA	NA	NA
Nickel	ND	10	30	50	1.7	NSD	Moderate/Moderate
Potassium	470	1900	NA	NA	NA	NA	NA
Sodium	120	200	NA	NA	NA	NA	NA
Vanadium	7.6	22	NA	NA	NA	NA	NA
Zinc	10	30	120	270	2.2	260	High/High
OTHER (mg/kg):							
TRPH	32	20	NA	NA	NA	NA	NA

NSD – Not sufficient data NA – Not available

(a) Effects Range – Low; Lower 10 percentile of concentrations reported having an effect on aquatic life.

(b) Effects Range – Median; Median range of concentrations reported having an effect on aquatic life.

(c) A ratio of the ER-L value to the ER-M value.

(d) The sediment concentration above which statistically significant biological effects always occur, and therefore, are always expected.

(e) Degree of confidence based on amount of data available and quality of studies.

Source: National Oceanic and Atmospheric Administration, Technical Memorandum, NOS OMA 52, 1990.

range is evaluated relative to the sediment chemical data available from the National Status and Trends Program. The ER-L and ER-M values are generated as a result of this process. The ER-L is the 10th percentile of this effects range, while the ER-M is the 50th percentile of the reported range of concentrations associated with biological effects.

A description of the relative degree of confidence associated with the ER-L and ER-M values is also provided by NOAA. The ER-L and ER-M values associated with a high degree of confidence were supported by clusters of data with similar concentrations, by data from multiple geographic locations, by data sets that included more than results from an approach, and for chemicals for which the overall apparent effects threshold was similar to or within the range of the ER-L and ER-M values (NOAA, 1990). Values associated with a low degree of confidence were based on data sets without these qualities.

The sediment concentrations of arsenic, cadmium, chromium, copper, lead, nickel, and zinc did not exceed available NOAA ER-L and ER-M threshold values. All other constituents detected did not have available NOAA Sediment Concentrations. As the support of aquatic life in Threemile Creek may be limited, the impact of metals in the sediments on aquatic life is expected to be minimal. Riparian species using this habitat may potentially be affected by the site constituents.

6.2.2.3 Soils - No criteria have been established yet for the protection of terrestrial organisms from potential exposure to constituents present in soils. Soils could serve as a potential source of contaminants to surface water through surface runoff. Also, metals have been shown to accumulate in plants (ATSDR, 1987-1993). The uptake of metals by plants depends upon metal availability in the soil, which in turn is related to metal speciation and soil properties such as pH, mineralogy, organic content, and aeration. The effect of metals on plants depends on whether or not the element is plant essential.

Generally, nonessential metals are toxic even at low concentrations, while essential elements become toxic only at high concentrations. The accumulation of such constituents in plants may be directly toxic to the plants as well, and such accumulation provides an exposure pathway for grazing animals and other herbivorous creatures. Presently there is no indication of harm to terrestrial vegetation with respect to growth and foliage in the area.

6.2.3 Risk Characterization

The risk characterization integrates the results of the exposure and toxicity assessments into a qualitative expression of risk. First, contaminant concentrations detected in site media are compared to available ARARs or To Be Considered (TBC) requirements. In addition to exceedances of criteria, ecological risk characterization may involve both temporal and spatial components. That is, the risk assessor may predict (if sufficient information is available) how long the media and ecological receptors will be affected by site contamination, and how large an area will be affected by the constituents detected on the site.

Currently, there is no available guidance that describes criteria for classifying risks to ecological receptors. Therefore, ecological risk assessors typically conduct the risk characterization portion of an ecological risk assessment using professional judgement (USEPA, 1989c). During the site walkover during September 1992, the aquatic system and the surrounding terrestrial ecosystems were observed. This walkover included a day-long reconnaissance of the SFL site and adjacent land areas within a 5 mile radius. Near optimal conditions, i,e, growing season, for observing the terrestrial ecosystems were present. For purposes of this assessment, the magnitude of risk that each sampled medium may present to biota living on or passing through the site will be qualitatively characterized into three categories, as follows:

LOW -	A small number of species (1-2), if any at all, may be adversely affected by contamination present in site media. Adverse effects are to individual members of each species and are not long-lasting or long-reaching. No reproductive effects or other multi-generational effects are noted.
MEDIUM -	More species are affected with some potential flux in communities, but not every species. Some systemic (acute) or reproductive effects may be seen, but the results do not upset the total ecosystem.
HIGH -	Almost all species in the vicinity are expected to be affected by the contaminated media on the site. Reproductive and acute toxic effects are common; the ecosystem, as a result, may become imbalanced due to impacts to communities, food webs, and total ecosystem populations.

In this assessment, risk is characterized by grouping general species categories for each medium of concern. The general species categories used for this assessment follow:

AQUATIC	TERRESTRIAL
Benthic organisms	Herbivores (non-grass eaters and grazers/browsers)
Amphibian	Reptiles
Fish	Raptors (birds of prey)

6.2.3.1 Surface Water - As stated in Section 6.2.2.1, AWQC were exceeded by concentrations of iron and chloride in Threemile Creek. Because the creek provides a limited aquatic habitat, the impact of the exceedance of ARARs for surface water is expected to be limited under current conditions. Terrestrial organisms passing through the site may also drink any surface water present in the channel. Likewise, the terrestrial organisms using ponded surface water on the SFL site as drinking water have a low risk potential because this source of water is only periodically present. Given the nature of the stream, its small size, and the ready availability of surface water in the Kansas River, environmental impacts of site surface water exceedances appear to be low for both aquatic and terrestrial species.

ARARs exceedances may be more significant in times of increased surface water flow during storm events, if surface water contaminants are carried with the flow. However, metals sorb to soils and sediments and move very slowly through the environment. Therefore, any impacts to the Kansas River via constituents migrating from the SFL is believed to be low, even under circumstances of high flow.

6.2.3.2 Sediments - In Section 6.2.2.2, the concentrations of the metals detected at the SFL did not exceed the NOAA sediment effects range concentration.

As no exceedances of NOAA sediment criteria were observed, site sediments should not adversely affect downstream surface water and sediments, because the flow within the creek is seasonally low and sediments are not readily flushed out of the channel. Based on this evaluation, the impact of site sediment contamination appears to be limited to the benthic organisms present in stream sediments, and may possibly impact any bank-dwelling species residing on the site through bioaccumulation. Since the stream does not support larger aquatic life, the decreased number and size of the benthic species is not a concern. Likewise, bank-dwelling species would most likely be minimally affected, with other sources of surface water located nearby. Therefore, the overall impact that the SFL sediment contamination has on the ecosystem is expected to be minimal or low.

6.2.3.3 Soils - There are currently no criteria established for the protection of ecological receptors from potential exposure to constituents present in soils. As stated earlier, some metals constituents detected in site soils have the ability to concentrate in plants. While the presence of these constituents may not be directly toxic to the plants themselves, metals present in plant matter may potentially affect terrestrial species that graze/browse in the area for food.

Metals were detected in site surface soils. The presence of these constituents in site soils may impact animals foraging or burrowing in the area. However, there are many other areas adjacent to the site that may be populated by foraging species. Therefore, the overall impact of surface soil contamination to these species appears to be low.

Based on this qualitative evaluation, the impact that site surface soil contamination has on terrestrial species passing through and habitating the site appears to be low.

6.2.4 Uncertainties

Uncertainties can arise from many sources in any qualitative risk assessment. These sources include:

- Confidence that all key contaminants were identified and quantified accurately
- Dependence on toxicity data which are the foundation for all health-based ARARs and which are based on animal experiments and epidemiological study groups
- Confidence in the identification of all exposure parameters and exposure pathways appropriate to the site
- Uncertainty in the comparison of site concentrations to ARARs by which additive effects may be overlooked
- Uncertainty in the comparison of site concentrations to ARARs or TBCs that may not be truly applicable to site conditions
- Confidence in the identification and characterization of the exposed populations, both current and future, and also the current and future land use

Qualitative risk assessments which rely on a comparison to background concentrations and chemical-specific ARARs are somewhat limited in that they cannot account for cumulative toxic effects from several chemicals or several exposure routes.

Additional uncertainties in the present assessment of risk to environmental receptors are derived in part from the imprecision of present scientific data on exactly what constituent concentrations pose a hazard to environmental receptors. For example, NOAA guidance with respect to coastal and estuarine sediments was used to evaluate the possible hazards associated with site-specific constituents in riverain sediments due to the absence of appropriate reference criteria for freshwater sediments.

Additional uncertainty in the assessment of the potential toxicity of constituent concentrations present in surface water at the site and whether they will affect surface water areas off-site.

6.2.5 Summary

Negative impacts (chronic or acute) on flora and fauna by constituents exceeding relevant ARARs is not readily apparent at this time. Body burden and reproductive effects are examples of chronic effects. Acute effects result in death. Terrestrial and aquatic life in the area of Threemile Creek may potentially suffer negative impacts from constituents currently detected in on-site sediment and surface water, which may in turn impact surface water and sediment downstream. Terrestrial and riparian communities periodically using this stream for a water source or habitat may be negatively impacted by constituent concentrations in surface waters and sediments. Based on the flow rate within the Kansas River, downstream surface water impacts are expected to be minimal.

6.3 EFFECT OF FOURTH QUARTER GROUNDWATER DATA ON THE BASELINE RISK ASSESSMENT

Five volatile organic compounds were detected during the fourth quarter groundwater sampling effort. Two of these, benzene and 1,1-dichloroethane, were detected at concentrations similar to previously detected concentrations. Vinyl chloride was detected for the first time since the Baseline Quarter. One of the concentrations of vinyl chloride detected in the fourth quarter is similar to baseline concentrations; the other detected concentration was almost three times the greatest baseline concentration. Inclusion of the fourth quarter data for vinyl chloride in the 95 percent UCL calculations used in the risk assessment would raise the exposure concentration from 5.4 μg/L to 6.1 μg/L. This would result in approximately a 13 percent increase in the estimated carcinogenic risk from exposure to ground water. Chloroethane and tetrachloroethane were each detected only once in the fourth quarter and not in any of the previous groundwater sampling efforts.

In addition to the five volatile organic compounds, six inorganic compounds were detected in the groundwater during the Fourth Quarter sampling effort. One of these, selenium, was not detected at a concentration greater than background concentrations. Arsenic, barium, cadmium, and chromium were detected at concentrations similar to previously detected concentrations. Finally, lead was detected in five well clusters at concentrations greater than background in the fourth quarter. Prior to the fourth quarter, lead had not been detected at concentrations greater than background. However, only one of these detected concentrations was greater than the MCL for lead.

The estimated risk from exposure to groundwater presented in this risk assessment exceeds the range of acceptable risks defined by the NCP; therefore, inclusion of the fourth quarter data would not alter the conclusions of this risk assessment.

7.0 SUMMARY AND CONCLUSIONS

Summaries and conclusion statements for the RI at the SFL are presented in this section. Figure 7-1 summarizes the exposure routes, potentially unacceptable risks, and constituents of primary concern based on the baseline risk assessment.

7.1 NATURE AND EXTENT OF CONTAMINATION

The following section lists the conclusions derived from the nature and extent of contamination data.

- Organic constituents in the groundwater were detected in each of the eight monitoring well clusters. Organics were detected at the landfill in the monitoring well SFL92-601 for the baseline sampling event and were confirmed in samples collected in the subsequent four quarterly sampling events. Organics were also detected in wells SFL92-801 and -802 and SFL92-501, -502, and -503 during the baseline sampling. Low levels of 1,2-dichloroethane and trans-1,2-dichloroethene were subsequently detected in the first, second, and third quarter sampling events in SFL92-501 and -502 (but not in the fourth quarter event). Because the 500 Series wells are located east of Threemile Creek, which acts as a hydraulic boundary condition constraining groundwater flow, the likelihood is small that they were impacted by SFL. However, due to the possibility of intermittent groundwater flow under Threemile Creek, impacts at the 500 Series wells by the SFL cannot be entirely precluded.

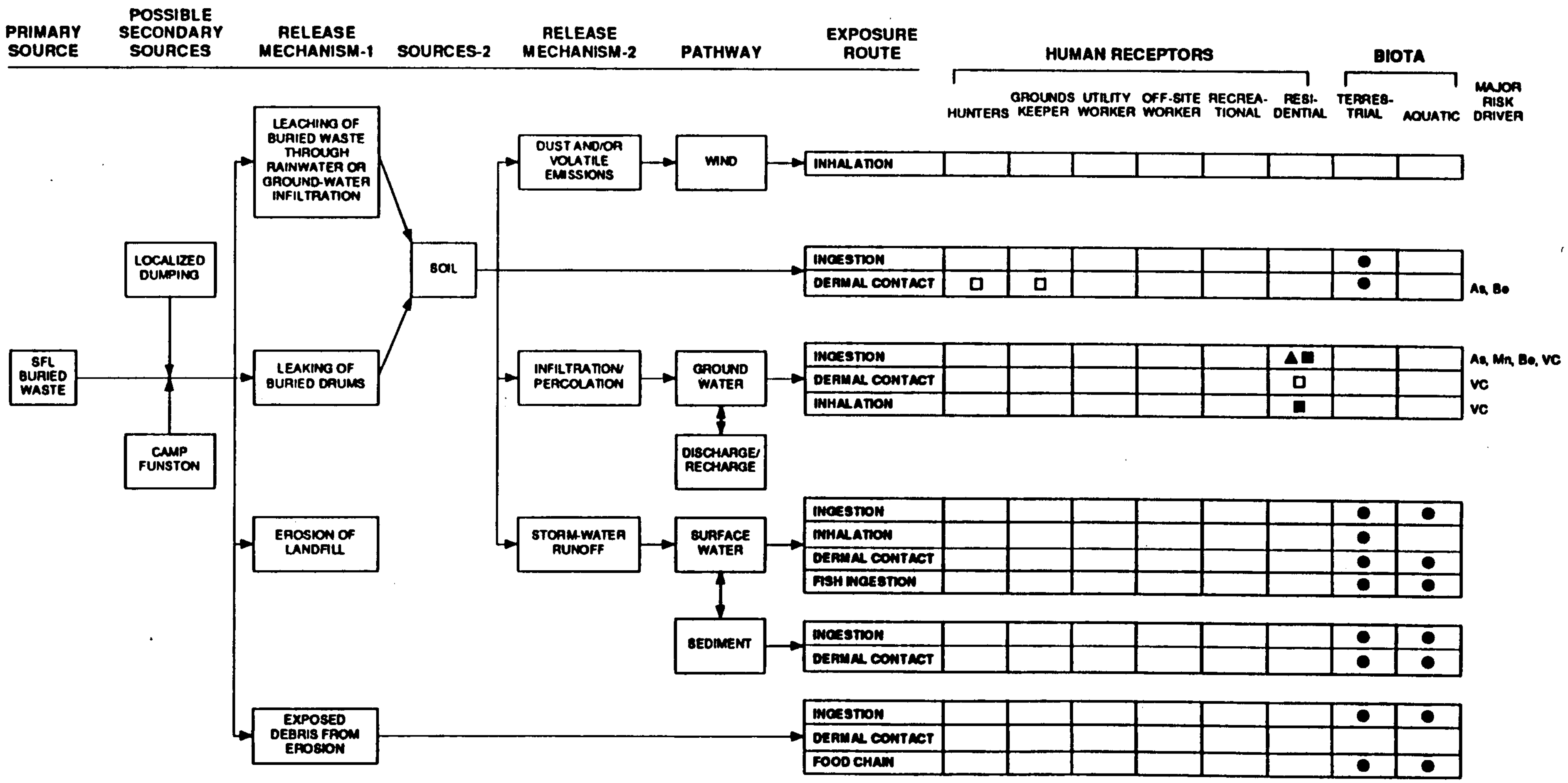
- The metals detected in the groundwater that exceeded secondary MCLs (manganese, iron, and aluminum) were detected in upgradient (background) and downgradient samples, indicating that these metals may occur naturally in this area above secondary MCLs. The only metals detected that exceeded primary MCLs were antimony (detected once in well SFL92-703 during the first quarterly sampling and once in well SFL92-803 during the second quarterly sampling event) and lead (detected above MCL in well SFL92-403 during the fourth quarter sampling event only).

- The chemical results of the subsurface soil analysis indicate the presence of volatile organics, a pesticide degradation product (DDE), Aroclor-1248, and phthalates. The volatile and pesticide concentrations are below all proposed RCRA Corrective Action Levels (CALs) and therefore do not warrant remediation.

FIGURE 7-1

SITE MODEL

SOUTHWEST FUNSTON LANDFILL
FORT RILEY, KANSAS



PATHWAY	EXPOSURE ROUTE	HUNTERS	GROUNDS KEEPER	UTILITY WORKER	OFF-SITE WORKER	RECREATIONAL	RESIDENTIAL	TERRESTRIAL	AQUATIC	MAJOR RISK DRIVER
WIND	INHALATION									
SOIL	INGESTION							●		
	DERMAL CONTACT	□	□					●		As, Be
GROUND WATER	INGESTION						▲■			As, Mn, Be, VC
	DERMAL CONTACT						□			VC
	INHALATION						■			VC
SURFACE WATER	INGESTION							●	●	
	INHALATION							●		
	DERMAL CONTACT							●	●	
	FISH INGESTION							●	●	
SEDIMENT	INGESTION							●	●	
	DERMAL CONTACT							●	●	
EXPOSED DEBRIS FROM EROSION	INGESTION							●	●	
	DERMAL CONTACT									
	FOOD CHAIN							●	●	

KEY

AS - ARSENIC

1,2 DBE - 1,2 DIBROMOETHANE

VC - VINYL CHLORIDE

● - INDICATES A COMPLETE ENVIRONMENTAL RECEPTOR PATHWAY

▲ - EXCEEDS ACCEPTABLE NONCARCINOGENIC RISK (HAZARD INDEX >1)

■ - EXCEEDS ACCEPTABLE CARCINOGENIC RISK (RISK > 1X10-4)

□ - EXCEEDS STANDARD POINT OF DEPARTURE (RISK > 10-6) BUT RISKS ARE WITHIN THE ACCEPTABLE CARCINOGENIC RISK RANGE (10-4 TO 10-6)

- Various metals were detected in the soil samples upgradient and downgradient of the site. Only beryllium and thallium concentrations in the soil samples analyzed exceeded CALs; these constituents were present in both upgradient and downgradient samples at comparable levels and thus do not appear to be site-related.

- The surface water and sediment results indicate that the SFL is not contributing any organic contaminants to the Kansas River. Metals were detected in both upstream and downstream samples at comparable levels which are consistent with historical data for the Kansas River. Therefore, the SFL does not appear to be impacting the Kansas River.

7.2 FATE AND TRANSPORT

The dominant transport pathways of importance at the SFL include:

- Groundwater movement toward the Kansas River and Threemile Creek, and any episodic, high river-stage event that temporarily reverses groundwater flow away from the river or the creek along portions of the southern and eastern boundaries of the landfill. Because of the possibility of intermittent groundwater flow under Threemile Creek, potential groundwater movement from SFL toward Camp Funston cannot be precluded.

- Infiltration of rainwater through underlying waste and soils, both in areas where landfill activities are known to have occurred and areas where suspected surface dumping may have occurred (e.g., near well SFL92-801). Such infiltration would contribute to groundwater contamination.

- Migration of constituents off site occurs primarily via groundwater discharge to the adjacent surface water bodies. Under certain circumstances, intermittent groundwater flow toward the Camp Funston area may also occur, with subsequent discharge to the Kansas River. However, there are no discernible, site-wide, contaminated plumes in the groundwater.

- Leaching, precipitation, and adsorption are likely transport processes for metals as indicated by the presence of metals in both soil and groundwater.

- Metals and VOCs in the groundwater result from percolation of rainwater through the landfill cover and underlying waste material. Also, upward migration of groundwater into waste material not normally saturated (except during high-water conditions) can occur, resulting in additional leaching to the groundwater system.

7.3 BASELINE RISK ASSESSMENT

This section presents the findings of the Baseline Risk Assessment for the SFL site.

7.3.1 Human Health Evaluation

- The SFL site lies entirely within the 100- and 500-year floodplain of the Kansas River. Therefore, the only receptors expected to be on or adjacent to the site are occupational and recreational receptors. The risks to these receptors (utility workers, grounds maintenance workers, and recreational hunters) are within the acceptable range for both noncarcinogenic and carcinogenic compounds.

- Future residential development of the site is not considered in this risk assessment. However, because the state of Kansas considers the aquifer beneath the SFL to be a potential future potable water source, the potential risks to future residential users of this groundwater were estimated. A hazard index greater than one was calculated for future residential adults (HI = 16) and children (HI = 29) using the groundwater as a source of drinking water. Arsenic, antimony, and manganese are the major contributors to this risk. Arsenic concentrations detected in the groundwater were all at levels below the maximum contaminant level (MCL) of 0.05 mg/L. Manganese concentrations were consistent with historical levels of manganese in alluvial wells throughout the Kansas River valley. Antimony was only detected once in two of the four groundwater sampling events, in different wells. Therefore, it is questionable whether antimony is a widespread, site-related constituent.

- Risks due to the carcinogenic compounds are also calculated as part of the human health evaluation. The acceptable cancer risk range of 1×10^{-6} to 1×10^{-4} is exceeded for future residential adults using the groundwater beneath the SFL as a potable water source (cancer risk = 5×10^{-4}). The constituents contributing most to this risk estimate are vinyl chloride, 1,1,2,2-tetrachloroethane, arsenic, and beryllium. Neither arsenic nor beryllium were detected at concentrations greater than their MCLs. However, several organics including vinyl chloride, 1,1,2,2-tetrachloroethane, 1,2-dichloroethane, benzene, 1,1,2-trichloroethane, and cis-1,3-dichloropropane were detected at concentrations greater than their MCLs or KALs. Therefore, remedial actions to address volatile organics in groundwater may be warranted.

- It should be noted that the estimate of risk for the groundwater pathways is very conservative, as it is based on the assumption that all of the drinking water ingested in a given day comes from the contaminated source. In addition, the reduction of constituent concentrations through attenuation are not accounted for in the assessment. Since a public water supply of potable water is already available in the area, and since it is highly improbable that the SFL site will be developed for residential use or be developed as a residential water supply field in the future, the calculated risks due to the consumption of on-site groundwater are likely to be overestimations.

7.3.2 Environmental Evaluation

- Negative impacts on flora and fauna by constituents exceeding relevant ARARs are not readily apparent at this time. Terrestrial and aquatic life in the area of Threemile Creek may potentially suffer negative impacts from constituents currently detected in on-site sediment and surface water, which may in turn impact surface water and sediment downstream. However, the natural character of the channel (effluent dominated) provides only a limited aquatic habitat. Terrestrial and riparian communities periodically using this intermittent stream for a water source or habitat may be negatively impacted by constituent concentrations in surface waters and sediments. Based on the flow rate within the channel, downstream surface water impacts are not expected.

- Uncertainties may arise from many sources in any qualitative risk assessment. Qualitative risk assessments which rely on a comparison to background concentrations and chemical-specific ARARs are somewhat limited in that they cannot account for cumulative toxic effects from several chemicals or several exposure routes.

7.4 CONCLUSIONS

Based on the results of the Remedial Investigation and the Baseline Risk Assessment, it was determined that remedial actions to address the low-levels of volatile organics in the shallow, alluvial aquifer at Southwest Funston Landfill may be warranted. Several volatile organics were detected at concentrations greater than the Maximum Contaminant Levels and the risk assessment indicated potentially unacceptable risks if the groundwater were ever to be used as a potable water supply.

Remedial actions to address the metals in the groundwater at the landfill are not warranted because 1) none of the metals which contribute to the unacceptable risk estimates, except antimony, are present at concentrations which exceed primary Maximum Contaminant Levels, and 2) the levels of iron and manganese detected, which exceed secondary Maximum

Contaminant Levels, are consistent with historical data for naturally-occurring metals in the alluvial groundwater of the Kansas River valley. Antimony was only detected once in two of the five groundwater sampling events in different monitoring wells (i.e., detected in less than five percent of the samples). Therefore, it is questionable whether antimony is a widespread, site-related constituent that warrants remediation. Lead was detected for the first time in the fourth quarter sampling event in a number of wells. However, only one of the detected lead concentrations exceeded the Maximum Contaminant Level. Continued monitoring to confirm the presence or absence of antimony and lead in the groundwater may be warranted.

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PLATE 1

SOUTHWEST FUNSTON
TOPOGRAPHICAL SURVEY
LANDFILL AREA
FORT RILEY, KANSAS

▫ DENOTES HUB AND LATH SET AT 100' INTERVALS

THE GRID LINES SHOWN HEREON ARE THE GRID AS MARKED IN THE FIELD AND USED FOR OBTAINING TOPOGRAPHICAL INFORMATION.

BENCHMARK:

FR-56 – APPROXIMATELY 1650' SOUTHWEST OF BRIDGE ON WEST EDGE OF CAMP FUNSTON, 45' EAST OF INTERSECTION OF OLD SANITARY LANDFILL ROAD AND SANITARY LANDFILL ENTRANCE, 33' NORTH OF CENTERLINE OF LANDFILL ROAD. A RAILROAD SPIKE 12" ABOVE THE ROAD IN THE SOUTHWEST SIDE OF A 24" COTTONWOOD TREE MARKED BY A 5" BY 5" CORPS OF ENGINEER'S YELLOW SIGN.

ELEVATION = 1054.50

November 19, 1991
For:
LAW ENVIRONMENTAL, INC.
10100 North Executive Hills Boulevard
Suite 350
Kansas City, Missouri 64153

Attn: Mr. Rick Nusy

PREPARED BY:

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DRN.	P.C.	CK.	APP.